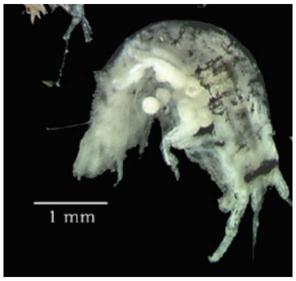
E.2 NONSTRUCTURAL ALTERNATIVE

E.2.1 ANS Potentially Invading the Great Lakes Basin

E.2.1.1 Crustaceans



E.2.1.1.1 Scud (*Apocorophium lacustre*)

NONSTRUCTURAL ALTERNATIVE

This alternative would potentially include a combination of the following measures that may be implemented at time step 0 (T_0, in units of years) by local, state, and federal agencies and the public. The Nonstructural Alternative would include the development of a monitoring and response program.

Nonstructural Alternative Measures for Apocorophium lacustre

Option or Technology	Description	
Education and Outreach	• Signage, pamphlets, and brochures on how to identify ANS and control the spread of ANS; promote national campaigns (i.e., “Stop Aquatic Hitchhikers”) • Education of recreational waterway users	
Anti-fouling Hull Paints	• Education of vessel owners and operators to promote use of anti-fouling hull paints	
Ballast/Bilge-water Exchange	• Ballast/bilge-water exchange	
Monitoring	• Agency monitoring • Voluntary occurrence reporting	
Laws and Regulations	• FWS Lacey Act listing • Mandatory watercraft inspection and decontamination	
	ANS Controls	**ANS Factsheet[a]**
ANS Control Methods	Piscicides	Piscicides
	Controlled Harvest and Overfishing	Controlled Harvest and Overfishing
	Desiccation (Water Drawdown)	Lethal Temperature

[a] For more information refer to GLMRIS Team (2012).

PATHWAY 1

WILMETTE PUMPING STATION (WPS) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	*High*	–[a]	*High*	–	*High*	–	*High*	–

[a] "–" Indicates an uncertainty rating was not assigned to P(establishment) because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Wilmette Pumping Station (WPS) and Brandon Road Lock and Dam over the next 50 years. The Nonstructural Alternative does not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

A. lacustre is a tube-dwelling, benthic filter-feeding amphipod (Grigorovich et al. 2008). The species is a sideswimmer (NEANS 2003). During reproduction, females brood embryos on their underside, which hatch out as crawling juveniles; therefore, there is no planktonic stage. *A. lacustre* was first reported from freshwater in North America in 1987–1988 from the lower Mississippi River between 820 and 829 km (510 and 515 river miles [rm]) (Grigorovich et al. 2008). In 1989, it was detected downriver at 719 km (447 rm). In 1996, it was first found in the Ohio River and subsequently moved 1,149 km (714 mi) up the Ohio River within a year (Grigorovich et al. 2008). On the basis of these movement data, this species exhibits a very rapid invasion speed. By 2003, *A. lacustre* invaded the Illinois River and expanded into the upper Mississippi River in 2005 (USGS 2011). "*A. lacustre* rapidly expanded its range into the upper reaches of the Ohio and Illinois Rivers. These discontinuous rapid expansions within the upper Mississippi River waterway are attributed to shipping transport, most likely via hull-fouling" (Grigorovich et al. 2008). *A. lacustre* typically moves downstream, not upstream (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* from natural dispersion through aquatic pathways to Brandon Road Lock and Dam.

b. Human-Mediated Transport through Aquatic Pathways

The species may be transported by attaching to boat hulls or ballast water, and vessel traffic is the fastest means of upstream spread (Grigorovich et al. 2008; Johnson et al. 2007). There is also heavy commercial and recreational traffic through Brandon Road Lock and Dam from the lower Mississippi River Basin (USACE 2011b), suggesting a high probability of human-mediated transport to the pathway. The Nonstructural Alternative includes ballast and bilge water transfer, to address the transfer of *A. lacustre* via this type of human-mediated transport.

Anti-fouling hull paints are a possible measure for controlling hull fouling of *A. lacustre* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling aquatic nuisance species (ANS) due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include the type of anti-fouling hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared with the manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* from human-mediated transport through aquatic pathways to Brandon Road Lock and Dam.

c. ***Current Abundance*** **and** ***Reproductive Capacity***

T_0: The species does not densely populate the Mississippi River Basin but can be locally abundant. "A kick sample from the upper Mississippi River in 2006 yielded 196 *A. lacustre* (density = 457 individuals/m^{-2}), but most samples had far fewer specimens. Population density of *A. lacustre* in the Ohio River increased from 6.7 (±6.3; standard deviation)/m^{-2} in 2004 to 15.7 (±31.1)/m^{-2} in 2006, and density in the upper Mississippi River increased from 65.6 (±87.3)/m^{-2} in 2005 to 87.3 (±182.1) individuals/m^{-2} in 2006; these differences, however, were not statistically significant" (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of *A. lacustre*.

T_{10}: See T_0. Abundance is expected to increase beyond T_0 levels.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

d. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers. This species is at or close to the pathway and moved through several locks as it moved northward from the lower Mississippi River Basin.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: In 2005, *A. lacustre* was found in the Illinois River just above the Dresden Lock and Dam, less than 32.2 km (20 mi) from Brandon Road Lock and Dam in the Illinois River (USGS 2011).

The Nonstructural Alternative is not expected to limit the movement of *A. lacustre* outside of its current distribution.

T_{10}: See T_0. The species may be closer to the pathway or at the pathway entrance.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Suitable habitat for this species includes the benthos of estuaries, rivers, and lakes, and intertidal zones in native estuarine habitat; *A. lacustre* has been collected on snags and in the benthos in the Ohio and upper Mississippi Rivers (Angradi et al. 2009). In the upper Mississippi River, this species is associated with rocks and snags (Angradi et al. 2009); in the Ohio River, where cobble and boulder habitats are less common, it is primarily associated with sand and snags (Grigorovich et al. 2008). The species tolerates a wide range of temperatures based on existing distribution. *A. lacustre* is a pollution-tolerant species (Ysebaert et al. 2000) and is not found in fast-flowing or turbid water (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to reduce the habitat suitability for *A. lacustre* in the Mississippi River Basin.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The species does not densely populate the Mississippi River Basin but can be locally abundant (section 2d). In 2011, *A. lacustre* was located less than 32.2 km (20 mi) from Brandon Road Lock and Dam (section 2e) and is capable of increasing its range by hundreds of miles in a single year via vessel-mediated transport (sections 2a, 2b).

Though the Nonstructural Alternative includes measures to address vessel transport, there is heavy upbound boat traffic through the Chicago Area Water System (CAWS) (section 2b), suggesting a high potential for human transport to Brandon Road Lock and Dam. *A. lacustre* is a pollution-tolerant species (Ysebaert et al. 2000), and there is suitable habitat present in the vicinity of Brandon Road Lock and Dam (section 2f), where populations could establish.

In light of its close proximity since at least 2011, the Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* through aquatic pathways to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: This species has been empirically verified to spread rapidly and over large distances via boat traffic (sections 2a, 2b). Hull-fouling and natural species dispersal may still occur. The last survey for this species was Grigorovich et al. (2008). Thus, its current distribution is unknown, but it may currently be even closer than 32 km (20 mi) from Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of A. *lacustre* through aquatic pathways to Brandon Road Lock and Dam. Therefore, the uncertainty remains low.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

A. lacustre is a tube-dwelling, benthic filter-feeding amphipods (Grigorovich et al. 2008). *A. lacustre* is a sideswimmer (NEANS 2003). During reproduction, females brood embryos on their underside, which hatch out as crawling juveniles (Bousfield 1973). This species exhibits a very rapid invasion speed and is capable of increasing its range by hundreds of miles in a single year via vessel-mediated transport (Grigorovich et al. 2008). *A. lacustre* typically moves downstream, not upstream (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming, crawling, and passive drift) of *A. lacustre* through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of *A. lacustre* as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

In 2008, about 15.9 million tons of commodity traffic moved on the CAWS, accounting for about 43% of traffic on the entire Illinois Waterway (USACE 2011a). About 71% of this traffic moved through the Lockport Lock and Dam facility (USACE 2011a). *A. lacustre* may be transported via ballast water and hull-fouling

(Grigorovich et al. 2008; Johnson et al. 2007). Commercial traffic through the Brandon Road Lock and Dam moves to the T.J. O'Brien Lock and Dam or the Chicago River Controlling Works (CRCW); it does not go to the WPS. Recreational boat fishing occurs on the North Shore Channel leading to the WPS, but boats cannot move from the North Shore Channel into Lake Michigan. The WPS regulates the amount of Lake Michigan flow allowed down the North Shore Channel; the sluice gate is a means by which excess stormwater is reversed back into the lake (USACE 2011b). The species typically moves downstream, not upstream (Grigorovich et al. 2008). Thus, it may require human-mediated transport to move through the Brandon Road Lock and Dam area and up the North Shore Channel to the WPS.

The Nonstructural Alternative includes ballast and bilge water exchange and promotion of the use of anti-fouling paints. Ballast and bilge water exchange would address *A. lacustre* transport through this vector. In addition, anti-fouling hull paints are a possible measure for controlling *A. lacustre* fouling of vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include the type of anti-fouling hull paint (toxic [with biocide] or nontoxic), frequency and method of application, frequency of hull cleaning compared to the manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the human-mediated transport of *A. lacustre* through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: The sluice gate at the WPS is a barrier that could retard dispersion by boat transport. *A. lacustre* moved through several locks as it moved northward from the lower Mississippi River Basin, suggesting that the locks are not a barrier.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: *A. lacustre* is not found in fast-flowing or turbid water (Grigorovich et al. 2008). The pathway from Brandon Road Lock and Dam to the mouth of Lake Michigan is a slow-moving eutrophic river with a flow of 0.05–0.27 m/s (0.16–0.89 ft/s) (LimnoTech 2010). The low flow of the North Shore Channel may allow the species to naturally move upstream without assistance. *A. lacustre* has been collected from shallow 2.5- to 4-m

(8.2- to 13.1-ft) depths (Grigorovich et al. 2008). The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically about 5 m (16.4 ft) (LimnoTech 2010). Suitable habitat includes rocky and/or sandy shoals (Angradi et al. 2009; Grigorovich et al. 2008). Near-shore nonvegetated areas, potentially including man-made structures like a harbor, are suitable habitat for the species. The banks of the Chicago Sanitary and Ship Canal (CSSC) are vertical walls, rock, and some vegetative debris. Sediments in the CSSC can be rock, to soft sediment and sand. The Chicago River is more than 90% vertical wall and has a sludge or silt bottom. The upper north branch of the Chicago River and the North Shore channel are more natural habitats with cobble banks and woody debris (LimnoTech 2010). This species tolerates pollution (Ysebaert et al. 2000) and a wide range of temperatures based on existing distribution. *A. lacustre* typically moves downstream, not upstream (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to affect habitat suitability for *A. lacustre* in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: This species has moved hundreds of miles in a single year via vessel-mediated transport (section 3a). According to the literature, *A. lacustre* require human-mediated transport to travel far distances upstream (sections 3b, 3d), and there is vessel traffic from Brandon Road Lock and Dam to the Chicago River but not to the WPS. The upper north branch of the Chicago River and the North Shore Channel are suitable for this species.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. Ballast and bilge water may address the passage of *A. lacustre* through the aquatic pathway. In addition, anti-fouling hull paints are a possible measure for controlling *A. lacustre* fouling of vessels; however, before anti-fouling hull paints could be considered an effective measure to control hull fouling in the CAWS, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *A. lacustre*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of *A. lacustre* through the aquatic pathway due to fouled vessels. The alternative does not include measures to address the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport via hull fouling. Therefore, the Nonstructural

Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Given time to spread upstream naturally and assisted by hull fouling through the North Shore Channel, the species may be able to pass through the passage during this time step.

T_{25}: See T_{10}. *A. lacustre* is capable of spreading rapidly, and the probability of this species reaching the WPS increases over time.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: *A. lacustre* is a rapid invader and is documented to have moved hundreds of miles in a single year by vessel-mediated transport (section 3a). The only documented upstream movement has been associated with human-mediated transport via ballast water or hull-fouling. There is documented vessel traffic in the CAWS that could potentially transport this species upstream to the Chicago River, but upstream movement to the WPS may require natural dispersal.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains low.

T_{10}: See T_0. The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{25}: See T_0. Over time, it is more certain that this species will spread to the WPS.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 2

CHICAGO RIVER CONTROLLING WORKS (CRCW) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Chicago River Controlling Works (CRCW) and Brandon Road Lock and Dam over the next 50 years. The Nonstructural Alternative does not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

A. lacustre is a tube-dwelling, benthic filter-feeding amphipod (Grigorovich et al. 2008). The species is a side swimmer (NEANS 2003). During reproduction, females brood embryos on their underside, which hatch out as crawling juveniles; therefore, there is no planktonic stage (Bousfield 1973). *A. lacustre* was first reported from freshwater in North America in 1987–1988 from the lower Mississippi River between 820 and 829 km (510 and 515 river miles [rm]) (Grigorovich et al. 2008). In 1989, it was detected downriver at 719 km (447 rm). The species was first found in the Ohio River in 1996 and subsequently moved 1,149 km (714 mi) up the Ohio River within a year (Grigorovich et al. 2008). On the basis of these movement data, this species exhibits a very rapid invasion speed. By 2003, *A. lacustre* had invaded the Illinois River; it expanded to the upper Mississippi River in 2005 (USGS 2011). "*A. lacustre* rapidly expanded its range into the upper reaches of the Ohio and Illinois Rivers. These discontinuous rapid expansions within the upper Mississippi River waterway are attributed to shipping transport, most likely via hull-fouling" (Grigorovich et al. 2008). *A. lacustre* typically moves downstream, not upstream (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* from natural dispersion through aquatic pathways to Brandon Road Lock and Dam.

b. Human-Mediated Transport through Aquatic Pathways

The species may be transported by attaching to boat hulls or through ballast water, and vessel traffic is the fastest means of upstream spread (Grigorovich et al. 2008; Johnson et al. 2007). However, there is little ballast water discharge at ports near Brandon Road Lock and Dam (NBIC 2012). Hull-fouling could be an important vector for the secondary spread of established freshwater aquatic nonindigenous species within the Great Lakes (Reid and Ruiz 2007). In 2008, about 15.9 million tons of commodity traffic moved on the Chicago Area Water System (CAWS), accounting for about 43% of traffic on the entire Illinois Waterway. About 71% of this traffic moved through the Lockport Lock and Dam facility (USACE 2011a). There is also heavy commercial and recreational traffic through Brandon Road Lock and Dam from the lower Mississippi River Basin (USACE 2011b), suggesting a high probability of human-mediated transport to the pathway. The Nonstructural Alternative includes ballast and bilge water transfer, to address the transfer of *A. lacustre* via this type of human-mediated transport.

Anti-fouling hull paints are a possible measure for controlling hull fouling of *A. lacustre* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling aquatic nuisance species (ANS) due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include the type of anti-fouling hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared with the manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* from human-mediated transport through aquatic pathways to Brandon Road Lock and Dam.

c. Current Abundance and Reproductive Capacity

T_0: The species does not densely populate the Mississippi River Basin but can be locally abundant. “A kick sample from the upper Mississippi River in 2006 yielded 196 *A. lacustre* (density = 457 individuals/m^{-2}), but most samples had far fewer specimens. Population density of *A. lacustre* in the Ohio River increased from 6.7 (±6.3; standard deviation)/m^{-2} in 2004 to 15.7 (±31.1)/m^{-2} in 2006, and density in the upper Mississippi River increased from 65.6 (±87.3)/m^{-2} in 2005 to 87.3 (±182.1) individuals/m^{-2} in 2006; these differences, however, were not statistically significant” (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of *A. lacustre*.

T_{10}: See T_0. Abundance is expected to increase beyond T_0 levels.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

d. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers. This species is at or close to the pathway and moved through several locks as it moved northward from the lower Mississippi River Basin.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: In 2005, *A. lacustre* was found in the Illinois River just above Dresden Lock and Dam, less than 32 km (20 mi) from Brandon Road Lock and Dam in the Illinois River (USGS 2011).

The Nonstructural Alternative is not expected to limit the movement of *A. lacustre* outside of its current distribution.

T_{10}: See T_0. The species may be closer to the pathway or at the pathway entrance.

T_{25}: See T_{10}.
T_{50}: See T_{10}.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Suitable habitat includes the benthos of estuaries, rivers, and lakes, and intertidal zones in native estuarine habitat (Angradi et al. 2009); in addition, the species has been collected on snags and in the benthos in the Ohio and upper Mississippi Rivers (Angradi et al. 2009). In the upper Mississippi River, it is associated with rocks and snags (Angradi et al. 2009); in the Ohio River, where cobble and boulder habitats are less common, habitat is primarily sand and snags (Grigorovich et al. 2008). On the basis of existing distribution, the species tolerates a wide range of temperatures. *A. lacustre* is a pollution-tolerant species (Ysebaert et al. 2000) and is not found in fast-flowing or turbid water (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to reduce the habitat suitability for *A. lacustre* in the Mississippi River Basin.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The species does not densely populate the Mississippi River Basin but can be locally abundant (section 2d). *A. lacustre* is located less than 32 km (20 mi) from Brandon Road Lock and Dam (section 2e) and is capable of increasing its range by hundreds of miles in a single year via vessel-mediated transport (sections 2a, 2b). There is heavy upbound boat traffic through the CAWS (section 2b), suggesting there is high potential for human transport to Brandon Road Lock and Dam. *A. lacustre* is a pollution-tolerant species (Ysebaert et al. 2000), and there is suitable habitat present in the vicinity of Brandon Road Lock and Dam (section 2f) where populations could establish.

The Nonstructural Alternative includes education and outreach, promotion of anti-hull fouling paints, ballast/bilge water exchange, monitoring, and laws and regulations. In light of *A. lacustre*'s close proximity since 2011, this alternative is not expected to affect the arrival of *A. lacustre* through aquatic pathways to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.

T_{50}: See T_0.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: This species has been empirically verified to spread rapidly and over large distances via boat traffic. There is documented vessel traffic between the lower Mississippi River Basin and Brandon Road Lock and Dam. The last survey for this species was Grigorovich et al. (2008); thus, its current distribution is not documented, but it may currently be even closer than 32 km (20 mi) from Brandon Road Lock and Dam.

The Nonstructural Alternative includes education and outreach, promotion of anti-hull fouling paints, ballast/bilge water exchange, monitoring, and laws and regulations. This alternative is not expected to affect the arrival of *A. lacustre* through aquatic pathways to Brandon Road Lock and Dam. Therefore, the uncertainty remains low.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

3. P(passage) T_0-T_{50} : HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

A. lacustre is a tube-dwelling, benthic filter-feeding amphipod (Grigorovich et al. 2008). *A. lacustre* is a sideswimmer (NEANS 2003). During reproduction, females brood embryos on their underside, which hatch out as crawling juveniles (Bousfield 1973). This species exhibits a very rapid invasion speed and is capable of increasing its range by hundreds of miles in a single year via vessel-mediated transport (Grigorovich et al. 2008). *A. lacustre* typically moves downstream, not upstream (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming, crawling, and passive drift) of *A. lacustre* through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of *A. lacustre* as it passes through the CAWS.

b. *Human-Mediated Transport through Aquatic Pathways*

In 2008, about 15.9 million tons of commodity traffic moved on the CAWS, accounting for about 43% of traffic on the entire Illinois Waterway (USACE 2011a). About 71% of this traffic moved through the Lockport Lock and Dam facility (USACE 2011a). *A. lacustre* may be transported via ballast water and hull-fouling (Grigorovich et al. 2008; Johnson et al. 2007). There is vessel traffic between Brandon Road Lock and Dam and the CRCW (USACE 2011a). At the CRCW, there is an average of 711,902 commercial one-way trips and 41,071 noncargo-vessel one-way trips a year (USACE 2011b).

The Nonstructural Alternative includes ballast and bilge water exchange and promotion for the use of anti-fouling paints. Ballast and bilge water exchange would address *A. lacustre* transport through this vector. In addition, anti-fouling hull paints are a possible measure for controlling *A. lacustre* fouling of vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include the type of anti-fouling hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared with the manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of *A. lacustre* through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: *A. lacustre* moved through several locks as it moved northward from the lower Mississippi River Basin, suggesting that the locks are not a barrier.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: *A. lacustre* is not found in fast-flowing or turbid water (Grigorovich et al. 2008). The pathway from Brandon Road Lock and Dam to the mouth of Lake Michigan is a slow-moving eutrophic river. The south branch of the Chicago River has a flow of 0.05–0.25 m/s (0.16–0.89 ft/s) (LimnoTech 2010). The low flow of the CAWS may allow the species to naturally move upstream without assistance. The species has been collected from shallow 2.5- to 4-m (8.2- to 13.1-ft) depths (Grigorovich et al. 2008). The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically about 5 m (16.4 ft) (LimnoTech 2010). Suitable habitat includes rocky and/or sandy shoals (Angradi et al. 2009; Grigorovich et al. 2008). Vegetative and woody debris are very limited in the CAWS (LimnoTech 2010). Near-shore nonvegetated areas, potentially including man-made structures like a harbor, are suitable habitat for the species (Power et al. 2006). The banks of the Chicago Sanitary and Ship Canal (CSSC) are vertical walls, rock, and some vegetative debris. Substrates in the CSSC are typically rock, cobble, or silt. The Chicago River is less than 90% vertical wall and has a sludge or silt bottom. *A. lacustre* tolerates pollution (Ysebaert et al. 2000) and a wide range of temperatures based on existing distribution.

The Nonstructural Alternative is not expected to affect habitat suitability for *A. lacustre* in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Suitable habitat is present in portions of the CAWS for the species (section 3e). This species has moved hundreds of miles in a single year via vessel-mediated transport (section 3a). According to the literature, *A. lacustre* requires human-mediated transport to travel far distances upstream, and the vessel traffic between Brandon Road Lock and Dam and the CRCW provides opportunity (sections 3b, 3d). The low flow of the CAWS may also allow *A. lacustre* to naturally disperse upstream through the south branch of the Chicago River and through the CRCW.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. Ballast and bilge water may address the passage of *A. lacustre* through the aquatic pathway. In addition, anti-fouling hull paints are a possible measure for controlling *A. lacustre* fouling of vessels; however, before anti-fouling hull paints could be considered an effective measure to control hull fouling in the CAWS, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *A. lacustre*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at reducing the passage of *A. lacustre* due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of *A. lacustre* by natural dispersion or hull-fouling through the CAWS. Therefore, the Nonstructural Alternative's

high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: *A. lacustre* is a rapid invader and is documented to have moved hundreds of miles in a single year by vessel-mediated transport (section 3a). Passage will likely occur via human-mediated transport, which has been rapid in the Mississippi River Basin. There is documented vessel traffic in the CAWS that could potentially transport this species upstream to the CRCW. However, the rate of vessel transport in the CAWS is uncertain. The potential rate of upstream movement by natural dispersion is not known, although the slow flow of the river may allow *A. lacustre* to spread upstream.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains low.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 3

CALUMET HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Calumet Harbor and Brandon Road Lock and Dam over the next 50 years. The Nonstructural Alternative would not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

A. lacustre is a tube-dwelling, benthic filter-feeding amphipod (Grigorovich et al. 2008). The species is a side swimmer (NEANS 2003). During reproduction, females brood embryos on their underside, which hatch out as crawling juveniles; therefore, there is no planktonic stage (Bousfield 1973). *A. lacustre* was first reported from freshwater in North America in 1987–1988 from the lower Mississippi River between 820 and 829 km (510 and 515 river miles [rm]) (Grigorovich et al. 2008). In 1989, it was detected downriver at 719 km (447 rm) (Grigorovich et al. 2008). It was first found in the Ohio River in 1996 and subsequently moved 1,149 km (714 mi) up the Ohio River within a year (Grigorovich et al. 2008). On the basis of these movement data, this species exhibits a very rapid invasion speed. By 2003, *A. lacustre* had invaded the Illinois River; in 2005, it expanded into the upper Mississippi River (USGS 2011). "*A. lacustre* rapidly expanded its range into the upper reaches of the Ohio and Illinois Rivers. These discontinuous rapid expansions within the upper Mississippi River waterway are attributed to shipping transport, most likely via hull-fouling" (Grigorovich et al. 2008). *A. lacustre* typically moves downstream, not upstream (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* from natural dispersion through aquatic pathways to Brandon Road Lock and Dam.

b. Human-Mediated Transport through Aquatic Pathways

The species may be transported by attaching to boat hulls or through ballast water, and vessel traffic is the fastest means of upstream spread (Grigorovich et al. 2008; Johnson et al. 2007). However, there is little ballast water discharge at ports near Brandon Road Lock and Dam (NBIC 2012). Hull-fouling could be an important vector for the secondary spread of established freshwater aquatic nonindigenous species within the Great Lakes (Reid and Ruiz 2007). There is also heavy commercial and recreational traffic through Brandon Road Lock and Dam (USACE 2011b), suggesting a high probability of human-mediated transport. At the T.J. O'Brien Lock and Dam, there is an average of 179 commercial passenger one-way trips and 19,274 noncargo-vessel one-way trips a year (USACE 2011b) that connect the Chicago Area Water System (CAWS) to Lake Michigan via Calumet Harbor. The Nonstructural Alternative includes ballast and bilge water transfer, to address the transfer of *A. lacustre* via this type of human-mediated transport.

Anti-fouling hull paints are a possible measure for controlling hull fouling of *A. lacustre* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling aquatic nuisance species (ANS) due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include the type of anti-fouling hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared with the manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* from human-mediated transport through aquatic pathways to Brandon Road Lock and Dam.

c. *Current Abundance and Reproductive Capacity*

T_0: The species does not densely populate the Mississippi River Basin but can be locally abundant. "A kick sample from the upper Mississippi River in 2006 yielded 196 *A. lacustre* (density = 457 individuals/m^{-2}), but most samples had far fewer specimens. Population density of *A. lacustre* in the Ohio River increased from 6.7 (± 6.3; standard deviation)/m^{-2} in 2004 to 15.7 (±31.1)/m^{-2} in 2006, and density in the upper Mississippi River increased from 65.6 (±87.3)/m^{-2} in 2005 to 87.3 (±182.1) individuals/m^{-2} in 2006; these differences, however, were not statistically significant" (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of *A. lacustre*.

T_{10}: See T_0. Abundance is expected to increase beyond T_0 levels.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

d. *Existing Physical Human/Natural Barriers*

T_0: The T.J. O'Brien Lock and Dam are between the current location of *A. lacustre* and Calumet Harbor. However, this species is at or close to the pathway and moved through several locks as it moved northward from the lower Mississippi River Basin.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. *Distance from Pathway*

T_0: In 2005, *A. lacustre* was found in the Illinois River just above the Dresden Lock and Dam, less than 32 km (20 mi) from Brandon Road Lock and Dam in the Illinois River (USGS 2011).

The Nonstructural Alternative is not expected to limit the movement of *A. lacustre* outside of its current distribution.

T_{10}: See T_0. The species may be closer to the pathway or at the pathway entrance.
T_{25}: See T_{10}.
T_{50}: See T_{10}.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Suitable habitat for *A. lacustre* includes the benthos of estuaries, rivers, and lakes, and intertidal zones in native estuarine habitat (Angradi et al. 2009); the species has been collected on snags and in the benthos in the Ohio and upper Mississippi Rivers (Angradi et al. 2009). In the upper Mississippi River, it is associated with rocks and snags (Angradi et al. 2009); in the Ohio River, where cobble and boulder habitats are less common, the species is primarily associated with sand and snags (Grigorovich et al. 2008). On the basis of existing distribution, the species tolerates a wide range of temperatures. *A. lacustre* is a pollution-tolerant species (Ysebaert 2000) and is not found in fast-flowing or turbid water (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to reduce the habitat suitability for *A. lacustre* in the Mississippi River Basin.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The species does not densely populate the Mississippi River Basin but can be locally abundant (section 2d). *A. lacustre* is located less than 32 km (20 mi) from Brandon Road Lock and Dam (section 2e) and is capable of increasing its range by hundreds of miles in a single year via vessel-mediated transport (sections 2a,2b). There is heavy upbound boat traffic through the CAWS (section 2b), suggesting there is high potential for human transport to Brandon Road Lock and Dam. *A. lacustre* is a pollution-tolerant species (Ysebaert 2000), and there is suitable habitat present in the vicinity of Brandon Road Lock and Dam (section 2f) where populations could establish.

The Nonstructural Alternative includes education and outreach, promotion of hull-fouling paints, ballast/bilge water exchange, monitoring, and laws and regulations. In light of its close proximity in 2011, this alternative is not expected to affect the arrival of *A. lacustre* through aquatic pathways to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: This species has been empirically verified to spread rapidly and over large distances via boat traffic. Although ballast water intake in inland Illinois is unlikely, hull-fouling and natural species dispersal may occur. The last survey for this species was Grigorovich et al. (2008); thus, its current distribution is uncertain, but it may currently be even closer than 32 km (20 mi) from Brandon Road Lock and Dam.

The Nonstructural Alternative includes education and outreach, promotion of hull fouling paints, ballast/bilge water exchange, monitoring, and laws and regulations. This alternative is not expected to affect the arrival of *A. lacustre* through aquatic pathways to Brandon Road Lock and Dam. Therefore, the uncertainty remains low.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

A. lacustre is a tube-dwelling, benthic filter-feeding amphipod (Grigorovich et al. 2008). *A. lacustre* is a sideswimmer (NEANS 2003). During reproduction, females brood embryos on their underside, which hatch out as crawling juveniles (Bousfield 1973). This species exhibits a very rapid invasion speed and is capable of increasing its range by hundreds of miles in a single year via vessel-mediated transport (Grigorovich et al. 2008). *A. lacustre* typically moves downstream, not upstream (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming, crawling, and passive drift) of *A. lacustre* through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of *A. lacustre* as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

Transport may occur through ballast water and hull-fouling (Grigorovich et al. 2008; Johnson et al. 2007). Hull-fouling could be an important vector for the secondary spread of established freshwater aquatic nonindigenous species within the Great Lakes (Reid and Ruiz 2007). Most commercial traffic through Brandon Road Lock and Dam moves to the T.J. O'Brien Lock and Dam located 8 km (5 mi) south of Calumet Harbor (USACE 2011a; NBIC 2012).

The Nonstructural Alternative includes ballast and bilge water exchange and promotion for the use of anti-fouling paints. Ballast and bilge water exchange would address *A. lacustre* transport by ballast and bilge. In addition, anti-fouling hull paints are a possible measure for controlling *A. lacustre* fouling of vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include the type of anti-fouling hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared with the manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of *A. lacustre* through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: Existing potential barriers include the three lock and dam structures along the pathway. *A. lacustre* moved through several locks as it moved northward from the lower Mississippi River Basin, suggesting that the locks are not a barrier.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *A. lacustre* is not found in fast-flowing or turbid water and typically moves downstream, not upstream (Grigorovich et al. 2008). The pathway from Brandon Road Lock and Dam to the mouth of Lake Michigan at Calumet Harbor is a slow-moving eutrophic river averaging 0.13 m/s (0.43 ft/s) (LimnoTech 2010). The low flow of the Calumet Sag Channel may allow the species to naturally move upstream without assistance. *A. lacustre* has been collected from shallow 2.5- to 4-m (8.2- to 13.1-ft) depths (Grigorovich et al. 2008). The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically about 5 m (16.4 ft) (LimnoTech 2010). Suitable habitat includes rocky and/or sandy shoals (Angradi et al. 2009; Grigorovich et al. 2008).

Vegetation and woody debris are very limited in the CAWS (LimnoTech 2010). The banks of the CSSC are vertical walls, rock, and some vegetative debris. Sediments in the CSSC can be rock, to soft sediment and sand. Near-shore nonvegetated areas, including potentially man-made structures like a harbor, are suitable habitat for the species. The banks of the Calumet Sag Channel are vertical walls, rock, and some vegetative debris. Sediments can be gravel to soft sediment. This species tolerates pollution (Ysebaert 2000) and a wide range of temperatures based on existing distribution.

The Nonstructural Alternative is not expected to affect habitat suitability for *A. lacustre* in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Suitable habitat is present in portions of the CAWS for the species (section 3e). This species has moved hundreds of miles in a single year via vessel-mediated transport (section 2a). According to the literature, *A. lacustre* requires human-mediated transport to travel far distances upstream, and the vessel traffic between Brandon Road Lock and Dam and the T.J. O'Brien Lock and Dam, as well as the heavy vessel use of Calumet Harbor, provide opportunity for the species to be transported (sections 3b, 3d). The low flow of the CAWS may allow *A. lacustre* to naturally disperse upstream through the Calumet River and through Calumet Harbor.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. Ballast and bilge water may address the passage of *A. lacustre* through the aquatic pathway. In addition, anti-fouling hull paints are a possible measure for controlling *A. lacustre* fouling of vessels; however, before anti-fouling hull paints could be considered to be an effective measure to control hull fouling in the CAWS, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *A. lacustre*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of *A. lacustre* through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of *A. lacustre* by natural dispersion or hull-fouling through the CAWS. Therefore, the Nonstructural Alternative's

high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: *A. lacustre* is a rapid invader and is documented to have moved hundreds of miles in a single year by vessel-mediated transport (section 3a). There is documented vessel traffic in the CAWS that could potentially transport this species upstream to Calumet Harbor. In addition, the slow flow of the river may allow the species to spread upstream without human-mediated transport. However, the potential rate of upstream movement by natural dispersion is not known.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains low.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. **P(spreads) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 4

INDIANA HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Medium	Medium	Medium	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Medium	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Medium	Medium	Medium	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Medium	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Indiana Harbor and Brandon Road Lock and Dam over the next 50 years. The Nonstructural Alternative would not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The species is a tube-dwelling, benthic filter-feeding amphipod (Grigorovich et al. 2008). The species is a sideswimmer (NEANS 2003). During reproduction, females brood embryos on their underside, which hatch out as crawling juveniles; therefore, there is no planktonic stage (Bousfield 1973). *A. lacustre* was first reported from freshwater in North America in 1987–1988 from the lower Mississippi River between 820 and 829 km (510 and 515 rm) (Grigorovich et al. 2008). In 1989, it was detected downriver at 719 km (447 rm). It was first found in the Ohio River in 1996 and subsequently moved 1,149 km (714 mi) up the Ohio River within a year (Grigorovich et al. 2008). On the basis of these movement data, this species exhibits a very rapid invasion speed. By 2003, *A. lacustre* invaded the Illinois River and expanded into the upper Mississippi River in 2005 (USGS 2011). *"A. lacustre* rapidly expanded its range into the upper reaches of the Ohio and Illinois Rivers. These discontinuous rapid expansions within the upper Mississippi River waterway are attributed to shipping transport, most likely via hull fouling" (Grigorovich et al. 2008). *A. lacustre* typically moves downstream, not upstream (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* from natural dispersion through aquatic pathways to Brandon Road Lock and Dam.

b. Human-Mediated Transport through Aquatic Pathways

The species may be transported by attaching to boat hulls or ballast water, and vessel traffic is the fastest means of upstream spread (Grigorovich et al. 2008; Johnson et al. 2007). However, there is little ballast water discharge at ports near Brandon Road Lock and Dam (NBIC 2012). Hull-fouling could be an important vector for the secondary spread of established freshwater aquatic nonindigenous species within the Great Lakes (Reid and Ruiz 2007). There is heavy commercial and recreational traffic through Brandon Road Lock and Dam from the lower Mississippi River Basin (USACE 2011b), suggesting a high probability of human-mediated transport to the pathway. The Nonstructural Alternative includes ballast and bilge water transfer to address the transfer of *A. lacustre* via this type of human-mediated transport.

Anti-fouling hull paints are a possible measure for controlling hull fouling of *A. lacustre* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling aquatic nuisance species (ANS) due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include the type of anti-fouling hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared with the manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* from human-mediated transport through aquatic pathways to the Brandon Road Lock and Dam.

c. *Current Abundance and Reproductive Capacity*

T_0: The species does not densely populate the Mississippi River Basin but can be locally abundant. “A kick sample from the upper Mississippi River in 2006 yielded 196 *A. lacustre* (density = 457 individuals/m^{-2}), but most samples had far fewer specimens. Population density of *A. lacustre* in the Ohio River increased from 6.7 (±6.3; standard deviation)/m^{-2} in 2004 to 15.7 (±31.1)/m^{-2} in 2006, and density in the upper Mississippi River increased from 65.6 (±87.3)/m^{-2} in 2005 to 87.3 (±182.1) individuals/m^{-2} in 2006; these differences, however, were not statistically significant” (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of *A. lacustre*.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Existing Physical Human/Natural Barriers*

T_0: There are no existing barriers. This species is at or close to the pathway and moved through several locks as it moved northward from the lower Mississippi River Basin.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. *Distance from Pathway*

T_0: In 2005, *A. lacustre* was found in the Illinois River just above the Dresden Lock and Dam, less than 32.2 km (20 mi) from Brandon Road Lock and Dam in the Illinois River (USGS 2011).

The Nonstructural Alternative is not expected to limit the movement of *A. lacustre* outside of its current distribution.

T_{10}: See T_0. The species may be closer to the pathway or at the pathway entrance.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Suitable habitat includes the benthos of estuaries, rivers, and lakes, and intertidal zones in native estuarine habitat; in addition, the species has been collected on snags and in the benthos in the Ohio and upper Mississippi Rivers (Angradi et al. 2009). In the upper Mississippi River, it is associated with rocks and snags (Angradi et al. 2009); in the Ohio River where cobble and boulder habitats are less common, habitat is primarily sand and snags (Grigorovich et al. 2008). On the basis of existing distribution, the species tolerates a wide range of temperatures. *A. lacustre* is a pollution-tolerant species (Ysebaert et al. 2000) and is not found in fast-flowing or turbid water (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to reduce the habitat suitability for *A. lacustre* in the Mississippi River Basin.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The species does not densely populate the Mississippi River Basin but can be locally abundant (section 2d). *A. lacustre* is located less than 32.2 km (20 mi) from Brandon Road Lock and Dam (section 2e) and is capable of increasing its range by hundreds of miles in a single year via vessel-mediated transport (sections 2a, 2b). There is heavy upbound boat traffic through the Chicago Area Water System (CAWS) (section 2b), suggesting there is high potential for human-mediated transport to Brandon Road Lock and Dam. *A. lacustre* is a pollution-tolerant species (Ysebaert et al. 2000), and there is suitable habitat present in the vicinity of Brandon Road Lock and Dam (section 2f) where populations could establish.

In light of its close proximity in 2011, the Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* through aquatic pathways to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: This species has been empirically verified to spread rapidly and over large distances via boat traffic. The last survey for this species was Grigorovich et al. 2008; thus, its current distribution is unclear, but it may currently be even closer than 32.2 km (20 mi) from Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* through aquatic pathways to Brandon Road Lock and Dam. Therefore, the uncertainty remains low.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

3. P(passage) T_0-T_{50}: LOW-HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

A. lacustre is a tube-dwelling, benthic filter-feeding amphipod (Grigorovich et al. 2008). *A. lacustre* is a sideswimmer (NEANS 2003). During reproduction, females brood embryos on their underside, which hatch out as crawling juveniles (Bousfield 1973). This species exhibits a very rapid invasion speed and is capable of increasing its range by hundreds of miles in a single year via vessel-mediated transport (Grigorovich et al. 2008). *A. lacustre* typically moves downstream, not upstream (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming, crawling, and passive drift) of *A. lacustre* through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of *A. lacustre* as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

A. lacustre may be transported via ballast water and hull-fouling (Grigorovich et al. 2008; Johnson et al. 2007). There is cargo traffic between Brandon Road Lock and Dam and the T.J. O'Brien Lock and Dam (USACE 2011a; NBIC 2012), but vessel traffic to Indiana Harbor is lake wide. Therefore, natural dispersal upstream through the Grand Calumet River may be required for *A. lacustre* to move through the Grand Calumet River to Indiana Harbor.

The Nonstructural Alternative includes ballast and bilge water exchange and promotion for the use of anti-fouling paints. Ballast and bilge water exchange may address *A. lacustre* transport through this vector. In addition, anti-fouling hull paints are a possible measure for controlling *A. lacustre* fouling of vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include the type of anti-fouling hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared with the manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of *A. lacustre* through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: *A. lacustre* moved through several locks as it moved northward from the lower Mississippi River Basin, suggesting that the locks are not a barrier. The Grand Calumet River is shallow and turbid. The channel depth is 0.3 m (1 ft) or less in portions of the West Branch near the state line (LimnoTech 2010). There is no documentation of the species being collected at less than 2.5 m (8.2 ft) in depth (Grigorovich et al. 2008). There is sheet pile across the Grand Calumet River between the Indiana Harbor Canal and the Calumet River that could act as a temporary barrier, especially under low flows.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *A. lacustre* is not found in fast-flowing or turbid water (Grigorovich et al. 2008). The pathway from Brandon Road Lock and Dam and the mouth of Lake Michigan at Indiana Harbor is a slow-moving, turbid, eutrophic river averaging 0.13 m/s (0.43 ft/s) (LimnoTech 2010). The low flow of the Calumet Sag Channel may allow the species to naturally move upstream without assistance. The species has been collected from shallow 2.5- to 4-m (8.2- to 13.1-ft) depths (Grigorovich et al. 2008). The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically about 5 m (16.4 ft) (LimnoTech 2010). Suitable habitat includes rocky and/or sandy shoals (Angradi et al. 2009; Grigorovich et al. 2008). Vegetative and woody debris are very limited in the CAWS (LimnoTech 2010). Near-shore nonvegetated areas, potentially including man-made structures like a harbor, are suitable habitat for the species. The banks of the Chicago Sanitary and Ship Canal (CSSC) are vertical walls, rock, and some vegetative debris. Substrates in the CSSC are typically rock, cobble, or silt. The banks of the Calumet Sag Channel and the Grand Calumet River are vertical walls, rock, and some vegetative debris. Sediments can be gravel to soft sediment. The species tolerates pollution (Ysebaert et al. 2000) and a wide range of temperatures based on existing distribution. Water flows out of Indiana Harbor into Lake Michigan. West of the Indiana Harbor Canal, the eastern-most sections of the Grand Calumet River also generally flow toward Lake Michigan, while other sections can flow east or west depending on location (Weiss et al. 1997). Thus, *A. lacustre* would be able to flow with the current out into Lake Michigan once it reached the eastern section of the Grand Calumet.

The Nonstructural Alternative is not expected to affect habitat suitability for *A. lacustre* in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Medium	High	High
Nonstructural Alternative Rating	Low	Medium	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: This species has moved hundreds of miles in a single year via vessel-mediated transport (section 3a). According to the literature, *A. lacustre* requires human-mediated transport to travel far distances upstream (sections 3b, 3d), and there is vessel traffic from Brandon Road Lock and Dam to the T.J. O'Brien Lock and Dam, but not to Indiana Harbor. The low flow of water in the CAWS may allow the species to swim upstream (section 3d). Suitable habitat is present in portions of the CAWS (section 3e). The Grand Calumet River is turbid and shallow and may not be suitable for this species (section 3e). However, portions flow toward Lake Michigan and will allow the species to flow with current.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. Ballast and bilge water may address the passage of *A. lacustre* through the aquatic pathway. In addition, anti-fouling hull paints are a possible measure for controlling *A. lacustre* fouling of vessels; however, before anti-fouling hull paints could be considered an effective measure to control hull fouling in the CAWS, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *A. lacustre*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of *A. lacustre* through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of *A. lacustre* by natural dispersion or hull-fouling through the CAWS. Therefore, the Nonstructural Alternative's low probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Given time to naturally spread upstream, the species may be able to move through the passage during this time step.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's medium probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}. *A. lacustre* is capable of spreading rapidly, and the probability of this species reaching Indiana Harbor increases over time.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: *A. lacustre* is a rapid invader and is documented to have moved hundreds of miles in a single year by vessel-mediated transport (section 3a). There is documented vessel traffic in the CAWS that could potentially transport this species upstream to the Chicago River, but upstream movement to Indiana Harbor may require natural dispersal. It is uncertain whether the species will move through the shallow, turbid water of the Grand Calumet River.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. Over time, it is more certain that this species will spread to Indiana Harbor.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{50}: See T_{25}.

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. **P(spreads) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 5

BURNS SMALL BOAT HARBOR (BSBH) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Medium	Medium	Medium	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Medium	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Medium	Medium	Medium	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Medium	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Burns Small Boat Harbor (BSBH) and Brandon Road Lock and Dam over the next 50 years. The Nonstructural Alternative would not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

A. lacustre is a tube-dwelling, benthic filter-feeding amphipod (Grigorovich et al. 2008). The species is a sideswimmer (NEANS 2003). During reproduction, females brood embryos on their underside, which hatch out as crawling juveniles; therefore, there is no planktonic stage (Bousfield 1973). *A. lacustre* was first reported from freshwater in North America in 1987–1988 from the Lower Mississippi River between 820 and 829 km (510 and 515 river miles [rm]) from the mouth (Grigorovich et al. 2008). In 1989, it was detected downriver at 719 km (447 rm) (Grigorovich et al. 2008). It was first found in the Ohio River in 1996 and subsequently moved 1,149 km (714 mi) up the Ohio River within a year (Grigorovich et al. 2008). On the basis of these movement data, this species exhibits a very rapid invasion speed. By 2003, *A. lacustre* had invaded the Illinois River; in 2005, its range had expanded to the upper Mississippi (USGS 2011). "*A. lacustre* rapidly expanded its range into the upper reaches of the Ohio and Illinois Rivers. These discontinuous, rapid expansions within the Upper Mississippi River waterway are attributed to shipping transport, most likely via hull-fouling" (Grigorovich et al. 2008). *A. lacustre* typically moves downstream, not upstream (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* from natural dispersion through aquatic pathways to the Brandon Road Lock and Dam.

b. Human-Mediated Transport through Aquatic Pathways

This species is documented to be transported by attaching to boat hulls or ballast water, and vessel traffic is the fastest means of upstream spread (Grigorovich et al. 2008; Johnson et al. 2007). However, there is little ballast water discharge at ports near Brandon Road Lock and Dam (NBIC 2012). Hull-fouling could be an important vector for the secondary spread of established freshwater aquatic nonindigenous aquatic species (NAS) (Reid and Ruiz 2007). There is also heavy commercial and recreational traffic through Brandon Road Lock and Dam from the lower Mississippi River Basin (USACE 2011b), suggesting a high probability of human-mediated transport to the pathway.

Anti-fouling hull paints are a possible measure for controlling hull fouling of *A. lacustre* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling aquatic nuisance species (ANS) due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include the type of anti-fouling hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared with the manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* from human-mediated transport through aquatic pathways to Brandon Road Lock and Dam.

c. Current Abundance and Reproductive Capacity

T_0: The species does not densely populate the Mississippi River Basin but can be locally abundant. "A kick sample from the Upper Mississippi River in 2006 yielded 196 *A. lacustre* (density = 457 individuals/m^{-2}), but most samples had far fewer specimens. Population density of *A. lacustre* in the Ohio River increased from 6.7 (±6.3; standard deviation)/m^{-2} in 2004 to 15.7 (±31.1)/m^{-2} in 2006, and density in the upper Mississippi River increased from 65.6 (±87.3)/m^{-2} in 2005 to 87.3 (±182.1) individuals/m^{-2} in 2006; these differences, however, were not statistically significant" (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of *A. lacustre*.

T_{10}: See T_0. Abundance is expected to increase beyond T_0 levels.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

d. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers. This species is at or close to the pathway and moved through several locks as it moved northward from the lower Mississippi River Basin.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: In 2005, *A. lacustre* was found in the Illinois River just above the Dresden Lock and Dam, less than 32 km (20 mi) from Brandon Road Lock and Dam in the Illinois River (USGS 2011).

The Nonstructural Alternative is not expected to limit the movement of *A. lacustre* outside of its current distribution.

T_{10}: See T_0. The species may be closer to the pathway or at the pathway entrance.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Suitable habitat for *A. lacustre* includes the benthos of estuaries, rivers, and lakes, and intertidal zones in native estuarine habitat (Angradi et al. 2009); the species has been collected on snags and in the benthos in the Ohio and upper Mississippi Rivers (Angradi et al. 2009). In the upper Mississippi River, it is associated with rocks and snags (Angradi et al. 2009); in the Ohio River, where cobble and boulder habitats were less common, *A. lacustre* is primarily associated with sand and snags (Grigorovich et al. 2008). The species tolerates a wide range of temperatures based on existing distribution. *A. lacustre* is a pollution-tolerant species (Ysebaert et al. 2000) and is not found in fast-flowing or turbid water (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to reduce the habitat suitability for *A. lacustre* in the Mississippi River Basin.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The species does not densely populate the Mississippi River Basin but can be locally abundant (section 2d). *A. lacustre* is a pollution-tolerant species (Ysebaert et al. 2000), and there is suitable habitat present in the vicinity of Brandon Road Lock and Dam (section 2f), where populations could establish. *A. lacustre* is located less than 32 km (20 mi) from Brandon Road Lock and Dam (section 2e) and is capable of increasing its range by hundreds of miles in a single year via vessel-mediated transport (sections 2a, 2b). There is heavy upbound boat traffic through the Chicago Area Water System (CAWS) from the lower Mississippi River Basin (section 2b), suggesting there is high potential for human transport to Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* through aquatic pathways to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: This species has been empirically verified to spread rapidly and over large distances via boat traffic. Hull-fouling and natural species dispersal may occur. The last survey for this species was Grigorovich et al. (2008); thus, its current distribution is unknown, but currently, it may be even closer than 32 km (20 mi) from Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of *A. lacustre* through aquatic pathways to Brandon Road Lock and Dam. Therefore, the uncertainty remains low.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

3. P(passage) T_0-T_{50}: LOW-HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

A. lacustre is a tube-dwelling, benthic filter-feeding amphipod (Grigorovich et al. 2008). *A. lacustre* is a sideswimmer (NEANS 2003). During reproduction, females brood embryos on their underside, which hatch out as crawling juveniles (Bousfield 1973). This species exhibits a very rapid invasion speed and is capable of increasing its range by hundreds of miles in a single year via vessel-mediated transport (Grigorovich et al. 2008). *A. lacustre* typically moves downstream, not upstream (Grigorovich et al. 2008).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming, crawling, and passive drift) of *A. lacustre* through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of *A. lacustre* as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

Transport may occur through ballast water and hull-fouling (Grigorovich et al. 2008). Most commercial traffic through the Illinois River moves to the T.J. O'Brien Lock and Dam (USACE 2011a; NBIC 2012). There is no cargo vessel traffic to the BSBH (USACE 2011a). Vessels could transport *A. lacustre* as far as the Little Calumet River. Therefore, natural dispersal upstream through the south branch of the Little Calumet River and Burns Ditch, approximately 64 km (40 mi), would be required to move to the BSBH.

There is small, nonmotorized, recreational boat use in the Little Calumet River that may assist in transporting the species.

The Nonstructural Alternative includes ballast and bilge water exchange and promotion for the use of anti-fouling paints. Ballast and bilge water exchange may address *A. lacustre* transport through this vector. In addition, anti-fouling hull paints are a possible measure for controlling *A. lacustre* fouling of vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include the type of anti-fouling hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared with the manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of *A. lacustre* through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: *A. lacustre* moved through several locks as it moved northward from the lower Mississippi River Basin, suggesting that the locks are not a barrier. A natural barrier is depth; both the Little Calumet and Burns Ditch are shallow. There is no documentation of the species being collected in depths less than 2.5 m (8.2 ft) (Grigorovich et al. 2008).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *A. lacustre* is not found in fast-flowing or turbid water (Grigorovich et al. 2008). The pathway from Brandon Road Lock and Dam to the mouth of Lake Michigan at the BSBH is a slow-moving, turbid, eutrophic river with a flow of 0.13 m/s (0.43 ft/s) (LimnoTech 2010). The low flow of the CAWS may allow the species to naturally move upstream without assistance. The species has been collected from shallow 2.5- to 4-m (8.2- to 13.1-ft) depths (Grigorovich et al. 2008). The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically about 5 m (16.4 ft) (LimnoTech 2010). Suitable habitat includes rocky and/or sandy shoals (Angradi et al. 2009; Grigorovich et al. 2008). Near-shore nonvegetated areas, potentially including man-made structures like a harbor, are suitable habitat for the species. Vegetative and woody debris are very limited in the CAWS (LimnoTech 2010). The banks of the Chicago Sanitary and Ship Canal (CSSC) are vertical walls, rock, and some vegetative debris. Substrate in the CSSC is typically rock, silt, or cobble (LimnoTech 2012). The Little Calumet River and Burns

Ditch are both shallow water. The banks of the Calumet Sag Channel and the Little Calumet River are vertical walls, rock, and some vegetative debris. Sediments can be gravel to soft sediment (LimnoTech 2010). The species tolerates pollution (Ysebaert et al. 2000) and a wide range of temperatures based on existing distribution. Water flows out of the BSBH into Lake Michigan. The eastern segment of the south branch of the Little Calumet River also generally flows toward Lake Michigan (GSWMD 2008). Thus, *A. lacustre* would be able to flow with the current out into Lake Michigan once it reached the eastern branch of the Little Calumet River.

The Nonstructural Alternative is not expected to affect habitat suitability for *A. lacustre* in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	High	High
Nonstructural Alternative Rating	Low	Medium	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: This species has moved hundreds of miles in a single year via vessel-mediated transport (section 3a). According to the literature, *A. lacustre* requires human-mediated transport to travel far distances upstream (sections 3b, 3d), and there is vessel traffic from Brandon Road Lock and Dam to the T.J. O'Brien Lock and Dam, but not to Indiana Harbor. The low flow of water in the CAWS may allow the species to swim upstream (section 3d). Suitable habitat is present in portions of the CAWS for the species (section 3e). The Calumet Sag Channel and the Little Calumet River are shallow and have a low flow. There is no documentation that the species survives at depths less than 2.5 m (8.2 ft) (section 3e). The portions of the Little Calumet River that flow toward Lake Michigan will allow the species to drift with current through the BSBH.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. Ballast and bilge water may address the passage of *A. lacustre* through the aquatic pathway. In addition, anti-fouling hull paints are a possible measure for controlling *A. lacustre* fouling of vessels; however, before anti-fouling hull paints could be considered an effective measure to control hull fouling in the CAWS, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *A. lacustre*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of *A. lacustre* through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of *A. lacustre* by natural dispersion or hull-fouling through the CAWS. Therefore, the Nonstructural Alternative's low probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Given time to naturally spread upstream, the species may be able to pass through the passage during this time step.

The Nonstructural Alternative is not expected to affect the passage for *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's medium probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}. *A. lacustre* is capable of spreading rapidly. Given time to establish in the CAWS, the species is likely to spread closer to the BSBH over time.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: *A. lacustre* is a rapid invader and is documented to have moved hundreds of miles in a single year by vessel-mediated transport (section 3a). There is documented vessel traffic in the CAWS that could potentially transport this species upstream to the Little Calumet River. Movement to the BSBH may require natural dispersal through the south branch of the Little Calumet River, and it is uncertain whether habitat is suitable in this waterway.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. Over time, it is more certain that this species will spread to Indiana Harbor.

The Nonstructural Alternative is not expected to affect the passage of *A. lacustre* through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

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E.2.1.2 Fish

E.2.1.2.1 Bighead Carp - *Hypophthalmichthys nobilisa*

NONSTRUCTURAL ALTERNATIVE

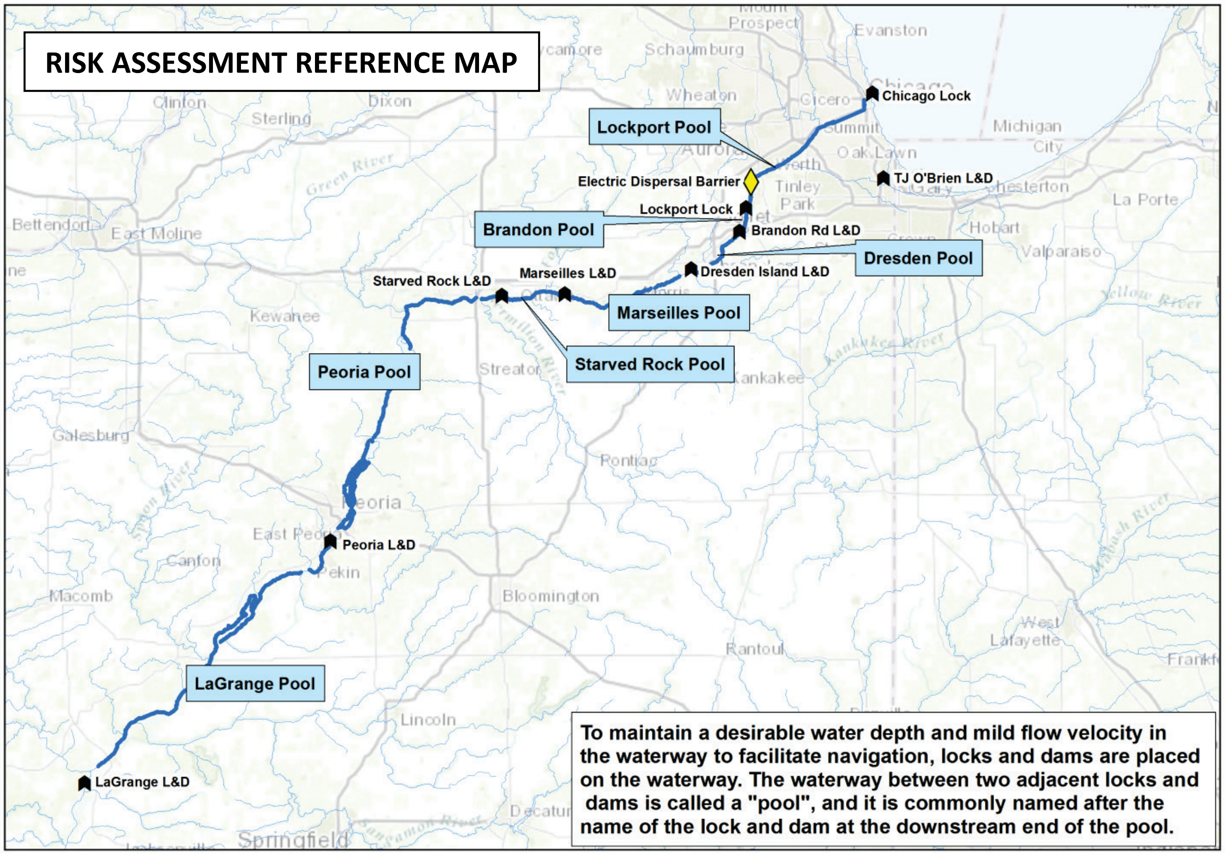
This alternative would potentially include the implementation of a combination of the following measures that may be implemented at time step 0 (T_0, in units of years) by local, state, and federal agencies and the public. Nonstructural measures that are in research and development at this time were not considered available for this alternative. When these measures are available for field application, they could be reconsidered.

Nonstructural Alternative Measures for the Bighead Carp

Option or Technology	Description
Education and Outreach	Education of recreational waterway users and bait shop owners
	Signage, pamphlets, and brochures on how to identify ANS and control the spread of ANS; promote national campaigns (i.e., "Don't Move Live Fish" campaign)
Ballast/Bilge-water Exchange	Ballast/bilge-water exchange
Monitoring	Agency monitoring
	Voluntary occurrence reporting
Laws and Regulations	Quarantine – restricted site access
	Prohibition of sale, husbandry, transport, release
	USFWS Lacey Act listing
	Mandatory watercraft and trailer inspection and decontamination

Option or Technology	ANS Control Methods	ANS Factsheet[a]
ANS Control Methods	Piscicides	Piscicides
	Controlled Harvest and Overfishing	Controlled Harvest and Overfishing
	Desiccation (Water Drawdown)	Lethal Temperature

[a] For more information, refer to GLMRIS Team (2012).


RISK ASSESSMENT REFERENCE MAP

To maintain a desirable water depth and mild flow velocity in the waterway to facilitate navigation, locks and dams are placed on the waterway. The waterway between two adjacent locks and dams is called a "pool", and it is commonly named after the name of the lock and dam at the downstream end of the pool.

◊ The Electric Dispersal Barrier System located approximately 5 mi upstream of the Lockport Lock and Dam is assumed to continue operation through T_{50}.

Pools of the Upper Illinois River and CAWS		
Pool	River Miles	Approximate Length (mi)
Lockport Pool[a]		
Electric Barrier System	296	–
To Chicago Lock	291–327	36
To T.J. O'Brien	291–326.5	35.5
Brandon Road Pool	286–291	5
Dresden Island Pool	271.5–286	14.5
Marseilles Pool	247–271.5	24.5
Starved Rock Pool	231–247	16
Peoria Pool	157.6–231	73.4
LaGrange Pool	80.2–157.6	77.4

Lock and Dams of the Upper Illinois and CAWS	
Lock and Dams	Approximate Distance from Electric Barrier System (mi)
Chicago Lock	31
T.J O'Brien Lock and Dam[a]	30.5
Lockport Lock and Dam	5
Brandon Road Lock and Dam	10
Dresden Island Lock and Dam	24.5
Marseilles Lock and Dam	49
Starved Rock Lock and Dam	65
Peoria Lock and Dam	138.4
LaGrange Lock and Dam	215.8

[a] Lockport Pool encompasses river miles both below and above the Electric Dispersal Barrier System. Upstream of the Electric Dispersal Barrier System, the Chicago Sanitary and Ship Canal (CSSC) continues north to the Chicago Lock at Lake Michigan. The Cal-Sag Channel connects with the CSSC at approximately river mile 303, and proceeds eastward toward the T.J. O'Brien Lock and Dam. Lake Michigan is approximately 6 mi north of the T.J. O'Brien Lock and Dam.

Note: River Miles were determined from the U.S. Army Corps of Engineers, Illinois Waterway Navigation Charts from Mississippi River at Grafton, Illinois to Lake Michigan at Chicago and Calumet Harbors, 1998.

PATHWAY 1

BRANDON ROAD LOCK AND DAM TO WILMETTE PUMPING STATION (WPS)

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE PROBABILITY OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are anticipated that would reduce or eliminate the hydrologic connection between Brandon Road Lock and Dam and WPS over the next 50 years.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Bighead carp are active swimmers. Total maximum distance traveled upstream by an individual was 163 km (101 mi) over 35 days (Peters et al. 2006), with an average of 4.5 km (2.8 mi) traveled per day. Average expansion rates for bighead carp are recorded at 9 river miles per year (Jerde et al. 2010) and they were able to move from Arkansas into Mississippi, Missouri, Ohio, and Illinois rivers. Bighead carp expansion rates were also tracked via the Long Term Resource Monitoring Program in the Mississippi and Illinois Rivers. First detections at Pool 26 (Mississippi River; 1991) to the La Grange reach (Illinois River; 1995) indicated the detectable population moved over 98 river miles in just 4 years (Irons et al. 2009) and continued upstream progression in the Illinois River to the Dresden Island Pool by 2007 (USGS 2013).

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the Chicago Area Waterway System (CAWS) by natural dispersion.

b. Human-Mediated Transport through Aquatic Pathways

There is commercial vessel and recreational boat traffic between the current location of bighead carp and the Brandon Road Lock and Dam. Bighead carp eggs, larvae, and fry have the potential to be spread by ballast water if water quality is suitable, although the viability of this ballast water transport is considered to be low (Heilprin et al. 2013).

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the CAWS from human-mediated transport through this aquatic pathways.

c. Current and Potential Abundance and Reproductive Capacity

T_0: Adult bighead carp are abundant in the Illinois Waterway from Starved Rock Lock & Dam (RM231) to the confluence with Mississippi River (Chick and Pegg 2001; Irons et al. 2009; ACRCC 2012; Garvey, et al. 2013; Wyffels et al. 2013). Bighead carp were reported to have high abundances within the La Grange pool of the Illinois River from sampling conducted from 2000 to 2006 (Irons et al. 2011). Bighead carp reached peak abundance levels in 2000 and have declined between 2004 and 2006, however these declines may be due to capture gear inefficiencies (Irons et al. 2011). Sampling efforts for Asian carp conducted in the upper pools of the Illinois River (Marseilles-Lockport) from 2010 through 2012 indicated a decreasing population from downstream to upstream (Ruebush et al. 2013).

A Monitoring and Response Work Group (MRWG) composed of academic, local, state and federal agencies was established in 2010 by the Asian Carp Coordinating Committee (ACRCC). The ACRCC's mission statement is to create a sustainable Asian carp control program for protecting the integrity and safety of the Great Lakes ecosystem by preventing introduction of a sustainable Asian carp population into the Great Lakes via all viable pathways (ACRCC 2013d). The MRWG has projects focusing on waterway monitoring, removal efforts, Electric Dispersal Barrier System efficacy, gear catch efficacy and alternative pathway monitoring. Regular electrofishing and netting efforts have consisted of 16,497 person-hours of sampling from the Starved Rock Pool to Lake Michigan resulting in the capture of 283,290 specimens from 2010 to 2012. Removal efforts below the barrier system include contracted commercial fishermen setting over 643.3 mi of nets through 2012 to remove 698.72 tons of bighead, silver and grass carp. Additional workgroup projects include juvenile, larval and egg sampling, ichthyoplankton surveys, telemetry studies, hydro-acoustic surveys, and alternative gear development all of which provide up-to-date information on the status of Asian carp populations and range expansion (ACRCC 2013a).

In 2013, a significant number of bighead carp were captured in the Rock Run Rookery Preserve Lake, a backwater in the Dresden Island pool, 4 mi downstream of the Brandon Road Lock and Dam (ACCRC 2013c). There are no physical barriers between Rock Run Rookery Preserve Lake and the Brandon Road Lock and Dam. It is unknown whether this represents a population increase in this pool since the rookery was not previously sampled.

Above Dresden Island Pool, one bighead was collected in 2009 within Lockport Pool downstream of the Electric Dispersal Barrier System during a rotenone application (ACRCC 2009). In 2010, a bighead was captured in Lake Calumet during routine monitoring upstream of the Electric Dispersal Barrier System (ACRCC 2012).

Bighead carp are broadcast spawners that spawn in large aggregates (Kolar et al. 2005). Female egg production is correlated with increased body mass and age. Females with as many as 1.1 million eggs have been found in the Yangtze River, China (Kolar et al. 2005). In the Missouri River the mean fecundity was measured as the average adult female producing 226,213 eggs (Shrank and Guy 2002). In 2004, in the Illinois River, mean egg production was measured as 180,000 per female (DeGrandchamp et al. 2007). Kolar et al. (2007) reported that their analysis suggested that populations appear to be growing exponentially at the time of the report. Garvey et al. (2006) points out that bighead carp have a slower population level somatic growth rate, higher survival, lower fecundity, later maturity and longer lives relative to silver carp. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock pool and none in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of bighead carp. Controlled harvest and overfishing measures have removed over 1.3 million lbs of Asian carp from the Illinois River between 2010 and 2012 (ACRCC 2013e). However, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The bighead carp has been listed as an injurious fish species under the Lacey Act (Federal Register 2011), and federal and state agencies have implemented components of the *National Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States* (Conover et al. 2007). However, ongoing barrier defense monitoring indicates that bighead carp remains abundant in the Illinois River (Wyffels et al. 2013) at the current level of harvest, regulation, and management.

Overall, the Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{10}: Based on the above information, bighead carp seem to have a high reproductive capacity in terms of producing new young per year. Therefore, current populations are expected to increase in abundance. Additionally, future environmental conditions or population genetics have the potential to shift in such a way that would allow a rapid growth and expansion of downstream populations that could lead to increased immigration into the pathway (Kolar et al. 2007); therefore, abundance is anticipated to increase below the Brandon Road Lock and Dam. This assessment is based on past invasion histories for multiple species (Crooks and Soulé 1996; Williamson 1996; Nico and Fuller 1999; Lockwood, Hoopes, and Marchetti 2007); also, see the above section *Type of Mobility/Invasion Speed* for more information.

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{25}: It is expected that, in areas with established populations, natural constraints on population growth would begin to reach a plateau. Thus, reproductive capacity would remain the same, but would no longer result in an exponentially increasing population. The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Though monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{50}: See T_{25}.

d. Existing Physical Human/Natural Barriers

T_0: None. There are no barriers to movement of bighead carp from their current position to Brandon Road Lock and Dam.

The Nonstructural Alternative would not affect existing physical human/natural barriers to the pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: There have been two recorded captures of bighead carp above the Brandon Road Pool. The first was collected in 2009 within the Lockport Pool, downstream of the Electric Dispersal Barrier System, during a rotenone application (ACRCC 2009). The second capture occurred during routine monitoring in Lake Calumet. Lake Calumet is directly connected to the Little Calumet River, only 6 mi from Lake Michigan (ACRCC 2012). Multiple bighead carp have been captured in landlocked Chicago-area urban fishing ponds above the barrier. It is likely that these fish were accidentally introduced during stocking for the Illinois Department of Natural Resources urban fishing program of catchable sized channel catfish in the 2002-2003 timeframe (ILDNR 2011; ACRCC 2013e). In addition, there have been multiple positive eDNA detections upstream of electric barriers for bighead carp (Jerde et al. 2011). However, there is no evidence to correlate the eDNA detections to an established Asian carp population above the Electric Dispersal Barrier System within the CAWS (ACRCC 2012; Environmental DNA Calibration Study 2013). Calibration studies are underway to better understand the relationship between positive eDNA and Asian carp populations (ACRCC 2013b).

Below the Brandon Road Pool, bighead carp have been detected in the Dresden Island pool. A significant number of adult bighead carp were captured approximately 4 mi downstream of the Brandon Road Lock and Dam in the Rock Run Rookery Preserve Lake in 2013 (ACCRC 2013c). The USACE telemetry program has also recorded one individual bighead carp that approached the Brandon Road Lock and Dam in 2012 before returning downstream to the mouth of the Kankakee River (Shanks and Barkowski 2013). Based on the persistent populations in Marseilles Pool, and the 2013 captures in Rock Run Rookery Preserve Lake approximately 4 mi from Brandon Road Lock and Dam, the bighead carp has arrived at the pathway (Brandon Road Lock and Dam).

The Nonstructural Alternative is not expected to affect the bighead carp's distance from the aquatic pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Bighead carp prefer eutrophic conditions but can survive with low growth rates under low plankton concentrations (Kolar et al. 2007). There was no difference in catch rate regarding location within the water column as measured within the backwaters of the Illinois River (Schultz et al. 2007). DeGrandchamp et al. (2008) suggest that bighead carp rarely occupy depths greater than 4 m (13 ft) regardless of abiotic factors. Other studies indicate that 3 m (9.8 ft) deep or more provides suitable conditions for bighead carp (Kolar et al. 2005). Bighead carp can be found in low velocity and off-channel habitats in the Mississippi, Missouri, Wabash and lower Ohio Rivers and all sizes collected in the Upper Mississippi River Basin were strongly associated with slow-moving water (<0.3 m/s [1.0 ft/s]) (Kolar et al. 2005). During low flow, bighead carp avoid channels & backwaters (DeGrandchamp et al. 2008), but will use spur dikes (Kolar et al. 2007; Cooke et al. 2009). These varied habitats are found throughout the Dresden Island Pool, including the Rock Run Rookery Preserve Lake and in the Kankakee River. This species is found in Swan Lake, which is connected to the Illinois River (DeGrandchamp et al. 2007). Heilprin (2013) found that larvae of bighead carp can survive under low DO conditions (0.86 mg/L) inside a barge ballast tank. This supports the findings of other studies that indicate adults (0.5 mg/L; Oregon Sea Grant 2011), juveniles (0.33 mg/L) and young (0.4 mg/L; Jennings 1988) can survive low DO conditions. Critical spawning temperature for bighead carp is reported as 18°C (64.4°F) (Irons et al. 2009). However, typically successful fertilization occurs between 21° and 26°C (69.8 and 78.8°F) (Kolar et al. 2005). The mean summer temperature of Lake Michigan near Chicago ranges between 20 and 23°C (64.4°F). Adult bighead carp can withstand water temperatures up to 38.8°C (101.8°F) (Bettoli et al. 1985).

The Nonstructural Alternative is not expected to affect the suitability of habitat for bighead carp.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Bighead carp have been documented at the Brandon Road Lock and Dam and Lockport Pool upstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway. The bighead carp has arrived at the pathway. Therefore, the probability of arrival remains high.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: A bighead carp was captured in the Lockport pool, upstream of the Brandon Road Lock and Dam; telemetric tracking of tagged individual bighead carp has provided evidence of at least one individual approaching the Brandon Road Lock and Dam in 2012; and in the spring of 2013, the capture of significant numbers of bighead carp at Rock Run Rookery Forest Preserve Lake, which is approximately 4 mi from the Brandon Road Lock and Dam. Therefore, there is no uncertainty whether this species has arrived at the pathway.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{10}: See T_0. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) can reduce Asian carp populations. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) can reduce Asian carp populations. However, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{25}: See T_0. It is uncertain whether Asian carp monitoring and harvesting activities in Dresden Island Pool will continue during this time step. Bighead carp populations in the Dresden Island Pool are expected to increase to existing levels or higher.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{50}: See T_{25}.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Bighead carp is an active swimmer that can swim against the slow current of the CAWS. An individual can travel as far as 4.5 km (2.8 mi) per day (Peters et al. 2006). Bighead carp expansion rates were also tracked via the Long Term Resource Monitoring Program in the Mississippi and Illinois Rivers. First detections at Pool 26 (Mississippi River 1991) to the La Grange Pool (Illinois River 1995) indicated the detectable population moved over 98 river miles in just 4 years (Irons et al. 2009) and continued upstream progression in the Illinois River to the Dresden Island Pool by 2007 (USGS 2013). Average expansion rates for bighead carp are recorded at 9 river miles per year (Jerde et al. 2010).

Asian carp were first sampled from the Illinois River during the 1990's and populations have since progressed upstream (Conover et al. 2007; Irons et al. 2009). Monitoring for bighead and silver carp was originally incidental to standard routine sampling by the Illinois Department of Natural Resources (IDNR) and the Illinois Natural History Survey (INHS). Sampling directed toward Asian carp in the upper Illinois Waterway began with the US Fish and Wildlife Service's (USFWS) annual Carp Corral & Round Goby Roundup. Subsequently, the US Army Corps of Engineers (USACE) adopted a plan specifically to monitor Asian carp downstream of the electric barrier system located near Romeoville, Illinois (ACRCC 2013a). By 2010, the ACRCC was formed to coordinate this intensive monitoring effort which was expanded to include techniques including but not limited to eDNA, electrofishing, netting, sonar, and telemetry above and below the barrier generally between Lake Michigan and the Peoria Lock and Dam (ACRCC 2010).

As noted above, in 2007, bighead carp were first captured in Dresden Island Pool. In 2009, one bighead carp was found in the Lockport Pool during a rotenone event (ACRCC 2009), and in 2010, a bighead was captured in Lake Calumet during routine monitoring upstream of the Electric Dispersal Barrier System (ACRCC 2012). Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring data, it appears that few bighead carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences.

Within the Marseilles and Dresden Island Pools, reproductively mature bighead carp have been captured but no fertilized eggs or larvae have been found. Hydraulic (e.g., seasonal high flows) and geomorphic conditions (e.g., floodplain habitat) within the Dresden Island and Lockport Pools do not offer suitable environmental cues to initiate spawning behavior (Chapman 2010). In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock pool and none in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. The nearest collection of Asian carp eggs was found near Henry, Illinois, within the Peoria Pool, five locks downstream of the Electric Dispersal Barrier System. Larval Asian carp were only collected in LaGrange Pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the natural dispersion (i.e., swimming and passive drift) of the bighead carp through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Bighead carp actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming will likely be the primary mechanism of movement through the

CAWS from the Brandon Road Lock and Dam. There is heavy commercial vessel traffic between Brandon Road Lock and Dam and the Chicago River (USACE 2011a,b) and there is the potential for bighead carp eggs and larvae to be transported upstream of the Electric Dispersal Barrier System by passive entrainment in a ballast tank (no pumping). Heilprin et al. (2011) found water sampled from barge ballast through a single summer to be within published water quality parameters to sustain juvenile and adult Asian carp. Additionally, survivability of larvae and eggs within ballast water was found to be high for periods up to 144 hours but a very low percentage of larvae survived pump passage when expelling the ballast water (Heilprin 2013).

USCG has established a regulated navigation area around the Electric Dispersal Barrier System which prohibits vessels from transiting the safety zone with any non-potable water on board if they intend to release that water in any form within, or on the other side of the safety zone (USCG, 2011).

Other vessel-related transport mechanisms that may reduce the effectiveness of the Electric Dispersal Barrier System are discussed in Section 4c, *Existing Physical Human/Natural Barriers*.

Commercial traffic through the Brandon Road Lock and Dam moves to the T.J. O'Brien Lock and Dam or the Chicago River Controlling Works (CRCW); it does not go to the WPS. Recreational boat fishing occurs on the North Shore Channel leading to the WPS, but boats cannot move from the North Shore Channel into Lake Michigan.

The Nonstructural Alternative includes ballast and bilge water discharge prior to entering the aquatic pathway and is expected to address the human-mediated transport of bighead carp through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: There are two lock complexes (Brandon Road Lock and Dam and Lockport Lock and Dam) within the pathway. The Brandon Road and Lockport locks and dams are expected to control the upstream movement of fish except during lockages. The complexity of navigating through the lock may slow the upstream passage of Asian carp. There is some leakage around and through the gates (Ackerson 2012) that small larvae could move through, but the larvae would not be able to swim against the current created by the leakage. It is unlikely larvae or other bigger individuals could move through closed lock gates. However, during normal operations, bighead carp are expected to be able to swim through open gates.

In addition, there is an electrical barrier complex referred to as the Electric Dispersal Barrier System. The Electric Dispersal Barrier System, located approximately 5 mi upstream of Lockport Lock and Dam and 31 mi downstream of Lake Michigan via Chicago Lock, consists of three electrical barriers: Demonstration Barrier, Barrier IIA, and Barrier IIB (USACE 2011c). The barriers consist of steel electrodes mounted across the bed of the Chicago Sanitary and Ship Canal (CSSC) that pulse direct current into the water at a strength, pulse duration, and frequency that repels and stuns fish.

The Demonstration Barrier has been operational since 2002 and was rehabilitated in 2008, but it was designed and built with materials that were not intended for long-term use because of its demonstration status. Barrier IIA was activated in April 2009 at the same settings as the Demonstration Barrier – 1 volt per in., 5 Hertz, and 4 milliseconds. These settings were increased in August 2009 to 2 volts per in., 15 Hertz, and 6.5 milliseconds in response to eDNA monitoring results that suggested Asian carp were closer to the barriers than earlier believed. Barrier IIB was activated in April 2011 at Barrier IIA's settings, and Barrier IIA was placed into warm standby mode. In October 2011, Barrier II's operational settings were changed to 2.3 volts per in., 30 Hertz and 2.5 milliseconds, based on laboratory research suggesting these settings would be more effective in deterring very small fish. The U.S. Army Corps of Engineers continues to study the optimal operating parameters to deter very small fish.

USFWS is evaluating feral fish populations and their behavior within the electric dispersal barrier using a dual-frequency identification SONAR (DIDSON; Sound Metrics Corp., Bellevue, WA) unit to evaluate fish populations throughout the entire barrier system (Parker 2013). Results of sampling across the entire barrier system during the summer of 2013, using DIDSON equipment, revealed a large accumulation of fish below the active barrier. Some of the fish that were immediately below the active barrier (either Barrier IIA or IIB) were observed persistently probing and challenging the barrier. DIDSON results showed schools of small fish breaching the barrier. Typically, as the schools of fish penetrated deeper into the zone of ultimate field strength, the size of the school contracted into a tight sphere shape and after they breached, the group expanded again. The sizes of the fish that breached the barrier are estimated to range from approximately 2 to 4 in. in length. To help determine the species of fish most likely observed breaching the barrier, the USFWS performed a limited amount of fish sampling within the narrow array on September 27, 2013 and caught gizzard shad (*Dorosoma cepedianum*), threadfin shad (*Dorosoma petenense*), and skipjack herring (*Alosa chrysochloris*) (USACE 2013). Additional study is underway to further evaluate operational protocols of the barriers and to identify any potential actions that may be employed to address the findings discussed in this paper.

There are several other mechanisms identified for potential barrier bypass. First, fish could swim through the Dispersal Barrier during times of power outage. According to records through March 2013, the Electric Dispersal Barrier System experienced a loss of power to the water for a total of 4 minutes prior to 2011, and a total of 13 minutes in 2012 (USACE unpublished data, Electric Dispersal Barrier System Power Outage Records, April 1, 2013). Work is underway on a redundant power supply for Barrier IIA and similar work is planned for Barrier IIB. In addition, automatic transfer mechanisms were installed on both Barriers IIA and IIB to maintain power in the water in the event of a power loss. Permanent Barrier I, the upgrade for the Demonstration Barrier, will provide yet another redundant electric field of the Dispersal Barrier System during power outages at Barrier IIA or IIB. Secondly, the Electric Dispersal Barrier System would be intentionally shut down completely in emergency situations under a man-overboard scenario; however, there have been no man-overboard scenarios near the Dispersal Barriers as far back as the initialization of the Demo Barrier in 2002.

Additional potential barrier aquatic bypass vectors are currently under investigation and include reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage and fish entrainment within barge induced water currents across the Electric Dispersal Barrier System. Preliminary research at the USACE Engineer Research and Development Center in Vicksburg, MS has shown model fish (soft plastic fish lures) to become entrained at numerous surface junctions, to varying degrees, between inter-barge and tow-barge connections on model tow-barge vessels. Additionally, electrical readings taken within the void created between a raked (sloped) bow and a boxed (flat) stern junction show that steel hulled barges reduce the in water electrical parameters in this area (USACE 2013).

The USFWS placed live surrogate species of fish in cages alongside and between junctions of barges in the CSSC to evaluate fish-barge interactions and assess the possibility of the fish becoming incapacitated as they traversed the electrical barrier. Fish were incapacitated as they encountered the electrical field at all barge locations, except the void space in the rake to box junction. Several feral fish were observed being entrained in two locations around the barges during trial runs indicating that wild fish do interact with barge traffic near the barriers. In order to determine if wild fish would stay in this void without a cage, a follow-up study was conducted with externally tagged fish (tethered to a float). Tethered fish placed in barge junctions breached the barrier to some degree in all but one barge configuration tested. When tethered fish were placed below the barriers as barges approached, some degree of fish breaching the barrier occurred with every different configuration tested (USACE 2013). Results from these ongoing studies are preliminary. This combination of increased possibility of entrainment and reduced electrical parameters due to barge traffic is expected to lead to an increased possibility of fish being transported over the barrier system. Vessel speed and tow/barge configuration are considered to be primary factors that affect the possible entrainment and transport of fish through the electric barriers (USACE 2013). Further research is being conducted to mitigate this bypass. While preliminary results from these investigations have shown these bypasses to be viable, the possibility of these bypasses occurring in the field is low at this time due to the low or non-existent population of bighead carp in the Lockport Pool.

In 2010, lateral barricades were constructed between the CSSC, the Des Plaines River, and the Illinois and Michigan Canal to control upstream bypass of the Electrical Dispersal Barrier System during flooding between these adjacent waterways. The Des Plaines River Barricade extends approximately 13 mi and consists of concrete barriers and specially fabricated 0.25-in. wire mesh that allows water to flow through the fence but controls the passage juvenile and adult fish, and the Illinois and Michigan Canal is walled-off using a stone berm. Small sections of the Des Plaines barricade fence failed during flooding in 2013; however, monitoring crews immediately responded and monitored for the presence of fish along breaches. Though these efforts indicated that fish (common carp) had moved through the breaches, no Asian carp were caught (Barkowski 2013), and prior monitoring efforts in the Des Plaines River had not captured or observed Asian carp, larval fish, or eggs (ACRCC 2013b).

Under current operational protocols, monitoring for Asian carp occurs downstream and upstream of the Electric Dispersal Barrier System. In the event an individual is found upstream of the Lockport Lock and Dam, protocol dictates the use of intensive electrofishing and netting to find and remove individuals or the use of rotenone to immobilize and kill all fish within the reach of concern (ACRCC 2011). It is anticipated that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp are above the Brandon Road Lock and Dam.

In addition, there are water control structures separating WPS from Lake Michigan, which are periodically opened and closed (LimnoTech 2010). When these structures are opened, bighead carp would be able to swim into Lake Michigan.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.

T_{10}: Future operations of the Brandon Road Lock and Dam and Lockport Lock and Dam locks are not expected to change as of the time of this assessment. The Electric Dispersal Barrier System is expected to have additional redundancies in power supply, thereby reducing potential power outage events**.** A new barrier is currently under construction that will upgrade the Demo Barrier to permanent status (Barrier I). Barrier I will be capable of producing higher electrical outputs than those of Barrier II and will add an additional narrow array on the downstream boundary. Barrier I is expected to become operational by 2016. Further study of the current Electric Dispersal Barrier System to address electric field shielding by steel-hulled vessels, fish entrainment within barge-induced water currents and very small fish would continue and would inform future operations.

Future operations of WPS sluice gate are not predicted to change. The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.

T_{25}: See T_{10}. Funding for research, monitoring and removal programs for bighead carp at this time step is highly uncertain. Currently, no funding source has been identified for any one agency to maintain the present level of effort.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.

T_{50}: See T_{10} and T_{25}.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Bighead carp prefer eutrophic conditions but survive with low growth rates with low plankton concentrations (Kolar et al. 2005, Cooke et al. 2009). The CAWS is the recipient of treated wastewater from numerous facilities that produces eutrophic conditions suitable for bighead carp. Additionally, recent plankton surveys within the CAWS suggest there are relatively high concentrations of zooplankton available as a food resource (ACRCC 2013a; Butler et al. 2013). Bighead carp utilize all parts of the water column in rivers (Schultz et al. 2007; DeGrandchamp et al. 2008; Kolar et al. 2005). They can be found in low velocity and off-channel habitats associated with slow-moving water (<0.3 m/s [1.0 ft/s]) (Kolar et al. 2005), but are capable of swimming in very-high-velocity habitats, with a maximum measured swimming speed of approximately 7.5 m/s (24.6 ft/s) (Konagaya and Cai 1987). During normal conditions, the CAWS has a slow-moving current (LimnoTech 2010). Sections of the CAWS also experience seasonally low dissolved oxygen (LimnoTech 2010). Heilprin et al. (2013a) found that larvae of bighead carp can survive under low dissolved oxygen conditions (0.86 mg/L) inside a barge ballast tank. This supports the findings of other studies that indicate the species can survive low dissolved oxygen conditions: adults (0.5 mg/L) (Oregon Sea Grant 2011), juveniles (0.33 mg/L), and young (0.4 mg/L) (Jennings 1988). Adult bighead carp can withstand water temperatures up to 38.8°C (101.8°F) (Bettoli et al. 1985). Overall, the conditions of the CAWS are not expected to impede movement of bighead carp.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for bighead carp.

T_{10}: See T_0. Conditions of the CAWS are predicted to change, but not in a way that would affect the likelihood of this species passing through this pathway. For example, the Metropolitan Water Reclamation District of Greater Chicago (MWRD) is in the process of evaluating ways to improve the water quality of the CAWS by decreasing the amount of organic materials released into the CAWS. This could potentially decrease the amount of plankton and other food species bighead carp would need to survive within the CAWS. In addition, in coordination with the USACE, MWRD will increase capacity of stormwater catchment and retention in adjacent tunnels and reservoirs. This will lead to a lower hydrologic peak during storm events. The environmental conditions within the CAWS may change slightly with the closing of two coal-fired power plants (Midwest Generation's Fisk and Crawford Plants) in August 2012. These plants used canal water in their cooling process and returned heated water back to the canal. As a result, temperature profiles may be reduced significantly in the near vicinity and to a lesser extent downstream. This is not expected to significantly affect the ability of bighead carp to pass through this pathway.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for bighead carp.

T_{25}: See T_{10}

T_{50}: See T_{10}

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Bighead carp would need to pass through the Brandon Road and Lockport locks and dams, the Electric Dispersal Barrier System and an intermittent sluice gate opening to pass through this pathway. Adults and all life sizes of bighead carp would be able to swim through the locks when the lock is in operation; however, the locks may slow passage of bighead carp through the pathway.

Based on the sampling and monitoring data, the abundance of individuals within the Lockport Pool below the dispersal barriers is expected to be low to non-existent at this timestep. Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring data, it appears that few bighead carp have expanded past the Brandon Road Lock and Dam. As discussed in *P(arrival)*, *Current and Potential Abundance and Reproductive Capacity*, in 2012, small Asian carp were relatively abundant in the LaGrange Lock and Dam and Peoria Lock and Dam. Only one was caught in the Starved Rock pool. No small age-1 Asian carp were found in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. Adult populations of bighead carp are in the Dresden Island Pool (ACRCC 2013a). In an effort to control the Asian carp population downstream of the barrier, fisherman have been contracted to remove these fish from the waterway.

Monitoring and research have found several potential bypass mechanisms for the Electric Barrier System: man overboard scenario when power to the barrier is intentionally turned off, power outages, bypass during flood events, stunned fish floating through the barrier during reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage and fish entrainment within barge induced water currents across the Electric Dispersal Barrier System. Bypass due to these various mechanisms is not likely, because the nearest detectable population of swimming bighead carp is in Dresden Island Pool and the nearest detected eggs, larvae, and fry are farther downstream (ACRCC 2013a). Additionally, research on these bypasses continues and will inform future operations.

In summary, current propagule pressure of this species immediately downstream of the Dispersal Barriers is considered low or non-existent as measured by monitoring efforts of local, state and federal agencies. The probability of passage for the bighead carp is low for T_0 because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier, then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The low passage rating is in conflict with the Canadian Science Advisory Report (2012) that rates passage through the CAWS as highly likely. However, the Canadian report explicitly did not evaluate the effectiveness of the Electric Dispersal Barrier System.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{10}: See $T_{0.}$ Bighead carp are expected to remain in low populations immediately below the Electric Dispersal Barrier System. Contracted fishermen are expected to continue to improve their fishing techniques to increase their catch rates. The Brandon Road and Lockport locks and dams may also slow bighead carp passage.

Federal and state natural resource agencies have monitored the upstream progress of Asian carp populations since their arrival in the IWW in the 1990's (Conover et al. 2007; Irons et al. 2009; ACRCC 2013a). Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring, it appears that few bighead carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences. Also, it is anticipated that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp above the Brandon Road Lock and Dam.

Further refinement of the Electric Dispersal Barrier System operations and redundant power sources are expected to decrease the number and length of potential power outages. Additionally, potential transport vectors across the barriers (e.g., vessel entrainment, insufficient operating parameters for small fish, reverse flow events, crevice shielding of electric field) will continue to be analyzed and future operations would informed by this analysis.

The probability of passage for the bighead carp is low for T_{10} because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, though monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}. Funding for monitoring and removal programs for bighead carp at this time step is uncertain because there is not a funding source identified to maintain the present level of management. With the continued expected immigration from the lower pools (Tsehaye et al. 2013), the propagule pressure at the Dispersal Barrier System is expected to increase, and thus increase the potential for an individual to move past the Barriers.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Though ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, though monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's medium probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{50}: See T_{10} and T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	High	High	High
Nonstructural Alternative Rating	Medium	High	High	High

Evidence for Uncertainty Rating

T_0: Although there has been an extraordinary effort from multiple agencies to research potential barrier bypass mechanisms, much of that research is currently underway and only preliminary results have been reported. Each risk assessment was conducted qualitatively under the assumption that bypass is possible but did not address the frequency that it might occur under a set of quantitative conditions. It is also uncertain whether additional bypass mechanisms could still be discovered. Though comprehensive monitoring upstream and downstream of the barrier for Asian carp is ongoing, uncertainty still exists concerning whether monitoring has identified the true abundance of bighead carp within upper Illinois River and the CAWS.

The Nonstructural Alternative is expected to affect the passage of bighead carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Overall, the uncertainty remains medium.

T_{10}: See T_0. Although empirical tests are underway to see if the potential transport mechanisms across the barriers are viable, at this time uncertainty increases with time because of unknown events. Additionally, funding for management actions that keep the populations of Asian carp in check immediately downstream of the Dispersal Barriers are not specified. The factors contributing to the historic absence of range expansion beyond the Brandon Road Lock and Dam are uncertain and may change.

The Nonstructural Alternative is expected to affect the passage of bighead carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Overall, the uncertainty remains high.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.
Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 2

BRANDON ROAD LOCK AND DAM TO CHICAGO RIVER CONTROLLING WORKS (CRCW)

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE PROBABILITY OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are anticipated that would reduce or eliminate the hydrologic connection between Brandon Road Lock and Dam and CRCW over the next 50 years.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Bighead carp are active swimmers. Total maximum distance traveled upstream by an individual was 163 km (101 mi) over 35 days (Peters et al. 2006), with an average of 4.5 km (2.8 mi) traveled per day. Average expansion rates for bighead carp are recorded at 9 river miles per year (Jerde et al. 2010) and they were able to move from Arkansas into Mississippi, Missouri, Ohio, and Illinois rivers. Bighead carp expansion rates were also tracked via the Long Term Resource Monitoring Program in the Mississippi and Illinois Rivers. First detections at Pool 26 (Mississippi River; 1991) to the La Grange reach (Illinois River; 1995) indicated the detectable population moved over 98 river miles in just 4 years (Irons et al. 2009) and continued upstream progression in the Illinois River to the Dresden Island Pool by 2007 (USGS 2013).

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the CAWS by natural dispersion.

b. Human-Mediated Transport through Aquatic Pathways

There is commercial vessel and recreational boat traffic between the current location of bighead carp and the Brandon Road Lock and Dam. Bighead carp eggs, larvae, and fry have the potential to be spread by ballast water if water quality is suitable, although the viability of this ballast water transport is considered to be low (Heilprin et al. 2013).

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the CAWS from human-mediated transport through this aquatic pathways.

c. Current and Potential Abundance and Reproductive Capacity

T_0: Adult bighead carp are abundant in the Illinois Waterway from Starved Rock Lock & Dam (RM231) to the confluence with Mississippi River (Chick and Pegg 2001; Irons et al. 2009; ACRCC 2012; Garvey, et al. 2013; Wyffels et al. 2013). Bighead carp were reported to have high abundances within the La Grange pool of the Illinois River from sampling conducted from 2000 to 2006 (Irons et al. 2011). Bighead carp reached peak abundance levels in 2000 and have declined between 2004 and 2006; however, these declines may be due to capture gear inefficiencies (Irons et al. 2011). Sampling efforts for Asian carp conducted in the upper pools of the Illinois River (Marseilles-Lockport) from 2010 through 2012 indicated a decreasing population from downstream to upstream (Ruebush et al. 2013).

A MRWG composed of academic, local, state and federal agencies was established in 2010 by the ACRCC. The ACRCC's mission statement is to create a sustainable Asian carp control program for protecting the integrity and safety of the Great Lakes ecosystem by preventing introduction of a sustainable Asian carp population into the Great Lakes via all viable pathways (ACRCC 2013d). The MRWG has projects focusing on waterway monitoring, removal efforts, Electric Dispersal Barrier System efficacy, gear

catch efficacy and alternative pathway monitoring. Regular electrofishing and netting efforts have consisted of 16,497 person-hours of sampling from the Starved Rock Pool to Lake Michigan resulting in the capture of 283,290 specimens from 2010 to 2012. Removal efforts below the barrier system include contracted commercial fishermen setting over 643.3 mi of nets through 2012 to remove 698.72 tons of bighead, silver and grass carp. Additional workgroup projects include juvenile, larval and egg sampling, ichthyoplankton surveys, telemetry studies, hydro-acoustic surveys, and alternative gear development all of which provide up-to-date information on the status of Asian carp populations and range expansion (ACRCC 2013a).

In 2013, a significant number of bighead carp were captured in the Rock Run Rookery Preserve Lake, a backwater in the Dresden Island pool, 4 mi downstream of the Brandon Road Lock and Dam (ACCRC 2013c). There are no physical barriers between Rock Run Rookery Preserve Lake and the Brandon Road Lock and Dam. It is unknown whether this represents a population increase in this pool since the rookery was not previously sampled.

Above Dresden Island Pool, one bighead was collected in 2009 within Lockport Pool downstream of the Electric Dispersal Barrier System during a rotenone application (ACRCC 2009). In 2010, a bighead was captured in Lake Calumet during routine monitoring upstream of the Electric Dispersal Barrier System (ACRCC 2012).

Bighead carp are broadcast spawners that spawn in large aggregates (Kolar et al. 2005). Female egg production is correlated with increased body mass and age. Females with as many as 1.1 million eggs have been found in the Yangtze River, China (Kolar et al. 2005). In the Missouri River the mean fecundity was measured as the average adult female producing 226,213 eggs (Shrank and Guy 2002). In 2004, in the Illinois River, mean egg production was measured as 180,000 per female (DeGrandchamp et al. 2007). Kolar et al. (2007) reported that their analysis suggested that populations appear to be growing exponentially at the time of the report. Garvey et al. (2006) points out that bighead carp have a slower population level somatic growth rate, higher survival, lower fecundity, later maturity and longer lives relative to silver carp. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock pool and none in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of bighead carp. Controlled harvest and overfishing measures have removed over 1.3 million lbs of Asian carp from the Illinois River betwen 2010 and 2012 (ACRCC 2013e). However, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The bighead carp has been listed as an injurious fish species under the Lacey Act (Federal Register 2011), and federal and state agencies have implemented components of the *National Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States* (Conover et al. 2007). However, ongoing barrier defense monitoring indicates that bighead carp remains abundant in the Illinois River (Wyffels et al. 2013) at the current level of harvest, regulation, and management.

Overall, the Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{10}: Based on the above information, bighead carp seem to have a high reproductive capacity in terms of producing new young per year. Therefore, current populations are expected to increase in abundance. Additionally, future environmental conditions or population genetics have the potential to shift in such a way that would allow a rapid growth and expansion of downstream populations that could lead to increased immigration into the pathway (Kolar et al. 2007); therefore, abundance is anticipated to increase below the Brandon Road Lock and Dam. This assessment is based on past invasion histories for multiple species (Crooks and Soulé 1996; Williamson 1996; Nico and Fuller 1999; Lockwood, Hoopes, and Marchetti 2007); also, see the above section *Type of Mobility/Invasion Speed* for more information. The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{25}: It is expected that, in areas with established populations, natural constraints on population growth would begin to reach a plateau. Thus, reproductive capacity would remain the same, but would no longer result in an exponentially increasing population. The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{50}: See T_{25}.

d. *Existing Physical Human/Natural Barriers*

T_0: None. There are no barriers to movement of bighead carp from their current position to Brandon Road Lock and Dam.

The Nonstructural Alternative would not affect existing physical human/natural barriers to the pathway.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. *Distance from Pathway*

T_0: There have been two recorded captures of bighead carp above the Brandon Road Pool. The first was collected in 2009 within the Lockport Pool, downstream of the

Electric Dispersal Barrier System, during a rotenone application (ACRCC 2009). The second capture occurred during routine monitoring in Lake Calumet. Lake Calumet is directly connected to the Little Calumet River, only 6 mi from Lake Michigan (ACRCC 2012). Multiple bighead carp have been captured in landlocked Chicago-area urban fishing ponds above the barrier. It is likely that these fish were accidentally introduced during stocking for the Illinois Department of Natural Resources urban fishing program of catchable sized channel catfish in the 2002-2003 timeframe (ILDNR 2011; ACRCC 2013e). In addition, there have been multiple positive eDNA detections upstream of electric barriers for bighead carp (Jerde et al. 2011). However, there is no evidence to correlate the eDNA detections to an established Asian carp population above the Electric Dispersal Barrier System within the CAWS (ACRCC 2012; Environmental DNA Calibration Study 2013). Calibration studies are underway to better understand the relationship between positive eDNA and Asian carp populations (ACRCC 2013b).

Below the Brandon Road Pool, bighead carp have been detected in the Dresden Island pool. A significant number of adult bighead carp were captured approximately 4 mi downstream of the Brandon Road Lock and Dam in the Rock Run Rookery Preserve Lake in 2013 (ACCRC 2013c). The USACE telemetry program has also recorded one individual bighead carp that approached the Brandon Road Lock and Dam in 2012 before returning downstream to the mouth of the Kankakee River (Shanks and Barkowski 2013). Based on the persistent populations in Marseilles Poo, and the 2013 captures in Rock Run Rookery Preserve Lake approximately 4 mi from Brandon Road Lock and Dam, the bighead carp has arrived at the pathway (Brandon Road Lock and Dam).

The Nonstructural Alternative is not expected to affect the bighead carp's distance from the aquatic pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Bighead carp prefer eutrophic conditions but can survive with low growth rates under low plankton concentrations (Kolar et al. 2007). There was no difference in catch rate regarding location within the water column as measured within the backwaters of the Illinois River (Schultz et al. 2007). DeGrandchamp et al. (2008) suggest that bighead carp rarely occupy depths greater than 4 m (13 ft) regardless of abiotic factors. Other studies indicate that 3 m (9.8 ft) deep or more provides suitable conditions for bighead carp (Kolar et al. 2005). Bighead carp can be found in low velocity and off-channel habitats in the Mississippi, Missouri, Wabash and lower Ohio Rivers and all sizes collected in the Upper Mississippi River Basin were strongly associated with slow-moving water (<0.3 m/s [1.0 ft/s]) (Kolar et al. 2005). During low flow, bighead carp avoid channels & backwaters (DeGrandchamp et al. 2008), but will use spur dikes (Kolar et al. 2007; Cooke et al. 2009). These varied habitats are found throughout the Dresden Island Pool, including the Rock Run Rookery Preserve Lake and in the Kankakee River. This species is found in Swan Lake, which is connected to the Illinois River

(DeGrandchamp et al. 2007). Heilprin (2013) found that larvae of bighead carp can survive under low DO conditions (0.86 mg/L) inside a barge ballast tank. This supports the findings of other studies that indicate adults (0.5 mg/L; Oregon Sea Grant 2011), juveniles (0.33 mg/L) and young (0.4 mg/L; Jennings 1988) can survive low DO conditions. Critical spawning temperature for bighead carp is reported as 18°C (64.4°F) (Irons et al. 2009). However, typically successful fertilization occurs between 21° and 26°C (69.8 and 78.8°F) (Kolar et al. 2005). The mean summer temperature of Lake Michigan near Chicago ranges between 20 and 23°C (64.4°F). Adult bighead carp can withstand water temperatures up to 38.8°C (101.8°F) (Bettoli et al. 1985).

The Nonstructural Alternative is not expected to affect the suitability of habitat for bighead carp.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Bighead carp have been documented at the Brandon Road Lock and Dam and Lockport Pool upstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp to the aquatic pathway. The bighead carp has arrived at the pathway. Therefore, the probability of arrival remains high.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: A bighead carp was captured in the Lockport pool, upstream of the Brandon Road Lock and Dam; telemetric tracking of tagged individual bighead carp has provided evidence of at least one individual approaching the Brandon Road Lock and Dam in 2012; and in the spring of 2013, the capture of significant numbers of bighead carp at Rock Run Rookery Forest Preserve Lake, which is approximately 4 mi from the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{10}: See T_0. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) can reduce Asian carp populations. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) can reduce Asian carp populations. However, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{25}: See T_0. It is uncertain whether Asian carp monitoring and harvesting activities in Dresden Island Pool will continue during this time step. Bighead carp populations in the Dresden Island Pool are expected to increase to existing levels or higher.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{50}: See T_{25}.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Bighead carp is an active swimmer that can swim against the slow current of the CAWS. An individual can travel as far as 4.5 km (2.8 mi) per day (Peters et al. 2006). Bighead carp expansion rates were also tracked via the Long Term Resource Monitoring Program in the Mississippi and Illinois Rivers. First detections at Pool 26 (Mississippi River 1991) to the La Grange Pool (Illinois River 1995) indicated the detectable population moved over 98 river miles in just 4 years (Irons et al. 2009) and continued progression in the Illinois River approximately 200 mi upstream to the Dresden Island Pool by 2007 (USGS 2013). Average expansion rates for bighead carp are recorded at 9 river miles per year (Jerde et al. 2010).

Asian carp were first sampled from the Illinois River during the 1990's and populations have since progressed upstream (Conover et al. 2007; Irons et al. 2009). Monitoring for bighead and silver carp was originally incidental to standard routine sampling by the Illinois Department of Natural Resources (IDNR) and the Illinois Natural History Survey (INHS). Sampling directed toward Asian carp in the upper Illinois Waterway began with the US Fish and Wildlife Service's (USFWS) annual Carp Corral & Round Goby Roundup. Subsequently, the US Army Corps of Engineers (USACE) adopted a plan specifically to monitor Asian carp downstream of the electric barrier system located near Romeoville, Illinois (ACRCC 2013a). By 2010, the ACRCC was formed to coordinate this intensive monitoring effort which was expanded to include techniques including but not limited to eDNA, electrofishing, netting, sonar, and telemetry above and below the barrier generally between Lake Michigan and the Peoria Lock and Dam (ACRCC 2010).

As noted above, in 2007, bighead carp were first captured in Dresden Island Pool. In 2009, one bighead carp was found in the Lockport Pool during a rotenone event (ACRCC 2009), and in 2010, a bighead was captured in Lake Calumet during routine monitoring upstream of the Electric Dispersal Barrier System (ACRCC 2012). Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring data, it appears that few bighead carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences.

Within the Marseilles and Dresden Island Pools, reproductively mature bighead carp have been captured but no fertilized eggs or larvae have been found. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock pool and none in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. The nearest population of juvenile sized individuals is in the Peoria Pool below Starved Rock Lock and Dam, five locks downstream of the Electric Dispersal Barrier System (Baerwaldt et al. 2013). The nearest collection of Asian carp eggs was found near Henry, Illinois, within the Peoria Pool, five locks downstream of the Electric Dispersal Barrier System. Larval Asian carp were only collected in LaGrange Pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the natural dispersion (i.e., swimming and passive drift) of the bighead carp through the aquatic pathway.

b. *Human-Mediated Transport through Aquatic Pathways*

Bighead carp actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming will likely be the primary mechanism of movement through the CAWS from the Brandon Road Lock and Dam. There is heavy commercial vessel traffic between Brandon Road Lock and Dam and the Chicago River (USACE 2011a,b) and there is the potential for bighead carp eggs and larvae to be transported upstream of the Electric Dispersal Barrier System by passive entrainment in a ballast tank (no pumping). Heilprin et al. (2011) found water sampled from barge ballast through a single summer to be within published water quality parameters to sustain juvenile and adult Asian carp. Additionally, survivability of larvae and eggs within ballast water was found to be high for periods up to 144 hours but a very low percentage of larvae survived pump passage when expelling the ballast water (Heilprin 2013).

USCG has established a regulated navigation area around the Electric Dispersal Barrier System which prohibits vessels from transiting the safety zone with any non-potable water on board if they intend to release that water in any form within, or on the other side of the safety zone (USCG, 2011).

Other vessel-related transport mechanisms that may reduce the effectiveness of the Electric Dispersal Barrier System are discussed in Section 4c, *Existing Physical Human/Natural Barriers*.

The Nonstructural Alternative includes ballast and bilge water discharge prior to entering the aquatic pathway and is expected to address the human-mediated transport of bighead carp through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: There are two lock complexes (Brandon Road Lock and Dam and Lockport Lock and Dam) within the pathway. The Brandon Road and Lockport locks and dams are expected to control the upstream movement of fish except during lockages. The complexity of navigating through the lock may slow the upstream passage of Asian carp. There is some leakage around and through the gates (Ackerson 2012) that small larvae could move through, but the larvae would not be able to swim against the current created by the leakage. It is unlikely larvae or other bigger individuals could move through closed lock gates. However, during normal operations, bighead carp are expected to be able to swim through open gates.

In addition, there is an electrical barrier complex referred to as the Electric Dispersal Barrier System. The Electric Dispersal Barrier System, located approximately 5 mi upstream of Lockport Lock and Dam and 31 mi downstream of Lake Michigan via the Chicago Lock, consists of three electrical barriers: Demonstration Barrier, Barrier IIA, and Barrier IIB (USACE 2011c). The barriers consist of steel electrodes mounted across the bed of the Chicago Sanitary and Ship Canal (CSSC) that pulse direct current into the water at a strength, pulse duration, and frequency that repels and stuns fish.

The Demonstration Barrier has been operational since 2002 and was rehabilitated in 2008, but it was designed and built with materials that were not intended for long-term use because of its demonstration status. Barrier IIA was activated in April 2009 at the same settings as the Demonstration Barrier – 1 volt per in., 5 Hertz, and 4 milliseconds. These settings were increased in August 2009 to 2 volts per in., 15 Hertz, and 6.5 milliseconds in response to eDNA monitoring results that suggested Asian carp were closer to the barriers than earlier believed. Barrier IIB was activated in April 2011 at Barrier IIA's settings, and Barrier IIA was placed into warm standby mode. In October 2011, Barrier II's operational settings were changed to 2.3 volts per in., 30 Hertz and 2.5 milliseconds, based on laboratory research suggesting these settings would be more effective in deterring very small fish. The U.S. Army Corps of Engineers continues to study the optimal operating parameters to deter very small fish.

USFWS is evaluating feral fish populations and their behavior within the electric dispersal barrier using a dual-frequency identification SONAR (DIDSON; Sound Metrics Corp., Bellevue, WA) unit to evaluate fish populations throughout the entire barrier system (Parker 2013). Results of sampling across the entire barrier system during the summer of 2013, using DIDSON equipment, revealed a large accumulation of fish below the active barrier. Some of the fish that were immediately below the active barrier (either Barrier IIA or IIB) were observed persistently probing and challenging the barrier. DIDSON results showed schools of small fish breaching the barrier. Typically, as the schools of fish penetrated deeper into the zone of ultimate field strength, the size of the school contracted into a tight sphere shape and after they breached, the group expanded again. The sizes of the fish that breached the barrier are estimated to range from approximately 2 to 4 in. in length. To help determine the species of fish most likely observed breaching the barrier, the USFWS performed a limited amount of fish sampling within the narrow array on September 27, 2013, and caught gizzard shad (*Dorosoma cepedianum*), threadfin shad (*Dorosoma petenense*), and skipjack herring (*Alosa chrysochloris*) (USACE 2013). Additional study is underway to further evaluate operational protocols of the barriers and to identify any potential actions that may be employed to address the findings discussed in this paper.

There are several other mechanisms identified for potential barrier bypass. First, fish could swim through the Dispersal Barrier during times of power outage. According to records through March 2013, the Electric Dispersal Barrier System experienced a loss of power to the water for a total of 4 minutes prior to 2011, and a total of 13 minutes in 2012 (USACE unpublished data, Electric Dispersal Barrier System Power Outage Records, April 1, 2013). Work is underway on a redundant power supply for Barrier IIA and similar work is planned for Barrier IIB. In addition, automatic transfer mechanisms were installed on both Barriers IIA and IIB to maintain power in the water in the event of a power loss. Permanent Barrier I, the upgrade for the Demonstration Barrier, will provide yet another redundant electric field of the Dispersal Barrier System during power outages at Barrier IIA or IIB. Secondly, the Electric Dispersal Barrier System would be intentionally shut down completely in emergency situations under a man-overboard scenario; however, there have been no man-overboard scenarios near the Dispersal Barriers as far back as the initialization of the Demo Barrier in 2002.

Additional potential barrier aquatic bypass vectors are currently under investigation and include reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage and fish entrainment within barge induced water currents across the Electric Dispersal Barrier System. Preliminary research at the USACE Engineer Research and Development Center in Vicksburg, MS has shown model fish (soft plastic fish lures) to become entrained at numerous surface junctions, to varying degrees, between inter-barge and tow-barge connections on model tow-barge vessels. Additionally, electrical readings taken within the void created between a raked (sloped) bow and a boxed (flat) stern junction show that steel hulled barges reduce the in water electrical parameters in this area (USACE 2013).

The USFWS placed live surrogate species of fish in cages alongside and between junctions of barges in the CSSC to evaluate fish-barge interactions and assess the possibility of the fish becoming incapacitated as they traversed the electrical barrier. Fish were incapacitated as they encountered the electrical field at all barge locations, except the void space in the rake to box junction. Several feral fish were observed being entrained in two locations around the barges during trial runs indicating that wild fish do interact with barge traffic near the barriers. In order to determine if wild fish would stay in this void without a cage, a follow-up study was conducted with externally tagged fish (tethered to a float). Tethered fish placed in barge junctions breached the barrier to some degree in all but one barge configuration tested. When tethered fish were placed below the barriers as barges approached, some degree of fish breaching the barrier occurred with every different configuration tested (USACE 2013). Results from these ongoing studies are preliminary. This combination of increased possibility of entrainment and reduced electrical parameters due to barge traffic is expected to lead to an increased possibility of fish being transported over the barrier system. Vessel speed and tow/barge configuration are considered to be primary factors that affect the possible entrainment and transport of fish through the electric barriers (USACE 2013). Further research is being conducted to mitigate this bypass. While preliminary results from these investigations have shown these bypasses to be viable, the possibility of these bypasses occurring in the field is low at this time due to the low or non-existent population of bighead carp in the Lockport Pool.

In 2010, lateral barricades were constructed between the CSSC, the Des Plaines River, and the Illinois and Michigan Canal to control upstream bypass of the Electrical Dispersal Barrier System during flooding between these adjacent waterways. The Des Plaines River Barricade extends approximately 13 mi and consists of concrete barriers and specially fabricated 0.25-in. wire mesh that allows water to flow through the fence but controls the passage juvenile and adult fish, and the Illinois and Michigan Canal is walled-off using a stone berm. Small sections of the Des Plaines barricade fence failed during flooding in 2013; however, monitoring crews immediately responded and monitored for the presence of fish along breaches. Though these efforts indicated that fish (common carp) had moved through the breaches, no Asian carp were caught (Barkowski 2013), and prior monitoring efforts in the Des Plaines River had not captured or observed Asian carp, larval fish, or eggs (ACRCC 2013b).

Under current operational protocols, monitoring for Asian carp occurs downstream and upstream of the Electric Dispersal Barrier System. In the event an individual is found upstream of the Lockport Lock and Dam, protocol dictates the use of intensive electrofishing and netting to find and remove individuals or the use of rotenone to immobilize and kill all fish within the reach of concern (ACRCC 2011). It is anticipated that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp are above the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.

T_{10}: Future operations of the Brandon Road Lock and Dam and Lockport Lock and Dam locks are not expected to change as of the time of this assessment. The Electric Dispersal Barrier System is expected to have additional redundancies in power supply, thereby reducing potential power outage events**.** A new barrier is currently under construction that will upgrade the Demo Barrier to permanent status (Barrier I). Barrier I will be capable of producing higher electrical outputs than those of Barrier II and will add an additional narrow array on the downstream boundary. Barrier I is expected to become operational by 2016. Further study of the current Electric Dispersal Barrier System to address electric field shielding by steel-hulled vessels, fish entrainment within barge-induced water currents and very small fish would continue and would inform future operations.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.

T_{25}: See T_{10}. Funding for research, monitoring and removal programs for bighead carp at this time step is highly uncertain. Currently, no funding source has been identified for any one agency to maintain the present level of effort.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.

T_{50}: See T_{10} and T_{25}.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Bighead carp prefer eutrophic conditions but survive with low growth rates with low plankton concentrations (Kolar et al. 2005; Cooke et al. 2009). The CAWS is the recipient of treated wastewater from numerous facilities that produces eutrophic conditions suitable for bighead carp. Additionally, recent plankton surveys within the CAWS suggest there are relatively high concentrations of zooplankton available as a food resource (ACRCC 2013a; Butler et al. 2013). Bighead carp utilize all parts of the water column in rivers (Schultz et al. 2007; DeGrandchamp et al. 2008; Kolar et al. 2005). They can be found in low velocity and off-channel habitats associated with slow-moving water (<0.3 m/s [1.0 ft/s]) (Kolar et al. 2005), but are capable of swimming in very-high-velocity habitats, with a maximum measured swimming speed of approximately 7.5 m/s (24.6 ft/s) (Konagaya and Cai 1987). During normal conditions, the CAWS has a slow-moving current (LimnoTech 2010). Sections of the CAWS also experience seasonally low dissolved oxygen (LimnoTech 2010). Heilprin et al. (2013a) found that larvae of bighead carp can survive under low dissolved oxygen conditions (0.86 mg/L) inside a barge ballast tank. This supports the findings of other studies that indicate the species can survive low dissolved oxygen conditions: adults (0.5 mg/L) (Oregon Sea Grant 2011), juveniles (0.33 mg/L), and young (0.4 mg/L) (Jennings 1988). Adult bighead carp can withstand water temperatures up to 38.8°C (101.8°F) (Bettoli et al. 1985). Overall, the conditions of the CAWS are not expected to impede movement of bighead carp.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for bighead carp.

T_{10}: See T_0. Conditions of the CAWS are predicted to change, but not in a way that would affect the likelihood of this species passing through this pathway. For example, the Metropolitan Water Reclamation District of Greater Chicago (MWRD) is in the process of evaluating ways to improve the water quality of the CAWS by decreasing the amount of organic materials released into the CAWS. This could potentially decrease the amount of plankton and other food species bighead carp would need to survive within the CAWS. In addition, in coordination with the USACE, MWRD will increase capacity of stormwater catchment and retention in adjacent tunnels and reservoirs. This will lead to a lower hydrologic peak during storm events. The environmental conditions within the CAWS may change slightly with the closing of two coal-fired power plants (Midwest Generation's Fisk and Crawford Plants) in August 2012. These plants used canal water in their cooling process and returned heated water back to the canal. As a result, temperature profiles may be reduced significantly in the near vicinity and to a lesser extent downstream. This is not expected to significantly affect the ability of bighead carp to pass through this pathway.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for bighead carp.

T_{25}: See T_{10}

T_{50}: See T_{10}

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Bighead carp would need to pass through the Brandon Road and Lockport locks and dams, the Electric Dispersal Barrier System and an intermittent sluice gate opening to pass through this pathway. Adults and all life sizes of bighead carp would be able to swim through the locks when the lock is in operation; however, the locks may slow passage of bighead carp through the pathway.

Based on the sampling and monitoring data, the abundance of individuals within the Lockport Pool below the dispersal barriers is expected to be low to non-existent at this timestep. Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring data, it appears that few bighead carp have not expanded past the Brandon Road Lock and Dam. As discussed in *P(arrival)*, *Current and Potential Abundance and Reproductive Capacity*, in 2012, small Asian carp were relatively abundant in the LaGrange Lock and Dam and Peoria Lock and Dam. Only one was caught in the Starved Rock pool. No small age-1 Asian carp were found in the Marseilles pool. The Marseilles Lock and Dam is over 68 mi from the barrier system. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. Adult populations of bighead carp are in the Dresden Island Pool (ACRCC 2013a). In an effort to control the Asian carp population downstream of the barrier, fisherman have been contracted to remove these fish from the waterway.

Monitoring and research have found several potential bypass mechanisms for the Electric Barrier System: man overboard scenario when power to the barrier is intentionally turned off, power outages, bypass during flood events, stunned fish floating through the barrier during reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage and fish entrainment within barge induced water currents across the Electric Dispersal Barrier System. Bypass due to these various mechanisms is not likely, because the nearest detectable population of swimming bighead carp is in Dresden Island Pool and the nearest detected eggs, larvae, and fry are farther downstream (ACRCC 2013a). Additionally, research on these bypasses continues and will inform future operations.

In summary, current propagule pressure of this species immediately downstream of the Dispersal Barriers is considered low or non-existent as measured by monitoring efforts of local, state and federal agencies. The probability of passage for the bighead carp is low for

T_0 because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier, then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The low passage rating is in conflict with the Canadian Science Advisory Report (2012) that rates passage through the CAWS as highly likely. However, the Canadian report explicitly did not evaluate the effectiveness of the Electric Dispersal Barrier System.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{10}: See $T_{0.}$ Bighead carp are expected to remain in low populations immediately below the Electric Dispersal Barrier System. Contracted fishermen are expected to continue to improve their fishing techniques to increase their catch rates. The Brandon Road and Lockport locks and dams may also slow bighead carp passage.

Federal and state natural resource agencies have monitored the upstream progress of Asian carp populations since their arrival in the IWW in the 1990's (Conover et al. 2007; Irons et al. 2009; ACRCC 2013a). Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring, it appears that few bighead carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences. Also, it is anticipated that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp above the Brandon Road Lock and Dam.

Further refinement of the Electric Dispersal Barrier System operations and redundant power sources are expected to decrease the number and length of potential power outages. Additionally, potential transport vectors across the barriers (e.g., vessel entrainment, insufficient operating parameters for small fish, reverse flow events, crevice shielding of electric field) will continue to be analyzed and future operations would informed by this analysis.

The probability of passage for the bighead carp is low for T_{10} because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at T_0. Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}. Funding for monitoring and removal programs for bighead carp at this time step is uncertain because there is not a funding source identified to maintain the present level of management. With the continued expected immigration from the lower pools (Tsehaye et al. 2013), the propagule pressure at the Dispersal Barrier System is expected to increase, and thus increase the potential for an individual to move past the Barriers.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at T_0. Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's medium probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{50}: See T_{10} and T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	High	High	High
Nonstructural Alternative Rating	Medium	High	High	High

Evidence for Uncertainty Rating

T_0: Although there has been an extraordinary effort from multiple agencies to research potential barrier bypass mechanisms, much of that research is currently underway and only preliminary results have been reported. Each risk assessment was conducted qualitatively under the assumption that bypass is possible but did not address the frequency that it might occur under a set of quantitative conditions. It is also uncertain whether additional bypass mechanisms could still be discovered. Though comprehensive monitoring upstream and downstream of the barrier for Asian carp is ongoing, uncertainty still exists concerning whether monitoring has identified the true abundance of bighead carp within upper Illinois River and the CAWS.

The Nonstructural Alternative is expected to affect the passage of bighead carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Overall, the uncertainty remains medium.

T_{10}: See T_0. Although empirical tests are underway to see if the potential transport mechanisms across the barriers are viable, at this time uncertainty increases with time because of unknown events. Additionally, funding for management actions that keep the populations of Asian carp in check immediately downstream of the Dispersal Barriers are not specified. The factors contributing to the historic absence of range expansion beyond the Brandon Road Lock and Dam are uncertain and may change.

The Nonstructural Alternative is expected to affect the passage of bighead carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Overall, the uncertainty remains high.

T_{25}: See T_{10}.
T_{50}: See T_{10}.

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. **P(spreads) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 3

BRANDON ROAD LOCK AND DAM TO CALUMET HARBOR

NONSTRUCTURAL ALTERNATIVE: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE PROBABILITY OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are anticipated that would reduce or eliminate the hydrologic connection between Brandon Road Lock and Dam and Calumet Harbor over the next 50 years.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Bighead carp are active swimmers. Total maximum distance traveled upstream by an individual was 163 km (101 mi) over 35 days (Peters et al. 2006), with an average of 4.5 km (2.8 mi) traveled per day. Average expansion rates for bighead carp are recorded at 9 river miles per year (Jerde et al. 2010) and they were able to move from Arkansas into Mississippi, Missouri, Ohio, and Illinois rivers. Bighead carp expansion rates were also tracked via the Long Term Resource Monitoring Program in the Mississippi and Illinois Rivers. First detections at Pool 26 (Mississippi River; 1991) to the La Grange reach (Illinois River; 1995) indicated the detectable population moved over 98 river miles in just 4 years (Irons et al. 2009) and continued upstream progression in the Illinois River to the Dresden Island Pool by 2007 (USGS 2013).

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp to the Chicago Area Waterway System (CAWS) by natural dispersion.

b. Human-Mediated Transport through Aquatic Pathways

There is commercial vessel and recreational boat traffic between the current location of bighead carp and the Brandon Road Lock and Dam. Bighead carp eggs, larvae, and fry have the potential to be spread by ballast water if water quality is suitable, although the viability of this ballast water transport is considered to be low (Heilprin et al. 2013).

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the CAWS from human-mediated transport through this aquatic pathway.

c. Current and Potential Abundance and Reproductive Capacity

T_0: Adult bighead carp are abundant in the Illinois Waterway from Starved Rock Lock & Dam (RM231) to the confluence with Mississippi River (Chick and Pegg 2001; Irons et al. 2009; ACRCC 2012; Garvey, et al. 2013; Wyffels et al. 2013). Bighead carp were reported to have high abundances within the La Grange pool of the Illinois River from sampling conducted from 2000 to 2006 (Irons et al. 2011). Bighead carp reached peak abundance levels in 2000 and have declined between 2004 and 2006, however these declines may be due to capture gear inefficiencies (Irons et al. 2011). Sampling efforts for Asian carp conducted in the upper pools of the Illinois River (Marseilles-Lockport) from 2010 through 2012 indicated a decreasing population from downstream to upstream (Ruebush et al. 2013).

A MRWG composed of academic, local, state and federal agencies was established in 2010 by the ACRCC. The ACRCC's mission statement is to create a sustainable Asian carp control program for protecting the integrity and safety of the Great Lakes ecosystem by preventing introduction of a sustainable Asian carp population into the Great Lakes via all viable pathways (ACRCC 2013d). The MRWG has projects focusing on waterway monitoring, removal efforts, Electric Dispersal Barrier System efficacy, gear catch efficacy and alternative pathway monitoring. Regular electrofishing and netting efforts have consisted of 16,497 person-hours of sampling from the Starved Rock Pool to Lake Michigan resulting in 283,290 the capture of specimens from 2010 to 2012. Removal efforts below the barrier system include contracted commercial fishermen setting over 643.3 mi of nets through 2012 to remove 698.72 tons of bighead, silver and grass carp. Additional workgroup projects include juvenile, larval and egg sampling, ichthyoplankton surveys, telemetry studies, hydro-acoustic surveys, and alternative gear development all of which provide up-to-date information on the status of Asian carp populations and range expansion (ACRCC 2013a).

In 2013, a significant number of bighead carp were captured in the Rock Run Rookery Preserve Lake, a backwater in the Dresden Island pool, 4 mi downstream of the Brandon Road Lock and Dam (ACCRC 2013c). There are no physical barriers between Rock Run Rookery Preserve Lake and the Brandon Road Lock and Dam. It is unknown whether this represents a population increase in this pool since the rookery was not previously sampled.

Above Dresden Island Pool, one bighead was collected in 2009 within Lockport Pool downstream of the Electric Dispersal Barrier System during a rotenone application (ACRCC 2009). In 2010, a bighead was captured in Lake Calumet during routine monitoring upstream of the Electric Dispersal Barrier System (ACRCC 2012).

Bighead carp are broadcast spawners that spawn in large aggregates (Kolar et al. 2005). Female egg production is correlated with increased body mass and age. Females with as many as 1.1 million eggs have been found in the Yangtze River, China (Kolar et al. 2005). In the Missouri River the mean fecundity was measured as the average adult female producing 226,213 eggs (Shrank and Guy 2002). In 2004, in the Illinois River, mean egg production was measured as 180,000 per female (DeGrandchamp et al. 2007). Kolar et al. (2007) reported that their analysis suggested that populations appear to be growing exponentially at the time of the report. Garvey et al. (2006) points out that bighead carp have a slower population level somatic growth rate, higher survival, lower fecundity, later maturity and longer lives relative to silver carp. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock pool and none in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of bighead carp. Controlled harvest and overfishing measures have removed over 1.3 million lb of Asian carp from the Illinois River from 2010 to 2012 (ACRCC 2013e). However, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The bighead carp has been listed as an injurious fish species under the Lacey Act (*Federal Register* 2011), and federal and state agencies have implemented components of the *National Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States* (Conover et al. 2007). However, ongoing barrier defense monitoring indicates that bighead carp remains abundant in the Illinois River (Wyffels et al. 2013) at the current level of harvest, regulation, and management.

Overall, the Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Though monitoring and overfishing techniques are expected to improve, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{10}: Based on the above information, bighead carp seem to have a high reproductive capacity in terms of producing new young per year. Therefore, current populations are expected to increase in abundance. Additionally, future environmental conditions or population genetics have the potential to shift in such a way that would allow a rapid growth and expansion of downstream populations that could lead to increased immigration into the pathway (Kolar et al. 2007); therefore, abundance is anticipated to increase below the Brandon Road Lock and Dam. This assessment is based on past invasion histories for multiple species (Crooks and Soulé 1996; Williamson 1996; Nico and Fuller 1999; Lockwood, Hoopes, and Marchetti 2007); also, see the above section *Type of Mobility/Invasion Speed* for more information.

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Though monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{25}: It is expected that, in areas with established populations, natural constraints on population growth would begin to reach a plateau. Thus, reproductive capacity would remain the same, but would no longer result in an exponentially increasing population.

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Though monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{50}: See T_{25}.

d. *Existing Physical Human/Natural Barriers*

T_0: None. There are no barriers to movement of bighead carp from their current position to Brandon Road Lock and Dam.

The Nonstructural Alternative would not affect existing physical human/natural barriers to the pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. *Distance from Pathway*

T_0: There have been two recorded captures of bighead carp above the Brandon Road Pool. The first was collected in 2009 within the Lockport Pool, downstream of the Electric Dispersal Barrier System, during a rotenone application (ACRCC 2009). The second capture occurred during routine monitoring in Lake Calumet. Lake Calumet is directly connected to the Little Calumet River, only 6 mi from Lake Michigan (ACRCC 2012). Multiple bighead carp have been captured in landlocked Chicago-area urban fishing ponds above the barrier. It is likely that these fish were accidentally introduced during stocking for the Illinois Department of Natural Resources urban fishing program of catchable sized channel catfish in the 2002-2003 timeframe (ILDNR 2011; ACRCC 2013e). In addition, there have been multiple positive eDNA detections upstream of electric barriers for bighead carp (Jerde et al. 2011). However, there is no evidence to correlate the eDNA detections to an established Asian carp population above the Electric Dispersal Barrier System within the CAWS (ACRCC 2012; Environmental DNA Calibration Study 2013). Calibration studies are underway to better understand the relationship between positive eDNA and Asian carp populations (ACRCC 2013b).

Below the Brandon Road Pool, bighead carp have been detected in the Dresden Island pool. A significant number of adult bighead carp were captured approximately 4 mi downstream of the Brandon Road Lock and Dam in the Rock Run Rookery Preserve Lake in 2013 (ACCRC 2013c). The USACE telemetry program has also recorded one individual bighead carp that approached the Brandon Road Lock and Dam in 2012 before returning downstream to the mouth of the Kankakee River (Shanks and Barkowski 2013). Based on the persistent populations in Marseilles Pool, and the 2013 captures in Rock Run Rookery Preserve Lake approximately 4 mi from Brandon Road Lock and Dam, the bighead carp has arrived at the pathway (Brandon Road Lock and Dam).

The Nonstructural Alternative is not expected to affect the bighead carp's distance from the aquatic pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: Bighead carp prefer eutrophic conditions but can survive with low growth rates under low plankton concentrations (Kolar et al. 2007). There was no difference in catch rate regarding location within the water column as measured within the backwaters of the Illinois River (Schultz et al. 2007). DeGrandchamp et al. (2008) suggest that bighead carp rarely occupy depths greater than 4 m (13 ft) regardless of abiotic factors. Other studies indicate that 3 m (9.8 ft) deep or more provides suitable conditions for bighead carp (Kolar et al. 2005). Bighead carp can be found in low velocity and off-channel habitats in the Mississippi, Missouri, Wabash and lower Ohio Rivers and all sizes collected in the Upper Mississippi River Basin were strongly associated with slow-moving water (<0.3 m/s [1.0 ft/s]) (Kolar et al. 2005). During low flow, bighead carp avoid channels & backwaters (DeGrandchamp et al. 2008), but will use spur dikes (Kolar et al. 2007; Cooke et al. 2009). These varied habitats are found throughout the Dresden Island Pool, including the Rock Run Rookery Preserve Lake and in the Kankakee River. This species is found in Swan Lake, which is connected to the Illinois River (DeGrandchamp et al. 2007). Heilprin (2013) found that larvae of bighead carp can survive under low DO conditions (0.86 mg/L) inside a barge ballast tank. This supports the findings of other studies that indicate adults (0.5 mg/L; Oregon Sea Grant 2011), juveniles (0.33 mg/L) and young (0.4 mg/L; Jennings 1988) can survive low DO conditions. Critical spawning temperature for bighead carp is reported as 18°C (64.4°F) (Irons et al. 2009). However, typically successful fertilization occurs between 21° and 26°C (69.8 and 78.8°F) (Kolar et al. 2005). The mean summer temperature of Lake Michigan near Chicago ranges between 20 and 23°C (64.4°F). Adult bighead carp can withstand water temperatures up to 38.8°C (101.8°F) (Bettoli et al. 1985).

The Nonstructural Alternative is not expected to affect the suitability of habitat for bighead carp.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Bighead carp have been documented at the Brandon Road Lock and Dam and Lockport Pool upstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp to the aquatic pathway. The bighead carp has arrived at the pathway. Therefore, the probability of arrival remains high.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: A bighead carp was captured in the Lockport pool, upstream of the Brandon Road Lock and Dam; telemetric tracking of tagged individual bighead carp has provided evidence of at least one individual approaching the Brandon Road Lock and Dam in 2012; and in the spring of 2013, the capture of significant numbers of bighead carp at Rock Run Rookery Forest Preserve Lake, which is approximately 4 mi from the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp to the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{10}: See T_0. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) can reduce Asian carp populations. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) can reduce Asian carp populations. However, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp to the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{25}: See T_0. It is uncertain whether Asian carp monitoring and harvesting activities in Dresden Island Pool will continue during this time step. Bighead carp populations in the Dresden Island Pool are expected to increase to existing levels or higher.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp to the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{50}: See T_{25}.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Bighead carp is an active swimmer that can swim against the slow current of the CAWS. An individual can travel as far as 4.5 km (2.8 mi) per day (Peters et al. 2006). Bighead carp expansion rates were also tracked via the Long Term Resource Monitoring Program in the Mississippi and Illinois Rivers. First detections at Pool 26 (Mississippi River 1991) to the La Grange Pool (Illinois River 1995) indicated the detectable population moved over 98 river miles in just 4 years (Irons et al. 2009) and continued upstream progression in the Illinois River to the Dresden Island Pool by 2007 (USGS 2013). Average expansion rates for bighead carp are recorded at 9 river miles per year (Jerde et al. 2010).

Asian carp were first sampled from the Illinois River during the 1990's and populations have since progressed upstream (Conover et al. 2007; Irons et al. 2009). Monitoring for bighead and silver carp was originally incidental to standard routine sampling by the Illinois Department of Natural Resources (IDNR) and the Illinois Natural History Survey (INHS). Sampling directed toward Asian carp in the upper Illinois Waterway began with the US Fish and Wildlife Service's (USFWS) annual Carp Corral & Round Goby Roundup. Subsequently, the US Army Corps of Engineers (USACE) adopted a plan specifically to monitor Asian carp downstream of the electric barrier system located near Romeoville, Illinois (ACRCC 2013a). By 2010, the ACRCC was formed to coordinate this intensive monitoring effort which was expanded to include techniques including but not limited to eDNA, electrofishing, netting, sonar, and telemetry above and below the barrier generally between Lake Michigan and the Peoria Lock and Dam (ACRCC 2010).

As noted above, in 2007, bighead carp were first captured in Dresden Island Pool. In 2009, one bighead carp was found in the Lockport Pool during a rotenone event (ACRCC 2009), and in 2010, a bighead was captured in Lake Calumet during routine monitoring upstream of the Electric Dispersal Barrier System (ACRCC 2012). Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring data, it appears that few bighead carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences.

Within the Marseilles and Dresden Island Pools, reproductively mature bighead carp have been captured but no fertilized eggs or larvae have been found. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock pool and none in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. The nearest population of juvenile sized individuals is in the Peoria Pool below Starved Rock Lock and Dam, five locks downstream of the Electric Dispersal Barrier System. The nearest collection of Asian carp eggs was found near Henry, Illinois, within the Peoria Pool, five locks downstream of the Electric Dispersal Barrier System. Larval Asian carp were only collected in LaGrange Pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the natural dispersion (i.e., swimming and passive drift) of the bighead carp through the aquatic pathway.

b. *Human-Mediated Transport through Aquatic Pathways*

Bighead carp actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming will likely be the primary mechanism of movement through the CAWS from the Brandon Road Lock and Dam. There is heavy commercial vessel traffic between Brandon Road Lock and Dam and the Chicago River (USACE 2011a,b) and there is the potential for bighead carp eggs and larvae to be transported upstream of the Electric Dispersal Barrier System by passive entrainment in a ballast tank (no pumping). Heilprin et al. (2011) found water sampled from barge ballast through a single summer to be within published water quality parameters to sustain juvenile and adult Asian carp. Additionally, survivability of larvae and eggs within ballast water was found to be high for periods up to 144 hours but a very low percentage of larvae survived pump passage when expelling the ballast water (Heilprin 2013).

USCG has established a regulated navigation area around the Electric Dispersal Barrier System which prohibits vessels from transiting the safety zone with any non-potable water on board if they intend to release that water in any form within, or on the other side of the safety zone (USCG, 2011).

Other vessel-related transport mechanisms that may reduce the effectiveness of the Electric Dispersal Barrier System are discussed in Section 4c, *Existing Physical Human/Natural Barriers*.

The Nonstructural Alternative includes ballast and bilge water discharge prior to entering the aquatic pathway and is expected to address the human-mediated transport of bighead carp through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: There are two lock complexes (Brandon Road Lock and Dam and Lockport Lock and Dam) within the pathway. The Brandon Road and Lockport locks and dams are expected to control the upstream movement of fish except during lockages. The complexity of navigating through the lock may slow the upstream passage of Asian carp. There is some leakage around and through the gates (Ackerson 2012) that small larvae could move through, but the larvae would not be able to swim against the current created by the leakage. It is unlikely larvae or other bigger individuals could move through closed lock gates. However, during normal operations, bighead carp are expected to be able to swim through open gates.

In addition, there is an electrical barrier complex referred to as the Electric Dispersal Barrier System. The Electric Dispersal Barrier System, located approximately 5 mi upstream of Lockport Lock and Dam and 31 mi downstream of Lake Michigan via the Chicago Lock, consists of three electrical barriers: Demonstration Barrier, Barrier IIA, and Barrier IIB (USACE 2011c). The barriers consist of steel electrodes mounted across the bed of the Chicago Sanitary and Ship Canal (CSSC) that pulse direct current into the water at a strength, pulse duration, and frequency that repels and stuns fish.

The Demonstration Barrier has been operational since 2002 and was rehabilitated in 2008, but it was designed and built with materials that were not intended for long-term use because of its demonstration status. Barrier IIA was activated in April 2009 at the same settings as the Demonstration Barrier – 1 volt per in., 5 Hertz, and 4 milliseconds. These settings were increased in August 2009 to 2 volts per in., 15 Hertz, and 6.5 milliseconds in response to eDNA monitoring results that suggested Asian carp were closer to the barriers than earlier believed. Barrier IIB was activated in April 2011 at Barrier IIA's settings, and Barrier IIA was placed into warm standby mode. In October 2011, Barrier II's operational settings were changed to 2.3 volts per in., 30 Hertz and 2.5 milliseconds, based on laboratory research suggesting these settings would be more effective in deterring very small fish. The U.S. Army Corps of Engineers continues to study the optimal operating parameters to deter very small fish.

USFWS is evaluating feral fish populations and their behavior within the electric dispersal barrier using a dual-frequency identification SONAR (DIDSON; Sound Metrics Corp., Bellevue, WA) unit to evaluate fish populations throughout the entire barrier system (Parker 2013). Results of sampling across the entire barrier system during the summer of 2013, using DIDSON equipment, revealed a large accumulation of fish below the active barrier. Some of the fish that were immediately below the active barrier (either Barrier IIA or IIB) were observed persistently probing and challenging the barrier. DIDSON results showed schools of small fish breaching the barrier. Typically, as the schools of fish penetrated deeper into the zone of ultimate field strength, the size of the school contracted into a tight sphere shape and after they breached, the group expanded again. The sizes of the fish that breached the barrier are estimated to range from approximately 2 to 4 in. in length. To help determine the species of fish most likely observed breaching the barrier, the USFWS performed a limited amount of fish sampling within the narrow array on September 27, 2013, and caught gizzard shad (*Dorosoma cepedianum*), threadfin shad (*Dorosoma petenense*), and skipjack herring (*Alosa chrysochloris*) (USACE 2013). Additional study is underway to further evaluate operational protocols of the barriers and to identify any potential actions that may be employed to address the findings discussed in this paper.

There are several other mechanisms identified for potential barrier bypass. First, fish could swim through the Dispersal Barrier during times of power outage. According to records through March 2013, the Electric Dispersal Barrier System experienced a loss of power to the water for a total of 4 minutes prior to 2011, and a total of 13 minutes in 2012 (USACE unpublished data, Electric Dispersal Barrier System Power Outage Records, April 1, 2013). Work is underway on a redundant power supply for Barrier IIA and similar work is planned for Barrier IIB. In addition, automatic transfer mechanisms were installed on both Barriers IIA and IIB to maintain power in the water in the event of a power loss. Permanent Barrier I, the upgrade for the Demonstration Barrier, will provide yet another redundant electric field of the Dispersal Barrier System during power outages at Barrier IIA or IIB. Secondly, the Electric Dispersal Barrier System would be intentionally shut down completely in emergency situations under a man-overboard scenario; however, there have been no man-overboard scenarios near the Dispersal Barriers as far back as the initialization of the Demo Barrier in 2002.

Additional potential barrier aquatic bypass vectors are currently under investigation and include reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage and fish entrainment within barge induced water currents across the Electric Dispersal Barrier System. Preliminary research at the USACE Engineer Research and Development Center in Vicksburg, MS has shown model fish (soft plastic fish lures) to become entrained at numerous surface junctions, to varying degrees, between inter-barge and tow-barge connections on model tow-barge vessels. Additionally, electrical readings taken within the void created between a raked (sloped) bow and a boxed (flat) stern junction show that steel hulled barges reduce the in water electrical parameters in this area (USACE 2013).

The USFWS placed live surrogate species of fish in cages alongside and between junctions of barges in the CSSC to evaluate fish-barge interactions and assess the possibility of the fish becoming incapacitated as they traversed the electrical barrier. Fish were incapacitated as they encountered the electrical field at all barge locations, except the void space in the rake to box junction. Several feral fish were observed being entrained in two locations around the barges during trial runs indicating that wild fish do interact with barge traffic near the barriers. In order to determine if wild fish would stay in this void without a cage, a follow-up study was conducted with externally tagged fish (tethered to a float). Tethered fish placed in barge junctions breached the barrier to some degree in all but one barge configuration tested. When tethered fish were placed below the barriers as barges approached, some degree of fish breaching the barrier occurred with every different configuration tested (USACE 2013). Results from these ongoing studies are preliminary. This combination of increased possibility of entrainment and reduced electrical parameters due to barge traffic is expected to lead to an increased possibility of fish being transported over the barrier system. Vessel speed and tow/barge configuration are considered to be primary factors that affect the possible entrainment and transport of fish through the electric barriers (USACE 2013). Further research is being conducted to mitigate this bypass. While preliminary results from these investigations have shown these bypasses to be viable, the possibility of these bypasses occurring in the field is low at this time due to the low or non-existent population of bighead carp in the Lockport Pool.

In 2010, lateral barricades were constructed between the CSSC, the Des Plaines River, and the Illinois and Michigan Canal to control upstream bypass of the Electrical Dispersal Barrier System during flooding between these adjacent waterways. The Des Plaines River Barricade extends approximately 13 mi and consists of concrete barriers and specially fabricated 0.25-in. wire mesh that allows water to flow through the fence but controls the passage juvenile and adult fish, and the Illinois and Michigan Canal is walled-off using a stone berm. Small sections of the Des Plaines barricade fence failed during flooding in 2013; however, monitoring crews immediately responded and monitored for the presence of fish along breaches. Though these efforts indicated that fish (common carp) had moved through the breaches, no Asian carp were caught (Barkowski 2013), and prior monitoring efforts in the Des Plaines River had not captured or observed Asian carp, larval fish or eggs (ACRCC 2013b).

Under current operational protocols, monitoring for Asian carp occurs downstream and upstream of the Electric Dispersal Barrier System. In the event an individual is found upstream of the Lockport Lock and Dam, protocol dictates the use of intensive electrofishing and netting to find and remove individuals or the use of rotenone to immobilize and kill all fish within the reach of concern (ACRCC 2011). It is anticipated that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp are above the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.

T_{10}: Future operations of the Brandon Road Lock and Dam and Lockport Lock and Dam locks are not expected to change as of the time of this assessment. The Electric Dispersal Barrier System is expected to have additional redundancies in power supply, thereby reducing potential power outage events**.** A new barrier is currently under construction that will upgrade the Demo Barrier to permanent status (Barrier I). Barrier I will be capable of producing higher electrical outputs than those of Barrier II and will add an additional narrow array on the downstream boundary. Barrier I is expected to become operational by 2016. Further study of the current Electric Dispersal Barrier System to address electric field shielding by steel-hulled vessels, fish entrainment within barge-induced water currents and very small fish would continue and would inform future operations.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.

T_{25}: See T_{10}. Funding for research, monitoring and removal programs for bighead carp at this time step is highly uncertain. Currently, no funding source has been identified for any one agency to maintain the present level of effort.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.
T_{50}: See T_{10} and T_{25}.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*
T_0: Bighead carp prefer eutrophic conditions but survive with low growth rates with low plankton concentrations (Kolar et al. 2005, Cooke et al. 2009). The CAWS is the recipient of treated wastewater from numerous facilities that produces eutrophic conditions suitable for bighead carp. Additionally, recent plankton surveys within the CAWS suggest there are relatively high concentrations of zooplankton available as a food resource (ACRCC 2013a; Butler et al. 2013). Bighead carp utilize all parts of the water column in rivers (Schultz et al. 2007; DeGrandchamp et al. 2008; Kolar et al. 2005). They can be found in low velocity and off-channel habitats associated with slow-moving water (<0.3 m/s [1.0 ft/s]) (Kolar et al. 2005), but are capable of swimming in very-high-velocity habitats, with a maximum measured swimming speed of approximately 7.5 m/s (24.6 ft/s) (Konagaya and Cai 1987). During normal conditions, the CAWS has a slow-moving current (LimnoTech 2010). Sections of the CAWS also experience seasonally low dissolved oxygen (LimnoTech 2010). Heilprin et al. (2013a) found that larvae of bighead carp can survive under low dissolved oxygen conditions (0.86 mg/L) inside a barge ballast tank. This supports the findings of other studies that indicate the species can survive low dissolved oxygen conditions: adults (0.5 mg/L) (Oregon Sea Grant 2011), juveniles (0.33 mg/L), and young (0.4 mg/L) (Jennings 1988). Adult bighead carp can withstand water temperatures up to 38.8°C (101.8°F) (Bettoli et al. 1985). Overall, the conditions of the CAWS are not expected to impede movement of bighead carp.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for bighead carp.
T_{10}: See T_0. Conditions of the CAWS are predicted to change, but not in a way that would affect the likelihood of this species passing through this pathway. For example, the Metropolitan Water Reclamation District of Greater Chicago (MWRD) is in the process of evaluating ways to improve the water quality of the CAWS by decreasing the amount of organic materials released into the CAWS. This could potentially decrease the amount of plankton and other food species bighead carp would need to survive within the CAWS. In addition, in coordination with the USACE, MWRD will increase capacity of stormwater catchment and retention in adjacent tunnels and reservoirs. This will lead to a lower hydrologic peak during storm events. The environmental conditions within the CAWS may change slightly with the closing of two coal-fired power plants (Midwest Generation's Fisk and Crawford Plants) in August 2012. These plants used canal water in their cooling process and returned heated water back to the canal. As a result, temperature profiles may be reduced significantly in the near vicinity and to a lesser extent downstream. This is not expected to significantly affect the ability of bighead carp to pass through this pathway.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for bighead carp.

T_{25}: See T_{10}

T_{50}: See T_{10}

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Bighead carp would need to pass through the Brandon Road and Lockport locks and dams, the Electric Dispersal Barrier System and an intermittent sluice gate opening to pass through this pathway. Adults and all life sizes of bighead carp would be able to swim through the locks when the lock is in operation; however, the locks may slow passage of bighead carp through the pathway.

Based on the sampling and monitoring data, the abundance of individuals within the Lockport Pool below the dispersal barriers is expected to be low to non-existent at this timestep. Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring data, it appears that few bighead carp have not expanded past the Brandon Road Lock and Dam. As discussed in P(arrival), *Current and Potential Abundance and Reproductive Capacity*, in 2012, small Asian carp were relatively abundant in the LaGrange Lock and Dam and Peoria Lock and Dam. Only one was caught in the Starved Rock pool. No small age-1 Asian carp were found in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. Adult populations of bighead carp are in the Dresden Island Pool (ACRCC 2013a). In an effort to control the Asian carp population downstream of the barrier, fisherman have been contracted to remove these fish from the waterway.

Monitoring and research have found several potential bypass mechanisms for the Electric Barrier System: man overboard scenario when power to the barrier is intentionally turned off, power outages, bypass during flood events, stunned fish floating through the barrier during reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage and fish entrainment within barge induced water currents across the Electric Dispersal Barrier System. Bypass due to these various mechanisms is not likely, because the nearest detectable population of swimming bighead carp is in Dresden Island Pool and the nearest detected eggs, larvae, and fry are farther downstream (ACRCC 2013a). Additionally, research on these bypasses continues and will inform future operations.

In summary, current propagule pressure of this species immediately downstream of the Dispersal Barriers is considered low or non-existent as measured by monitoring efforts of local, state and federal agencies. The probability of passage for the bighead carp is low for T_0 because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier, then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The low passage rating is in conflict with the Canadian Science Advisory Report (2012) that rates passage through the CAWS as highly likely. However, the Canadian report explicitly did not evaluate the effectiveness of the Electric Dispersal Barrier System.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Though ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, though monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{10}: See $T_{0.}$ Bighead carp are expected to remain in low populations immediately below the Electric Dispersal Barrier System. Contracted fishermen are expected to continue to improve their fishing techniques to increase their catch rates. The Brandon Road and Lockport locks and dams may also slow bighead carp passage.

Federal and state natural resource agencies have monitored the upstream progress of Asian carp populations since their arrival in the IWW in the 1990's (Conover et al. 2007; Irons et al. 2009; ACRCC 2013a). Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring, it appears that few bighead carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences. Also, it is anticipated that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp above the Brandon Road Lock and Dam.

Further refinement of the Electric Dispersal Barrier System operations and redundant power sources are expected to decrease the number and length of potential power outages. Additionally, potential transport vectors across the barriers (e.g., vessel entrainment, insufficient operating parameters for small fish, reverse flow events, crevice shielding of electric field) will continue to be analyzed and future operations would informed by this analysis.

The probability of passage for the bighead carp is low for T_{10} because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Though ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, though monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}. Funding for monitoring and removal programs for bighead carp at this time step is uncertain because there is not a funding source identified to maintain the present level of management. With the continued expected immigration from the lower pools (Tsehaye et al. 2013), the propagule pressure at the Dispersal Barrier System is expected to increase, and thus increase the potential for an individual to move past the Barriers.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Though ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, though monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's medium probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{50}: See T_{10} and T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	High	High	High
Nonstructural Alternative Rating	Medium	High	High	High

Evidence for Uncertainty Rating

T_0: Although there has been an extraordinary effort from multiple agencies to research potential barrier bypass mechanisms, much of that research is currently underway and only preliminary results have been reported. Each risk assessment was conducted qualitatively under the assumption that bypass is possible but did not address the frequency that it might occur under a set of quantitative conditions. It is also uncertain whether additional bypass mechanisms could still be discovered. Though comprehensive monitoring upstream and downstream of the barrier for Asian carp is ongoing, uncertainty still exists concerning whether monitoring has identified the true abundance of bighead carp within upper Illinois River and the CAWS.

The Nonstructural Alternative is expected to affect the passage of bighead carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Overall, the uncertainty remains medium.

T_{10}: See $T_{0.}$ Although empirical tests are underway to see if the potential transport mechanisms across the barriers are viable, at this time uncertainty increases with time because of unknown events. Additionally, funding for management actions that keep the populations of Asian carp in check immediately downstream of the Dispersal Barriers are not specified. The factors contributing to the historic absence of range expansion beyond the Brandon Road Lock and Dam are uncertain and may change.

The Nonstructural Alternative is expected to affect the passage of bighead carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Overall, the uncertainty remains high.

T_{25}: See T_{10}.
T_{50}: See $T_{10.}$

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Project risk assessment.

Uncertainty: MEDIUM

5. **P(spreads) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Project risk assessment.

Uncertainty: LOW

PATHWAY 4

BRANDON ROAD LOCK AND DAM TO INDIANA HARBOR

NONSTRUCTURAL ALTERNATIVE: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "-" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "-" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE PROBABILITY OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are anticipated that would reduce or eliminate the hydrologic connection between Brandon Road Lock and Dam and Indiana Harbor over the next 50 years.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Bighead carp are active swimmers. Total maximum distance traveled upstream by an individual was 163 km (101 mi) over 35 days (Peters et al. 2006), with an average of 4.5 km (2.8 mi) traveled per day. Average expansion rates for bighead carp are recorded at 9 river miles per year (Jerde et al. 2010) and they were able to move from Arkansas into Mississippi, Missouri, Ohio, and Illinois rivers. Bighead carp expansion rates were also tracked via the Long Term Resource Monitoring Program in the Mississippi and Illinois Rivers. First detections at Pool 26 (Mississippi River; 1991) to the La Grange reach (Illinois River; 1995) indicated the detectable population moved over 98 river miles in just 4 years (Irons et al. 2009) and continued upstream progression in the Illinois River to the Dresden Island Pool by 2007 (USGS 2013).

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the CAWS by natural dispersion.

b. Human-Mediated Transport through Aquatic Pathways

There is commercial vessel and recreational boat traffic between the current location of bighead carp and the Brandon Road Lock and Dam. Bighead carp eggs, larvae, and fry have the potential to be spread by ballast water if water quality is suitable, although the viability of this ballast water transport is considered to be low (Heilprin et al. 2013).

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the CAWS from human-mediated transport through this aquatic pathway.

c. Current and Potential Abundance and Reproductive Capacity

T_0: Adult bighead carp are abundant in the Illinois Waterway from Starved Rock Lock & Dam (RM231) to the confluence with Mississippi River (Chick and Pegg 2001; Irons et al. 2009; ACRCC 2012; Garvey, et al. 2013; Wyffels et al. 2013). Bighead carp were reported to have high abundances within the La Grange pool of the Illinois River from sampling conducted from 2000 to 2006 (Irons et al. 2011). Bighead carp reached peak abundance levels in 2000 and have declined between 2004 and 2006, however these declines may be due to capture gear inefficiencies (Irons et al. 2011). Sampling efforts for Asian carp conducted in the upper pools of the Illinois River (Marseilles-Lockport) from 2010 through 2012 indicated a decreasing population from downstream to upstream (Ruebush et al. 2013).

A MRWG composed of academic, local, state and federal agencies was established in 2010 by the ACRCC. The ACRCC’s mission statement is to create a sustainable Asian carp control program for protecting the integrity and safety of the Great Lakes ecosystem by preventing introduction of a sustainable Asian carp population into the Great Lakes via all viable pathways (ACRCC 2013d). The MRWG has projects focusing on waterway monitoring, removal efforts, Electric Dispersal Barrier System efficacy, gear

catch efficacy and alternative pathway monitoring. Regular electrofishing and netting efforts have consisted of 16,497 person-hours of sampling from the Starved Rock Pool to Lake Michigan resulting in the capture of 283,290 specimens from 2010 to 2012. Removal efforts below the barrier system include contracted commercial fishermen setting over 643.3 mi of nets through 2012 to remove 698.72 tons of bighead, silver and grass carp. Additional workgroup projects include juvenile, larval and egg sampling, ichthyoplankton surveys, telemetry studies, hydro-acoustic surveys, and alternative gear development all of which provide up-to-date information on the status of Asian carp populations and range expansion (ACRCC 2013a).

In 2013, a significant number of bighead carp were captured in the Rock Run Rookery Preserve Lake, a backwater in the Dresden Island pool, 4 mi downstream of the Brandon Road Lock and Dam (ACCRC 2013c). There are no physical barriers between Rock Run Rookery Preserve Lake and the Brandon Road Lock and Dam. It is unknown whether this represents a population increase in this pool since the rookery was not previously sampled.

Above Dresden Island Pool, one bighead was collected in 2009 within Lockport Pool downstream of the Electric Dispersal Barrier System during a rotenone application (ACRCC 2009). In 2010, a bighead was captured in Lake Calumet during routine monitoring upstream of the Electric Dispersal Barrier System (ACRCC 2012).

Bighead carp are broadcast spawners that spawn in large aggregates (Kolar et al. 2005). Female egg production is correlated with increased body mass and age. Females with as many as 1.1 million eggs have been found in the Yangtze River, China (Kolar et al. 2005). In the Missouri River the mean fecundity was measured as the average adult female producing 226,213 eggs (Shrank and Guy 2002). In 2004, in the Illinois River, mean egg production was measured as 180,000 per female (DeGrandchamp et al. 2007). Kolar et al. (2007) reported that their analysis suggested that populations appear to be growing exponentially at the time of the report. Garvey et al. (2006) points out that bighead carp have a slower population level somatic growth rate, higher survival, lower fecundity, later maturity and longer lives relative to silver carp. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock pool and none in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of bighead carp. Controlled harvest and overfishing measures have removed over 1.3 million lbs of Asian carp from the Illinois River between 2010 and 2012 (ACRCC 2013e). However, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The bighead carp has been listed as an injurious fish species under the Lacey Act (Federal Register 2011), and federal and state agencies have implemented components of the *National Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States* (Conover et al. 2007). However, ongoing barrier defense monitoring indicates that bighead carp remains abundant in the Illinois River (Wyffels et al. 2013) at the current level of harvest, regulation, and management.

Overall, the Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{10}: Based on the above information, bighead carp seem to have a high reproductive capacity in terms of producing new young per year. Therefore, current populations are expected to increase in abundance. Additionally, future environmental conditions or population genetics have the potential to shift in such a way that would allow a rapid growth and expansion of downstream populations that could lead to increased immigration into the pathway (Kolar et al. 2007); therefore, abundance is anticipated to increase below the Brandon Road Lock and Dam. This assessment is based on past invasion histories for multiple species (Crooks and Soulé 1996; Williamson 1996; Nico and Fuller 1999; Lockwood, Hoopes, and Marchetti 2007); also, see the above section *Type of Mobility/Invasion Speed* for more information.

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{25}: It is expected that, in areas with established populations, natural constraints on population growth would begin to reach a plateau. Thus, reproductive capacity would remain the same, but would no longer result in an exponentially increasing population. The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{50}: See T_{25}.

d. Existing Physical Human/Natural Barriers

T_0: None. There are no barriers to movement of bighead carp from their current position to Brandon Road Lock and Dam.

The Nonstructural Alternative would not affect existing physical human/natural barriers to the pathway.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: There have been two recorded captures of bighead carp above the Brandon Road Pool. The first was collected in 2009 within the Lockport Pool, downstream of the Electric Dispersal Barrier System, during a rotenone application (ACRCC 2009). The second capture occurred during routine monitoring in Lake Calumet. Lake Calumet is directly connected to the Little Calumet River, only 6 mi from Lake Michigan (ACRCC 2012). Multiple bighead carp have been captured in landlocked Chicago-area urban fishing ponds above the barrier. It is likely that these fish were accidentally introduced during stocking for the Illinois Department of Natural Resources urban fishing program of catchable sized channel catfish in the 2002-2003 timeframe (ILDNR 2011; ACRCC 2013e). In addition, there have been multiple positive eDNA detections upstream of electric barriers for bighead carp (Jerde et al. 2011). However, there is no evidence to correlate the eDNA detections to an established Asian carp population above the Electric Dispersal Barrier System within the CAWS (ACRCC 2012; Environmental DNA Calibration Study 2013). Calibration studies are underway to better understand the relationship between positive eDNA and Asian carp populations (ACRCC 2013b).

Below the Brandon Road Pool, bighead carp have been detected in the Dresden Island pool. A significant number of adult bighead carp were captured approximately 4 mi downstream of the Brandon Road Lock and Dam in the Rock Run Rookery Preserve Lake in 2013 (ACCRC 2013c). The USACE telemetry program has also recorded one individual bighead carp that approached the Brandon Road Lock and Dam in 2012 before returning downstream to the mouth of the Kankakee River (Shanks and Barkowski 2013). Based on the persistent populations in Marseilles Pool, and the 2013 captures in Rock Run Rookery Preserve Lake approximately 4 mi from Brandon Road Lock and Dam, the bighead carp has arrived at the pathway (Brandon Road Lock and Dam).

The Nonstructural Alternative is not expected to affect the bighead carp's distance from the aquatic pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Bighead carp prefer eutrophic conditions but can survive with low growth rates under low plankton concentrations (Kolar et al. 2007). There was no difference in catch rate regarding location within the water column as measured within the backwaters of the Illinois River (Schultz et al. 2007). DeGrandchamp et al. (2008) suggest that bighead carp rarely occupy depths greater than 4 m (13 ft) regardless of abiotic factors. Other studies indicate that 3 m (9.8 ft) deep or more provides suitable conditions for bighead carp (Kolar et al. 2005). Bighead carp can be found in low velocity and off-channel habitats in the Mississippi, Missouri, Wabash and lower Ohio Rivers and all sizes collected in the Upper Mississippi River Basin were strongly associated with slow-moving water (<0.3 m/s [1.0 ft/s]) (Kolar et al. 2005). During low flow, bighead carp avoid channels & backwaters (DeGrandchamp et al. 2008), but will use spur dikes (Kolar et al. 2007; Cooke et al. 2009). These varied habitats are found throughout the Dresden Island Pool, including the Rock Run Rookery Preserve Lake and in the Kankakee River. This species is found in Swan Lake, which is connected to the Illinois River (DeGrandchamp et al. 2007). Heilprin (2013) found that larvae of bighead carp can survive under low DO conditions (0.86 mg/L) inside a barge ballast tank. This supports the findings of other studies that indicate adults (0.5 mg/L; Oregon Sea Grant 2011), juveniles (0.33 mg/L) and young (0.4 mg/L; Jennings 1988) can survive low DO conditions. Critical spawning temperature for bighead carp is reported as 18°C (64.4°F) (Irons et al. 2009). However, typically successful fertilization occurs between 21° and 26°C (69.8 and 78.8°F) (Kolar et al. 2005). The mean summer temperature of Lake Michigan near Chicago ranges between 20 and 23°C (64.4°F). Adult bighead carp can withstand water temperatures up to 38.8°C (101.8°F) (Bettoli et al. 1985).

The Nonstructural Alternative is not expected to affect the suitability of habitat for bighead carp.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Bighead carp have been documented at the Brandon Road Lock and Dam and Lockport Pool upstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway. The bighead carp has arrived at the pathway. Therefore, the probability of arrival remains high.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: A bighead carp was captured in the Lockport pool, upstream of the Brandon Road Lock and Dam; telemetric tracking of tagged individual bighead carp has provided evidence of at least one individual approaching the Brandon Road Lock and Dam in 2012; and in the spring of 2013, the capture of significant numbers of bighead carp at Rock Run Rookery Forest Preserve Lake, which is approximately 4 mi from the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{10}: See T_0. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) can reduce Asian carp populations. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) can reduce Asian carp populations. However, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{25}: See T_0. It is uncertain whether Asian carp monitoring and harvesting activities in Dresden Island Pool will continue during this time step. Bighead carp populations in the Dresden Island Pool are expected to increase to existing levels or higher.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{50}: See T_{25}.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Bighead carp is an active swimmer that can swim against the slow current of the CAWS. An individual can travel as far as 4.5 km (2.8 mi) per day (Peters et al. 2006). Bighead carp expansion rates were also tracked via the Long Term Resource Monitoring Program in the Mississippi and Illinois Rivers. First detections at Pool 26 (Mississippi River 1991) to the La Grange Pool (Illinois River 1995) indicated the detectable population moved over 98 river miles in just 4 years (Irons et al. 2009) and continued upstream progression in the Illinois River to the Dresden Island Pool by 2007 (USGS 2013). Average expansion rates for bighead carp are recorded at 9 river miles per year (Jerde et al. 2010).

Asian carp were first sampled from the Illinois River during the 1990's and populations have since progressed upstream (Conover et al. 2007; Irons et al. 2009). Monitoring for bighead and silver carp was originally incidental to standard routine sampling by the Illinois Department of Natural Resources (IDNR) and the Illinois Natural History Survey (INHS). Sampling directed toward Asian carp in the upper Illinois Waterway began with the US Fish and Wildlife Service's (USFWS) annual Carp Corral & Round Goby Roundup. Subsequently, the US Army Corps of Engineers (USACE) adopted a plan specifically to monitor Asian carp downstream of the electric barrier system located near Romeoville, Illinois (ACRCC 2013a). By 2010, the ACRCC was formed to coordinate this intensive monitoring effort which was expanded to include techniques including but not limited to eDNA, electrofishing, netting, sonar, and telemetry above and below the barrier generally between Lake Michigan and the Peoria Lock and Dam (ACRCC 2010).

As noted above, in 2007, bighead carp were first captured in Dresden Island Pool. In 2009, one bighead carp was found in the Lockport Pool during a rotenone event (ACRCC 2009), and in 2010, a bighead was captured in Lake Calumet during routine monitoring upstream of the Electric Dispersal Barrier System (ACRCC 2012). Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring data, it appears that few bighead carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences.

Within the Marseilles and Dresden Island Pools, reproductively mature bighead carp have been captured but no fertilized eggs or larvae have been found. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock pool and none in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. The nearest population of juvenile sized individuals is in the Peoria Pool below Starved Rock Lock and Dam, five locks downstream of the Electric Dispersal Barrier System. The nearest collection of Asian carp eggs was found near Henry, Illinois, within the Peoria Pool, five locks downstream of the Electric Dispersal Barrier System. Larval Asian carp were only collected in LaGrange Pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the natural dispersion (i.e., swimming and passive drift) of the bighead carp through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Bighead carp actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming will likely be the primary mechanism of movement through the CAWS from the Brandon Road Lock and Dam. There is heavy commercial vessel traffic between Brandon Road Lock and Dam and the Chicago River (USACE 2011a,b) and there is the potential for bighead carp eggs and larvae to be transported upstream of the Electric Dispersal Barrier System by passive entrainment in a ballast tank (no pumping). Heilprin et al. (2011) found water sampled from barge ballast through a single summer to be within published water quality parameters to sustain juvenile and adult Asian carp. Additionally, survivability of larvae and eggs within ballast water was found to be high for periods up to 144 hours but a very low percentage of larvae survived pump passage when expelling the ballast water (Heilprin 2013).

USCG has established a regulated navigation area around the Electric Dispersal Barrier System which prohibits vessels from transiting the safety zone with any non-potable water on board if they intend to release that water in any form within, or on the other side of the safety zone (USCG 2011).

Other vessel-related transport mechanisms that may reduce the effectiveness of the Electric Dispersal Barrier System are discussed in Section 4c, *Existing Physical Human/Natural Barriers*.

The Nonstructural Alternative includes ballast and bilge water discharge prior to entering the aquatic pathway and is expected to address the human-mediated transport of bighead carp through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: There are two lock complexes (Brandon Road Lock and Dam and Lockport Lock and Dam) within the pathway. The Brandon Road and Lockport locks and dams are expected to control the upstream movement of fish except during lockages. The complexity of navigating through the lock may slow the upstream passage of Asian carp. There is some leakage around and through the gates (Ackerson 2012) that small larvae could move through, but the larvae would not be able to swim against the current created by the leakage. It is unlikely larvae or other bigger individuals could move through closed lock gates. However, during normal operations, bighead carp are expected to be able to swim through open gates.

In addition, there is an electrical barrier complex referred to as the Electric Dispersal Barrier System. The Electric Dispersal Barrier System, located approximately 5 mi upstream of Lockport Lock and Dam and 31 mi downstream of Lake Michigan via the Chicago Lock, consists of three electrical barriers: Demonstration Barrier, Barrier IIA, and Barrier IIB (USACE 2011c). The barriers consist of steel electrodes mounted across the bed of the Chicago Sanitary and Ship Canal (CSSC) that pulse direct current into the water at a strength, pulse duration, and frequency that repels and stuns fish.

The Demonstration Barrier has been operational since 2002 and was rehabilitated in 2008, but it was designed and built with materials that were not intended for long-term use because of its demonstration status. Barrier IIA was activated in April 2009 at the same settings as the Demonstration Barrier – 1 volt per in., 5 Hertz, and 4 milliseconds. These settings were increased in August 2009 to 2 volts per in., 15 Hertz, and 6.5 milliseconds in response to eDNA monitoring results that suggested Asian carp were closer to the barriers than earlier believed. Barrier IIB was activated in April 2011 at Barrier IIA's settings, and Barrier IIA was placed into warm standby mode. In October 2011, Barrier II's operational settings were changed to 2.3 volts per in., 30 Hertz and 2.5 milliseconds, based on laboratory research suggesting these settings would be more effective in deterring very small fish. The U.S. Army Corps of Engineers continues to study the optimal operating parameters to deter very small fish.

USFWS is evaluating feral fish populations and their behavior within the electric dispersal barrier using a dual-frequency identification SONAR (DIDSON; Sound Metrics Corp., Bellevue, Washington) unit to evaluate fish populations throughout the entire barrier system (Parker 2013). Results of sampling across the entire barrier system during the summer of 2013, using DIDSON equipment, revealed a large accumulation of fish below the active barrier. Some of the fish that were immediately below the active barrier (either Barrier IIA or IIB) were observed persistently probing and challenging the barrier. DIDSON results showed schools of small fish breaching the barrier. Typically, as the schools of fish penetrated deeper into the zone of ultimate field strength, the size of the school contracted into a tight sphere shape and after they breached, the group expanded again. The sizes of the fish that breached the barrier are estimated to range from approximately 2 to 4 in. in length. To help determine the species of fish most likely observed breaching the barrier, the USFWS performed a limited amount of fish sampling within the narrow array on September 27, 2013, and caught gizzard shad (*Dorosoma cepedianum*), threadfin shad (*Dorosoma petenense*), and skipjack herring (*Alosa chrysochloris*) (USACE 2013). Additional study is underway to further evaluate operational protocols of the barriers and to identify any potential actions that may be employed to address the findings discussed in this paper.

There are several other mechanisms identified for potential barrier bypass. First, fish could swim through the Dispersal Barrier during times of power outage. According to records through March 2013, the Electric Dispersal Barrier System experienced a loss of power to the water for a total of 4 minutes prior to 2011, and a total of 13 minutes in 2012 (USACE unpublished data, Electric Dispersal Barrier System Power Outage Records, April 1, 2013). Work is underway on a redundant power supply for Barrier IIA and similar work is planned for Barrier IIB. In addition, automatic transfer mechanisms were installed on both Barriers IIA and IIB to maintain power in the water in the event of a power loss. Permanent Barrier I, the upgrade for the Demonstration Barrier, will provide yet another redundant electric field of the Dispersal Barrier System during power outages at Barrier IIA or IIB. Secondly, the Electric Dispersal Barrier System would be intentionally shut down completely in emergency situations under a man-overboard scenario; however, there have been no man-overboard scenarios near the Dispersal Barriers as far back as the initialization of the Demo Barrier in 2002.

Additional potential barrier aquatic bypass vectors are currently under investigation and include reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage and fish entrainment within barge induced water currents across the Electric Dispersal Barrier System. Preliminary research at the USACE Engineer Research and Development Center in Vicksburg, MS has shown model fish (soft plastic fish lures) to become entrained at numerous surface junctions, to varying degrees, between inter-barge and tow-barge connections on model tow-barge vessels. Additionally, electrical readings taken within the void created between a raked (sloped) bow and a boxed (flat) stern junction show that steel hulled barges reduce the in water electrical parameters in this area (USACE 2013).

The US Fish and Wildlife Service placed live surrogate species of fish in cages alongside and between junctions of barges in the CSSC to evaluate fish-barge interactions and assess the possibility of the fish becoming incapacitated as they traversed the electrical barrier. Fish were incapacitated as they encountered the electrical field at all barge locations, except the void space in the rake to box junction. Several feral fish were observed being entrained in two locations around the barges during trial runs indicating that wild fish do interact with barge traffic near the barriers. In order to determine if wild fish would stay in this void without a cage, a follow-up study was conducted with externally tagged fish (tethered to a float). Tethered fish placed in barge junctions breached the barrier to some degree in all but one barge configuration tested. When tethered fish were placed below the barriers as barges approached, some degree of fish breaching the barrier occurred with every different configuration tested (USACE 2013). Results from these ongoing studies are preliminary. This combination of increased possibility of entrainment and reduced electrical parameters due to barge traffic is expected to lead to an increased possibility of fish being transported over the barrier system. Vessel speed and tow/barge configuration are considered to be primary factors that affect the possible entrainment and transport of fish through the electric barriers (USACE 2013). Further research is being conducted to mitigate this bypass. While preliminary results from these investigations have shown these bypasses to be viable, the possibility of these bypasses occurring in the field is low at this time due to the low or non-existent population of bighead carp in the Lockport Pool.

In 2010, lateral barricades were constructed between the CSSC, the Des Plaines River, and the Illinois and Michigan Canal to control upstream bypass of the Electrical Dispersal Barrier System during flooding between these adjacent waterways. The Des Plaines River Barricade extends approximately 13 mi and consists of concrete barriers and specially fabricated 0.25-in. wire mesh that allows water to flow through the fence but controls the passage juvenile and adult fish, and the Illinois and Michigan Canal is walled-off using a stone berm. Small sections of the Des Plaines barricade fence failed during flooding in 2013; however, monitoring crews immediately responded and monitored for the presence of fish along breaches. Though these efforts indicated that fish (common carp) had moved through the breaches, no Asian carp were caught (Barkowski 2013), and prior monitoring efforts in the Des Plaines River had not captured or observed Asian carp, larval fish, or eggs (ACRCC 2013b).

Under current operational protocols, monitoring for Asian carp occurs downstream and upstream of the Electric Dispersal Barrier System. In the event an individual is found upstream of the Lockport Lock and Dam, protocol dictates the use of intensive electrofishing and netting to find and remove individuals or the use of rotenone to immobilize and kill all fish within the reach of concern (ACRCC 2011). It is anticipated that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp are above the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.

T_{10}: Future operations of the Brandon Road Lock and Dam and Lockport Lock and Dam locks are not expected to change as of the time of this assessment. The Electric Dispersal Barrier System is expected to have additional redundancies in power supply, thereby reducing potential power outage events**.** A new barrier is currently under construction that will upgrade the Demo Barrier to permanent status (Barrier I). Barrier I will be capable of producing higher electrical outputs than those of Barrier II and will add an additional narrow array on the downstream boundary. Barrier I is expected to become operational by 2016. Further study of the current Electric Dispersal Barrier System to address electric field shielding by steel-hulled vessels, fish entrainment within barge-induced water currents and very small fish would continue and would inform future operations.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.

T_{25}: See T_{10}. Funding for research, monitoring and removal programs for bighead carp at this time step is highly uncertain. Currently, no funding source has been identified for any one agency to maintain the present level of effort.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.

T_{50}: See T_{10} and T_{25}.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: Bighead carp prefer eutrophic conditions but survive with low growth rates with low plankton concentrations (Kolar et al. 2005, Cooke et al. 2009). The CAWS is the recipient of treated wastewater from numerous facilities that produces eutrophic conditions suitable for bighead carp. Additionally, recent plankton surveys within the CAWS suggest there are relatively high concentrations of zooplankton available as a food resource (ACRCC 2013a; Butler et al. 2013). Bighead carp utilize all parts of the water column in rivers (Schultz et al. 2007; DeGrandchamp et al. 2008; Kolar et al. 2005). They can be found in low velocity and off-channel habitats associated with slow-moving water (<0.3 m/s [1.0 ft/s]) (Kolar et al. 2005), but are capable of swimming in very-high-velocity habitats, with a maximum measured swimming speed of approximately 7.5 m/s (24.6 ft/s) (Konagaya and Cai 1987). During normal conditions, the CAWS has a slow-moving current (LimnoTech 2010). Sections of the CAWS also experience seasonally low dissolved oxygen (LimnoTech 2010). Heilprin et al. (2013a) found that larvae of bighead carp can survive under low dissolved oxygen conditions (0.86 mg/L) inside a barge ballast tank. This supports the findings of other studies that indicate the species can survive low dissolved oxygen conditions: adults (0.5 mg/L) (Oregon Sea Grant 2011), juveniles (0.33 mg/L), and young (0.4 mg/L) (Jennings 1988). Adult bighead carp can withstand water temperatures up to 38.8°C (101.8°F) (Bettoli et al. 1985). Overall, the conditions of the CAWS are not expected to impede movement of bighead carp.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for bighead carp.

T_{10}: See T_0. Conditions of the CAWS are predicted to change, but not in a way that would affect the likelihood of this species passing through this pathway. For example, the Metropolitan Water Reclamation District of Greater Chicago (MWRD) is in the process of evaluating ways to improve the water quality of the CAWS by decreasing the amount of organic materials released into the CAWS. This could potentially decrease the amount of plankton and other food species bighead carp would need to survive within the CAWS. In addition, in coordination with the USACE, MWRD will increase capacity of stormwater catchment and retention in adjacent tunnels and reservoirs. This will lead to a lower hydrologic peak during storm events. The environmental conditions within the CAWS may change slightly with the closing of two coal-fired power plants (Midwest Generation's Fisk and Crawford Plants) in August 2012. These plants used canal water in their cooling process and returned heated water back to the canal. As a result, temperature profiles may be reduced significantly in the near vicinity and to a lesser extent downstream. This is not expected to significantly affect the ability of bighead carp to pass through this pathway.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for bighead carp.

T_{25}: See T_{10}

T_{50}: See T_{10}

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Bighead carp would need to pass through the Brandon Road and Lockport locks and dams, the Electric Dispersal Barrier System and an intermittent sluice gate opening to pass through this pathway. Adults and all life sizes of bighead carp would be able to swim through the locks when the lock is in operation; however, the locks may slow passage of bighead carp through the pathway.

Based on the sampling and monitoring data, the abundance of individuals within the Lockport Pool below the dispersal barriers is expected to be low to non-existent at this timestep. Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring data, it appears that few bighead carp have not expanded past the Brandon Road Lock and Dam. As discussed in P(arrival), *Current and Potential Abundance and Reproductive Capacity*, in 2012, small Asian carp were relatively abundant in the LaGrange Lock and Dam and Peoria Lock and Dam. Only one was caught in the Starved Rock pool. No small age-1 Asian carp were found in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. Adult populations of bighead carp are in the Dresden Island Pool (ACRCC 2013a). In an effort to control the Asian carp population downstream of the barrier, fisherman have been contracted to remove these fish from the waterway.

Monitoring and research have found several potential bypass mechanisms for the Electric Barrier System: man overboard scenario when power to the barrier is intentionally turned off, power outages, bypass during flood events, stunned fish floating through the barrier during reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage and fish entrainment within barge induced water currents across the Electric Dispersal Barrier System. Bypass due to these various mechanisms is not likely, because the nearest detectable population of swimming bighead carp is in Dresden Island Pool and the nearest detected eggs, larvae, and fry are farther downstream (ACRCC 2013a). Additionally, research on these bypasses continues and will inform future operations.

In summary, current propagule pressure of this species immediately downstream of the Dispersal Barriers is considered low or non-existent as measured by monitoring efforts of local, state and federal agencies. The probability of passage for the bighead carp is low for T_0 because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier, then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The low passage rating is in conflict with the Canadian Science Advisory Report (2012) that rates passage through the CAWS as highly likely. However, the Canadian report explicitly did not evaluate the effectiveness of the Electric Dispersal Barrier System.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{10}: See $T_{0.}$ Bighead carp are expected to remain in low populations immediately below the Electric Dispersal Barrier System. Contracted fishermen are expected to continue to improve their fishing techniques to increase their catch rates. The Brandon Road and Lockport locks and dams may also slow bighead carp passage.

Federal and state natural resource agencies have monitored the upstream progress of Asian carp populations since their arrival in the IWW in the 1990's (Conover et al. 2007; Irons et al. 2009; ACRCC 2013a). Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring, it appears that few bighead carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences. Also, it is anticipated that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp above the Brandon Road Lock and Dam.

Further refinement of the Electric Dispersal Barrier System operations and redundant power sources are expected to decrease the number and length of potential power outages. Additionally, potential transport vectors across the barriers (e.g., vessel entrainment, insufficient operating parameters for small fish, reverse flow events, crevice shielding of electric field) will continue to be analyzed and future operations would informed by this analysis.

The probability of passage for the bighead carp is low for T_{10} because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}. Funding for monitoring and removal programs for bighead carp at this time step is uncertain because there is not a funding source identified to maintain the present level of management. With the continued expected immigration from the lower pools (Tsehaye et al. 2013), the propagule pressure at the Dispersal Barrier System is expected to increase, and thus increase the potential for an individual to move past the Barriers.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's medium probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{50}: See T_{10} and T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	High	High	High
Nonstructural Alternative Rating	Medium	High	High	High

Evidence for Uncertainty Rating

T_0: Although there has been an extraordinary effort from multiple agencies to research potential barrier bypass mechanisms, much of that research is currently underway and only preliminary results have been reported. Each risk assessment was conducted qualitatively under the assumption that bypass is possible but did not address the frequency that it might occur under a set of quantitative conditions. It is also uncertain whether additional bypass mechanisms could still be discovered. Though comprehensive monitoring upstream and downstream of the barrier for Asian carp is ongoing, uncertainty still exists concerning whether monitoring has identified the true abundance of bighead carp within upper Illinois River and the CAWS.

The Nonstructural Alternative is expected to affect the passage of bighead carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Overall, the uncertainty remains medium.

T_{10}: See T_0. Although empirical tests are underway to see if the potential transport mechanisms across the barriers are viable, at this time uncertainty increases with time because of unknown events. Additionally, funding for management actions that keep the populations of Asian carp in check immediately downstream of the Dispersal Barriers are not specified. The factors contributing to the historic absence of range expansion beyond the Brandon Road Lock and Dam are uncertain and may change.

The Nonstructural Alternative is expected to affect the passage of bighead carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Overall, the uncertainty remains high.

T_{25}: See T_{10}.
T_{50}: See T_{10}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 5

BRANDON ROAD LOCK AND DAM TO BURNS SMALL BOAT HARBOR (BSBH)

NONSTRUCTURAL ALTERNATIVE: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE PROBABILITY OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are anticipated that would reduce or eliminate the hydrologic connection between Brandon Road Lock and Dam and BSBH over the next 50 years.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Bighead carp are active swimmers. Total maximum distance traveled upstream by an individual was 163 km (101 mi) over 35 days (Peters et al. 2006), with an average of 4.5 km (2.8 mi) traveled per day. Average expansion rates for bighead carp are recorded at 9 river miles per year (Jerde et al. 2010) and they were able to move from Arkansas into Mississippi, Missouri, Ohio, and Illinois rivers. Bighead carp expansion rates were also tracked via the Long Term Resource Monitoring Program in the Mississippi and Illinois Rivers. First detections at Pool 26 (Mississippi River; 1991) to the La Grange reach (Illinois River; 1995) indicated the detectable population moved over 98 river miles in just 4 years (Irons et al. 2009) and continued upstream progression in the Illinois River to the Dresden Island Pool by 2007 (USGS 2013). The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the CAWS by natural dispersion.

b. Human-Mediated Transport through Aquatic Pathways

There is commercial vessel and recreational boat traffic between the current location of bighead carp and the Brandon Road Lock and Dam. Bighead carp eggs, larvae, and fry have the potential to be spread by ballast water if water quality is suitable, although the viability of this ballast water transport is considered to be low (Heilprin et al. 2013). The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the CAWS from human-mediated transport through this aquatic pathway.

c. Current and Potential Abundance and Reproductive Capacity

T_0: Adult bighead carp are abundant in the Illinois Waterway from Starved Rock Lock & Dam (RM231) to the confluence with Mississippi River (Chick and Pegg 2001; Irons et al. 2009; ACRCC 2012; Garvey, et al. 2013; Wyffels et al. 2013). Bighead carp were reported to have high abundances within the La Grange pool of the Illinois River from sampling conducted from 2000 to 2006 (Irons et al. 2011). Bighead carp reached peak abundance levels in 2000 and have declined between 2004 and 2006, however these declines may be due to capture gear inefficiencies (Irons et al. 2011). Sampling efforts for Asian carp conducted in the upper pools of the Illinois River (Marseilles-Lockport) from 2010 through 2012 indicated a decreasing population from downstream to upstream (Ruebush et al. 2013).

A MRWG composed of academic, local, state and federal agencies was established in 2010 by the ACRCC. The ACRCC’s mission statement is to create a sustainable Asian carp control program for protecting the integrity and safety of the Great Lakes ecosystem by preventing introduction of a sustainable Asian carp population into the Great Lakes via all viable pathways (ACRCC 2013d). The MRWG has projects focusing on waterway monitoring, removal efforts, Electric Dispersal Barrier System efficacy, gear

catch efficacy and alternative pathway monitoring. Regular electrofishing and netting efforts have consisted of 16,497 person-hours of sampling from the Starved Rock Pool to Lake Michigan resulting in the capture of 283,290 specimens from 2010 to 2012. Removal efforts below the barrier system include contracted commercial fishermen setting over 643.3 mi of nets through 2012 to remove 698.72 tons of bighead, silver and grass carp. Additional workgroup projects include juvenile, larval and egg sampling, ichthyoplankton surveys, telemetry studies, hydro-acoustic surveys, and alternative gear development all of which provide up-to-date information on the status of Asian carp populations and range expansion (ACRCC 2013a).

In 2013, a significant number of bighead carp were captured in the Rock Run Rookery Preserve Lake, a backwater in the Dresden Island pool, 4 mi downstream of the Brandon Road Lock and Dam (ACCRC 2013c). There are no physical barriers between Rock Run Rookery Preserve Lake and the Brandon Road Lock and Dam. It is unknown whether this represents a population increase in this pool since the rookery was not previously sampled.

Above Dresden Island Pool, one bighead was collected in 2009 within Lockport Pool downstream of the Electric Dispersal Barrier System during a rotenone application (ACRCC 2009). In 2010, a bighead was captured in Lake Calumet during routine monitoring upstream of the Electric Dispersal Barrier System (ACRCC 2012).

Bighead carp are broadcast spawners that spawn in large aggregates (Kolar et al. 2005). Female egg production is correlated with increased body mass and age. Females with as many as 1.1 million eggs have been found in the Yangtze River, China (Kolar et al. 2005). In the Missouri River the mean fecundity was measured as the average adult female producing 226,213 eggs (Shrank and Guy 2002). In 2004, in the Illinois River, mean egg production was measured as 180,000 per female (DeGrandchamp et al. 2007). Kolar et al. (2007) reported that their analysis suggested that populations appear to be growing exponentially at the time of the report. Garvey et al. (2006) points out that bighead carp have a slower population level somatic growth rate, higher survival, lower fecundity, later maturity and longer lives relative to silver carp. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock pool and none in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of bighead carp. Controlled harvest and overfishing measures have removed over 1.3 million lbs of Asian carp from the Illinois River between 2010 and 2012 (ACRCC 2013e). However, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The bighead carp has been listed as an injurious fish species under the Lacey Act (Federal Register 2011), and federal and state agencies have implemented components of the *National Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States* (Conover et al. 2007). However, ongoing barrier defense monitoring indicates that bighead carp remains abundant in the Illinois River (Wyffels et al. 2013) at the current level of harvest, regulation, and management.

Overall, the Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{10}: Based on the above information, bighead carp seem to have a high reproductive capacity in terms of producing new young per year. Therefore, current populations are expected to increase in abundance. Additionally, future environmental conditions or population genetics have the potential to shift in such a way that would allow a rapid growth and expansion of downstream populations that could lead to increased immigration into the pathway (Kolar et al. 2007); therefore, abundance is anticipated to increase below the Brandon Road Lock and Dam. This assessment is based on past invasion histories for multiple species (Crooks and Soulé 1996; Williamson 1996; Nico and Fuller 1999; Lockwood, Hoopes, and Marchetti 2007); also, see the above section *Type of Mobility/Invasion Speed* for more information. The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{25}: It is expected that, in areas with established populations, natural constraints on population growth would begin to reach a plateau. Thus, reproductive capacity would remain the same, but would no longer result in an exponentially increasing population. The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{50}: See T_{25}.

d. Existing Physical Human/Natural Barriers

T_0: None. There are no barriers to movement of bighead carp from their current position to Brandon Road Lock and Dam.

The Nonstructural Alternative would not affect existing physical human/natural barriers to the pathway.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. *Distance from Pathway*

T_0: There have been two recorded captures of bighead carp above the Brandon Road Pool. The first was collected in 2009 within the Lockport Pool, downstream of the Electric Dispersal Barrier System, during a rotenone application (ACRCC 2009). The second capture occurred during routine monitoring in Lake Calumet. Lake Calumet is directly connected to the Little Calumet River, only 6 mi from Lake Michigan (ACRCC 2012). Multiple bighead carp have been captured in landlocked Chicago-area urban fishing ponds above the barrier. It is likely that these fish were accidentally introduced during stocking for the Illinois Department of Natural Resources urban fishing program of catchable sized channel catfish in the 2002-2003 timeframe (ILDNR 2011; ACRCC 2013e). In addition, there have been multiple positive eDNA detections upstream of electric barriers for bighead carp (Jerde et al. 2011). However, there is no evidence to correlate the eDNA detections to an established Asian carp population above the Electric Dispersal Barrier System within the CAWS (ACRCC 2012; Environmental DNA Calibration Study 2013). Calibration studies are underway to better understand the relationship between positive eDNA and Asian carp populations (ACRCC 2013b).

Below the Brandon Road Pool, bighead carp have been detected in the Dresden Island pool. A significant number of adult bighead carp were captured approximately 4 mi downstream of the Brandon Road Lock and Dam in the Rock Run Rookery Preserve Lake in 2013 (ACCRC 2013c). The USACE telemetry program has also recorded one individual bighead carp that approached the Brandon Road Lock and Dam in 2012 before returning downstream to the mouth of the Kankakee River (Shanks and Barkowski 2013). Based on the persistent populations in Marseilles Pool, and the 2013 captures in Rock Run Rookery Preserve Lake approximately 4 mi from Brandon Road Lock and Dam, the bighead carp has arrived at the pathway (Brandon Road Lock and Dam).

The Nonstructural Alternative is not expected to affect the bighead carp's distance from the aquatic pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: Bighead carp prefer eutrophic conditions but can survive with low growth rates under low plankton concentrations (Kolar et al. 2007). There was no difference in catch rate regarding location within the water column as measured within the backwaters of the Illinois River (Schultz et al. 2007). DeGrandchamp et al. (2008) suggest that bighead carp rarely occupy depths greater than 4 m (13 ft) regardless of abiotic factors. Other studies indicate that 3 m (9.8 ft) deep or more provides suitable conditions for bighead carp (Kolar et al. 2005). Bighead carp can be found in low velocity and off-channel habitats in the Mississippi, Missouri, Wabash and lower Ohio Rivers and all sizes collected in the Upper Mississippi River Basin were strongly associated with slow-moving water (<0.3 m/s [1.0 ft/s]) (Kolar et al. 2005). During low flow, bighead carp avoid channels & backwaters (DeGrandchamp et al. 2008), but will use spur dikes (Kolar et al. 2007; Cooke et al. 2009). These varied habitats are found throughout the Dresden Island Pool, including the Rock Run Rookery Preserve Lake and in the Kankakee River. This species is found in Swan Lake, which is connected to the Illinois River (DeGrandchamp et al. 2007). Heilprin (2013) found that larvae of bighead carp can survive under low DO conditions (0.86 mg/L) inside a barge ballast tank. This supports the findings of other studies that indicate adults (0.5 mg/L; Oregon Sea Grant 2011), juveniles (0.33 mg/L) and young (0.4 mg/L; Jennings 1988) can survive low DO conditions. Critical spawning temperature for bighead carp is reported as 18°C (64.4°F) (Irons et al. 2009). However, typically successful fertilization occurs between 21° and 26°C (69.8 and 78.8°F) (Kolar et al. 2005). The mean summer temperature of Lake Michigan near Chicago ranges between 20 and 23°C (64.4°F). Adult bighead carp can withstand water temperatures up to 38.8°C (101.8°F) (Bettoli et al. 1985).

The Nonstructural Alternative is not expected to affect the suitability of habitat for bighead carp.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Bighead carp have been documented at the Brandon Road Lock and Dam and Lockport Pool upstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway. The bighead carp has arrived at the pathway. Therefore, the probability of arrival remains high.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: A bighead carp was captured in the Lockport pool, upstream of the Brandon Road Lock and Dam; telemetric tracking of tagged individual bighead carp has provided evidence of at least one individual approaching the Brandon Road Lock and Dam in 2012; and in the spring of 2013, the capture of significant numbers of bighead carp at Rock Run Rookery Forest Preserve Lake, which is approximately 4 mi from the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{10}: See T_0. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) can reduce Asian carp populations. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) can reduce Asian carp populations. However, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{25}: See T_0. It is uncertain whether Asian carp monitoring and harvesting activities in Dresden Island Pool will continue during this time step. Bighead carp populations in the Dresden Island Pool are expected to increase to existing levels or higher.

The Nonstructural Alternative is not expected to affect the arrival of the bighead carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{50}: See T_{25}.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Bighead carp is an active swimmer that can swim against the slow current of the CAWS. An individual can travel as far as 4.5 km (2.8 mi) per day (Peters et al. 2006). Bighead carp expansion rates were also tracked via the Long Term Resource Monitoring Program in the Mississippi and Illinois Rivers. First detections at Pool 26 (Mississippi River 1991) to the La Grange Pool (Illinois River 1995) indicated the detectable population moved over 98 river miles in just 4 years (Irons et al. 2009) and continued upstream progression in the Illinois River to the Dresden Island Pool by 2007 (USGS 2013). Average expansion rates for bighead carp are recorded at 9 river miles per year (Jerde et al. 2010).

Asian carp were first sampled from the Illinois River during the 1990's and populations have since progressed upstream (Conover et al. 2007; Irons et al. 2009). Monitoring for bighead and silver carp was originally incidental to standard routine sampling by the Illinois Department of Natural Resources (IDNR) and the Illinois Natural History Survey (INHS). Sampling directed toward Asian carp in the upper Illinois Waterway began with the US Fish and Wildlife Service's (USFWS) annual Carp Corral & Round Goby Roundup. Subsequently, the US Army Corps of Engineers (USACE) adopted a plan specifically to monitor Asian carp downstream of the electric barrier system located near Romeoville, Illinois (ACRCC 2013a). By 2010, the ACRCC was formed to coordinate this intensive monitoring effort which was expanded to include techniques including but not limited to eDNA, electrofishing, netting, sonar, and telemetry above and below the barrier generally between Lake Michigan and the Peoria Lock and Dam (ACRCC 2010).

As noted above, in 2007, bighead carp were first captured in Dresden Island Pool. In 2009, one bighead carp was found in the Lockport Pool during a rotenone event (ACRCC 2009), and in 2010, a bighead was captured in Lake Calumet during routine monitoring upstream of the Electric Dispersal Barrier System (ACRCC 2012). Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring data, it appears that few bighead carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences.

Within the Marseilles and Dresden Island Pools, reproductively mature bighead carp have been captured but no fertilized eggs or larvae have been found. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock pool and none in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. The nearest population of juvenile sized individuals is in the Peoria Pool below Starved Rock Lock and Dam, five locks downstream of the Electric Dispersal Barrier System. The nearest collection of Asian carp eggs was found near Henry, Illinois, within the Peoria Pool, five locks downstream of the Electric Dispersal Barrier System. Larval Asian carp were only collected in LaGrange Pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the natural dispersion (i.e., swimming and passive drift) of the bighead carp through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Bighead carp actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming will likely be the primary mechanism of movement through the CAWS from the Brandon Road Lock and Dam. There is heavy commercial vessel traffic between Brandon Road Lock and Dam and the Chicago River (USACE 2011a,b) and there is the potential for bighead carp eggs and larvae to be transported upstream of the Electric Dispersal Barrier System by passive entrainment in a ballast tank (no pumping). Heilprin et al. (2011) found water sampled from barge ballast through a single summer to be within published water quality parameters to sustain juvenile and adult Asian carp. Additionally, survivability of larvae and eggs within ballast water was found to be high for periods up to 144 hours but a very low percentage of larvae survived pump passage when expelling the ballast water (Heilprin 2013).

USCG has established a regulated navigation area around the Electric Dispersal Barrier System which prohibits vessels from transiting the safety zone with any non-potable water on board if they intend to release that water in any form within, or on the other side of the safety zone (USCG, 2011).

Other vessel-related transport mechanisms that may reduce the effectiveness of the Electric Dispersal Barrier System are discussed in Section 4c, *Existing Physical Human/Natural Barriers*.

The Nonstructural Alternative includes ballast and bilge water discharge prior to entering the aquatic pathway and is expected to address the human-mediated transport of bighead carp through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: There are two lock complexes (Brandon Road Lock and Dam and Lockport Lock and Dam) within the pathway. The Brandon Road and Lockport locks and dams are expected to control the upstream movement of fish except during lockages. The complexity of navigating through the lock may slow the upstream passage of Asian carp. There is some leakage around and through the gates (Ackerson 2012) that small larvae could move through, but the larvae would not be able to swim against the current created by the leakage. It is unlikely larvae or other bigger individuals could move through closed lock gates. However, during normal operations, bighead carp are expected to be able to swim through open gates.

In addition, there is an electrical barrier complex referred to as the Electric Dispersal Barrier System. The Electric Dispersal Barrier System, located approximately 5 mi upstream of Lockport Lock and Dam and 31 mi downstream of Lake Michigan via the Chicago Lock, consists of three electrical barriers: Demonstration Barrier, Barrier IIA, and Barrier IIB (USACE 2011c). The barriers consist of steel electrodes mounted across the bed of the Chicago Sanitary and Ship Canal (CSSC) that pulse direct current into the water at a strength, pulse duration, and frequency that repels and stuns fish.

The Demonstration Barrier has been operational since 2002 and was rehabilitated in 2008, but it was designed and built with materials that were not intended for long-term use because of its demonstration status. Barrier IIA was activated in April 2009 at the same settings as the Demonstration Barrier – 1 volt per in., 5 Hertz, and 4 milliseconds. These settings were increased in August 2009 to 2 volts per in., 15 Hertz, and 6.5 milliseconds in response to eDNA monitoring results that suggested Asian carp were closer to the barriers than earlier believed. Barrier IIB was activated in April 2011 at Barrier IIA's settings, and Barrier IIA was placed into warm standby mode. In October 2011, Barrier II's operational settings were changed to 2.3 volts per in., 30 Hertz and 2.5 milliseconds, based on laboratory research suggesting these settings would be more effective in deterring very small fish. The U.S. Army Corps of Engineers continues to study the optimal operating parameters to deter very small fish.

USFWS is evaluating feral fish populations and their behavior within the electric dispersal barrier using a dual-frequency identification SONAR (DIDSON; Sound Metrics Corp., Bellevue, WA) unit to evaluate fish populations throughout the entire barrier system (Parker 2013). Results of sampling across the entire barrier system during the summer of 2013, using DIDSON equipment, revealed a large accumulation of fish below the active barrier. Some of the fish that were immediately below the active barrier (either Barrier IIA or IIB) were observed persistently probing and challenging the barrier. DIDSON results showed schools of small fish breaching the barrier. Typically, as the schools of fish penetrated deeper into the zone of ultimate field strength, the size of the school contracted into a tight sphere shape and after they breached, the group expanded again. The sizes of the fish that breached the barrier are estimated to range from approximately 2 to 4 in. in length. To help determine the species of fish most likely observed breaching the barrier, the USFWS performed a limited amount of fish sampling within the narrow array on September 27, 2013 and caught gizzard shad (*Dorosoma cepedianum*), threadfin shad (*Dorosoma petenense*), and skipjack herring (*Alosa chrysochloris*) (USACE 2013). Additional study is underway to further evaluate operational protocols of the barriers and to identify any potential actions that may be employed to address the findings discussed in this paper.

There are several other mechanisms identified for potential barrier bypass. First, fish could swim through the Dispersal Barrier during times of power outage. According to records through March 2013, the Electric Dispersal Barrier System experienced a loss of power to the water for a total of 4 minutes prior to 2011, and a total of 13 minutes in 2012 (USACE unpublished data, Electric Dispersal Barrier System Power Outage Records, April 1, 2013). Work is underway on a redundant power supply for Barrier IIA and similar work is planned for Barrier IIB. In addition, automatic transfer mechanisms were installed on both Barriers IIA and IIB to maintain power in the water in the event of a power loss. Permanent Barrier I, the upgrade for the Demonstration Barrier, will provide yet another redundant electric field of the Dispersal Barrier System during power outages at Barrier IIA or IIB. Secondly, the Electric Dispersal Barrier System would be intentionally shut down completely in emergency situations under a man-overboard scenario; however, there have been no man-overboard scenarios near the Dispersal Barriers as far back as the initialization of the Demo Barrier in 2002.

Additional potential barrier aquatic bypass vectors are currently under investigation and include reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage and fish entrainment within barge induced water currents across the Electric Dispersal Barrier System. Preliminary research at the USACE Engineer Research and Development Center in Vicksburg, MS has shown model fish (soft plastic fish lures) to become entrained at numerous surface junctions, to varying degrees, between inter-barge and tow-barge connections on model tow-barge vessels. Additionally, electrical readings taken within the void created between a raked (sloped) bow and a boxed (flat) stern junction show that steel-hulled barges reduce the in water electrical parameters in this area (USACE 2013).

The US Fish and Wildlife Service placed live surrogate species of fish in cages alongside and between junctions of barges in the CSSC to evaluate fish-barge interactions and assess the possibility of the fish becoming incapacitated as they traversed the electrical barrier. Fish were incapacitated as they encountered the electrical field at all barge locations, except the void space in the rake to box junction. Several feral fish were observed being entrained in two locations around the barges during trial runs indicating that wild fish do interact with barge traffic near the barriers. In order to determine if wild fish would stay in this void without a cage, a follow-up study was conducted with externally tagged fish (tethered to a float). Tethered fish placed in barge junctions breached the barrier to some degree in all but one barge configuration tested. When tethered fish were placed below the barriers as barges approached, some degree of fish breaching the barrier occurred with every different configuration tested (USACE 2013). Results from these ongoing studies are preliminary. This combination of increased possibility of entrainment and reduced electrical parameters due to barge traffic is expected to lead to an increased possibility of fish being transported over the barrier system. Vessel speed and tow/barge configuration are considered to be primary factors that affect the possible entrainment and transport of fish through the electric barriers (USACE 2013). Further research is being conducted to mitigate this bypass. While preliminary results from these investigations have shown these bypasses to be viable, the possibility of these bypasses occurring in the field is low at this time due to the low or non-existent population of bighead carp in the Lockport Pool.

In 2010, lateral barricades were constructed between the CSSC, the Des Plaines River, and the Illinois and Michigan Canal to control upstream bypass of the Electrical Dispersal Barrier System during flooding between these adjacent waterways. The Des Plaines River Barricade extends approximately 13 mi and consists of concrete barriers and specially fabricated 0.25-in. wire mesh that allows water to flow through the fence but controls the passage juvenile and adult fish, and the Illinois and Michigan Canal is walled-off using a stone berm. Small sections of the Des Plaines barricade fence failed during flooding in 2013; however, monitoring crews immediately responded and monitored for the presence of fish along breaches. Though these efforts indicated that fish (common carp) had moved through the breaches, no Asian carp were caught (Barkowski 2013), and prior monitoring efforts in the Des Plaines River had not captured or observed Asian carp, larval fish or eggs (ACRCC 2013b).

Under current operational protocols, monitoring for Asian carp occurs downstream and upstream of the Electric Dispersal Barrier System. In the event an individual is found upstream of the Lockport Lock and Dam, protocol dictates the use of intensive electrofishing and netting to find and remove individuals or the use of rotenone to immobilize and kill all fish within the reach of concern (ACRCC 2011). It is anticipated that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp are above the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.

T_{10}: Future operations of the Brandon Road Lock and Dam and Lockport Lock and Dam locks are not expected to change as of the time of this assessment. The Electric Dispersal Barrier System is expected to have additional redundancies in power supply, thereby reducing potential power outage events**.** A new barrier is currently under construction that will upgrade the Demo Barrier to permanent status (Barrier I). Barrier I will be capable of producing higher electrical outputs than those of Barrier II and will add an additional narrow array on the downstream boundary. Barrier I is expected to become operational by 2016. Further study of the current Electric Dispersal Barrier System to address electric field shielding by steel-hulled vessels, fish entrainment within barge-induced water currents and very small fish would continue and would inform future operations.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.

T_{25}: See T_{10}. Funding for research, monitoring and removal programs for bighead carp at this time step is highly uncertain. Currently, no funding source has been identified for any one agency to maintain the present level of effort.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the bighead carp.

T_{50}: See T_{10} and T_{25}.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Bighead carp prefer eutrophic conditions but survive with low growth rates with low plankton concentrations (Kolar et al. 2005, Cooke et al. 2009). The CAWS is the recipient of treated wastewater from numerous facilities that produces eutrophic conditions suitable for bighead carp. Additionally, recent plankton surveys within the CAWS suggest there are relatively high concentrations of zooplankton available as a food resource (ACRCC 2013a; Butler et al. 2013). Bighead carp utilize all parts of the water column in rivers (Schultz et al. 2007; DeGrandchamp et al. 2008; Kolar et al. 2005). They can be found in low velocity and off-channel habitats associated with slow-moving water (<0.3 m/s [1.0 ft/s]) (Kolar et al. 2005), but are capable of swimming in very-high-velocity habitats, with a maximum measured swimming speed of approximately 7.5 m/s (24.6 ft/s) (Konagaya and Cai 1987). During normal conditions, the CAWS has a slow-moving current (LimnoTech 2010). Sections of the CAWS also experience seasonally low dissolved oxygen (LimnoTech 2010). Heilprin et al. (2013a) found that larvae of bighead carp can survive under low dissolved oxygen conditions (0.86 mg/L) inside a barge ballast tank. This supports the findings of other studies that indicate the species can survive low dissolved oxygen conditions: adults (0.5 mg/L) (Oregon Sea Grant 2011), juveniles (0.33 mg/L), and young (0.4 mg/L) (Jennings 1988). Adult bighead carp can withstand water temperatures up to 38.8°C (101.8°F) (Bettoli et al. 1985). Overall, the conditions of the CAWS are not expected to impede movement of bighead carp.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for bighead carp.

T_{10}: See T_0. Conditions of the CAWS are predicted to change, but not in a way that would affect the likelihood of this species passing through this pathway. For example, the Metropolitan Water Reclamation District of Greater Chicago (MWRD) is in the process of evaluating ways to improve the water quality of the CAWS by decreasing the amount of organic materials released into the CAWS. This could potentially decrease the amount of plankton and other food species bighead carp would need to survive within the CAWS. In addition, in coordination with the USACE, MWRD will increase capacity of stormwater catchment and retention in adjacent tunnels and reservoirs. This will lead to a lower hydrologic peak during storm events. The environmental conditions within the CAWS may change slightly with the closing of two coal-fired power plants (Midwest Generation's Fisk and Crawford Plants) in August 2012. These plants used canal water in their cooling process and returned heated water back to the canal. As a result, temperature profiles may be reduced significantly in the near vicinity and to a lesser extent downstream. This is not expected to significantly affect the ability of bighead carp to pass through this pathway.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for bighead carp.

T_{25}: See T_{10}

T_{50}: See T_{10}

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Bighead carp would need to pass through the Brandon Road and Lockport locks and dams, the Electric Dispersal Barrier System and an intermittent sluice gate opening to pass through this pathway. Adults and all life sizes of bighead carp would be able to swim through the locks when the lock is in operation; however, the locks may slow passage of bighead carp through the pathway.

Based on the sampling and monitoring data, the abundance of individuals within the Lockport Pool below the dispersal barriers is expected to be low to non-existent at this timestep. Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring data, it appears that few bighead carp have not expanded past the Brandon Road Lock and Dam. As discussed in *P(arrival)*, *Current and Potential Abundance and Reproductive Capacity*, in 2012, small Asian carp were relatively abundant in the LaGrange Lock and Dam and Peoria Lock and Dam. Only one was caught in the Starved Rock pool. No small age-1 Asian carp were found in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. Adult populations of bighead carp are in the Dresden Island Pool (ACRCC 2013a). In an effort to control the Asian carp population downstream of the barrier, fisherman have been contracted to remove these fish from the waterway.

Monitoring and research have found several potential bypass mechanisms for the Electric Barrier System: man overboard scenario when power to the barrier is intentionally turned off, power outages, bypass during flood events, stunned fish floating through the barrier during reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage and fish entrainment within barge induced water currents across the Electric Dispersal Barrier System. Bypass due to these various mechanisms is not likely, because the nearest detectable population of swimming bighead carp is in Dresden Island Pool and the nearest detected eggs, larvae, and fry are farther downstream (ACRCC 2013a). Additionally, research on these bypasses continues and will inform future operations.

In summary, current propagule pressure of this species immediately downstream of the Dispersal Barriers is considered low or non-existent as measured by monitoring efforts of local, state and federal agencies. The probability of passage for the bighead carp is low for T_0 because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier, then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The low passage rating is in conflict with the Canadian Science Advisory Report (2012) that rates passage through the CAWS as highly likely. However, the Canadian report explicitly did not evaluate the effectiveness of the Electric Dispersal Barrier System.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative’s low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{10}: See $T_{0.}$ Bighead carp are expected to remain in low populations immediately below the Electric Dispersal Barrier System. Contracted fishermen are expected to continue to improve their fishing techniques to increase their catch rates. The Brandon Road and Lockport locks and dams may also slow bighead carp passage.

Federal and state natural resource agencies have monitored the upstream progress of Asian carp populations since their arrival in the IWW in the 1990’s (Conover et al. 2007; Irons et al. 2009; ACRCC 2013a). Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring, it appears that few bighead carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences. Also, it is anticipated that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp above the Brandon Road Lock and Dam.

Further refinement of the Electric Dispersal Barrier System operations and redundant power sources are expected to decrease the number and length of potential power outages. Additionally, potential transport vectors across the barriers (e.g., vessel entrainment, insufficient operating parameters for small fish, reverse flow events, crevice shielding of electric field) will continue to be analyzed and future operations would informed by this analysis.

The probability of passage for the bighead carp is low for T_{10} because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}. Funding for monitoring and removal programs for bighead carp at this time step is uncertain because there is not a funding source identified to maintain the present level of management. With the continued expected immigration from the lower pools (Tsehaye et al. 2013), the propagule pressure at the Dispersal Barrier System is expected to increase, and thus increase the potential for an individual to move past the Barriers.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of bighead carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's medium probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{50}: See T_{10} and T_{25}.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	High	High	High
Nonstructural Alternative Rating	Medium	High	High	High

Evidence for Uncertainty Rating

T_0: Although there has been an extraordinary effort from multiple agencies to research potential barrier bypass mechanisms, much of that research is currently underway and only preliminary results have been reported. Each risk assessment was conducted qualitatively under the assumption that bypass is possible but did not address the frequency that it might occur under a set of quantitative conditions. It is also uncertain whether additional bypass mechanisms could still be discovered. Though comprehensive monitoring upstream and downstream of the barrier for Asian carp is ongoing, uncertainty still exists concerning whether monitoring has identified the true abundance of bighead carp within upper Illinois River and the CAWS.

The Nonstructural Alternative is expected to affect the passage of bighead carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Overall, the uncertainty remains medium.

T_{10}: See T_0. Although empirical tests are underway to see if the potential transport mechanisms across the barriers are viable, at this time uncertainty increases with time because of unknown events. Additionally, funding for management actions that keep the populations of Asian carp in check immediately downstream of the Dispersal Barriers are not specified. The factors contributing to the historic absence of range expansion beyond the Brandon Road Lock and Dam are uncertain and may change.

The Nonstructural Alternative is expected to affect the passage of bighead carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of bighead carp through the aquatic pathway. Overall, the uncertainty remains high.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

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E.2.1.2.2 Silver Carp - *Hypophthalmichthys molitrix*

NONSTRUCTURAL ALTERNATIVE

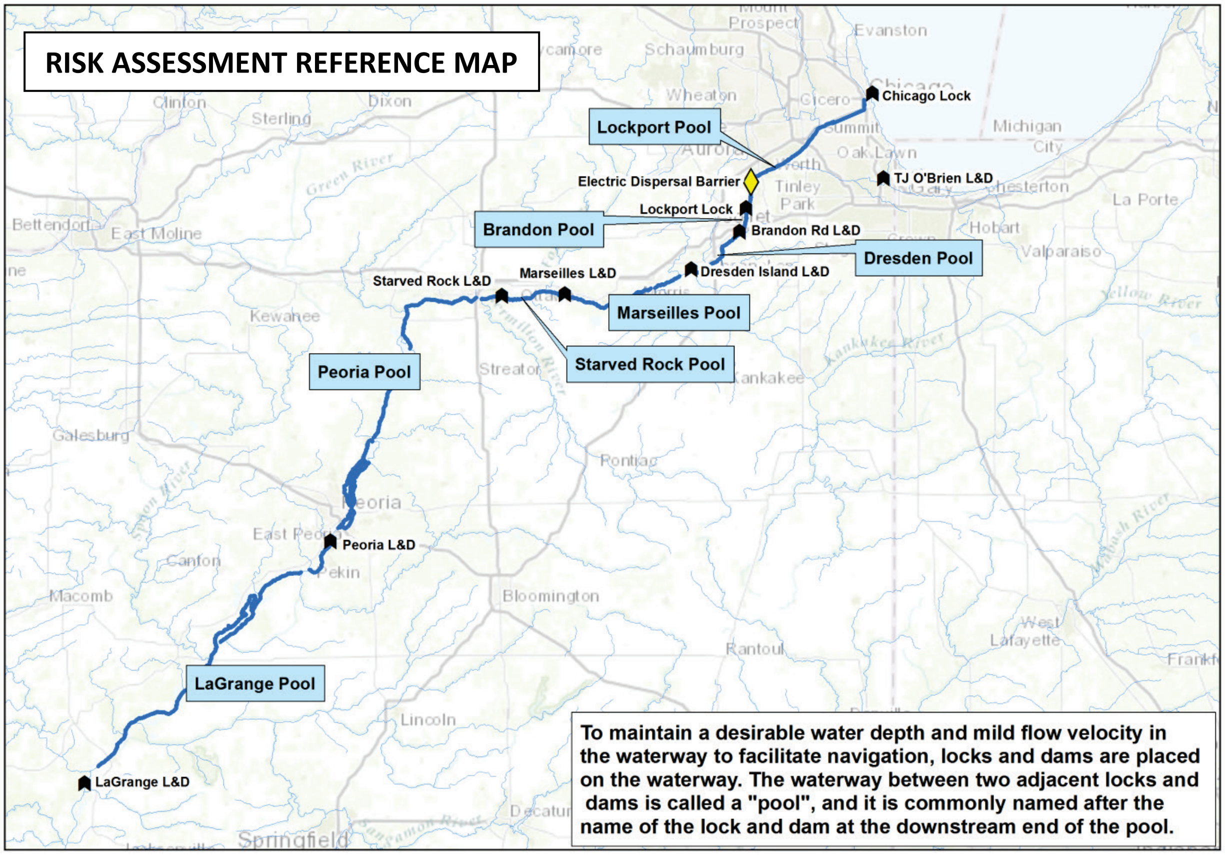
This alternative would potentially include the implementation of a combination of the following measures that may be implemented at time step 0 (T_0, in units of years) by local, state, and federal agencies and the public. The Nonstructural Alternative would include a monitoring and response program.

Nonstructural Alternative Measures for the Silver Carp

Option or Technology	Description
Education & Outreach	Education of recreational waterway users and bait shop owners
	Signage, pamphlets, brochures on how to identify ANS and control the spread of ANS; promote national campaigns (i.e., “Don’t Move Live Fish” campaign)
Ballast/Bilge-water Exchange	Ballast/Bilge-water Exchange
Monitoring	Agency Monitoring
	Voluntary occurrence reporting
Laws & Regulations	Quarantine — restricted site access
	Prohibition of sale, husbandry, transport, release
	FWS Lacey Act listing
	Mandatory watercraft and trailer inspection and decontamination

Option or Technology	ANS Controls	ANS Factsheet[a]
ANS Control Methods	Piscicides	Piscicides
	Controlled Harvest & Overfishing	Controlled Harvest & Overfishing
	Desiccation (Water Drawdown)	Lethal Temperature

[a] For more information refer to GLMRIS Team (2012).



RISK ASSESSMENT REFERENCE MAP

To maintain a desirable water depth and mild flow velocity in the waterway to facilitate navigation, locks and dams are placed on the waterway. The waterway between two adjacent locks and dams is called a "pool", and it is commonly named after the name of the lock and dam at the downstream end of the pool.

◊ The Electric Dispersal Barrier System located approximately 5 mi upstream of the Lockport Lock and Dam is assumed to continue operation through T_{50}.

Pools of the Upper Illinois River and CAWS			Lock and Dams of the Upper Illinois and CAWS	
Pool	River Miles	Approximate Length (mi)	Lock and Dams	Approximate Distance from Electric Barrier System (mi)
Lockport Pool[a]			Chicago Lock	31
Electric Barrier System	296	–	T.J O'Brien Lock and Dam[a]	30.5
To Chicago Lock	291–327	36	Lockport Lock and Dam	5
To T.J. O'Brien	291–326.5	35.5	Brandon Road Lock and Dam	10
Brandon Road Pool	286–291	5	Dresden Island Lock and Dam	24.5
Dresden Island Pool	271.5–286	14.5	Marseilles Lock and Dam	49
Marseilles Pool	247–271.5	24.5	Starved Rock Lock and Dam	65
Starved Rock Pool	231–247	16	Peoria Lock and Dam	138.4
Peoria Pool	157.6–231	73.4	LaGrange Lock and Dam	215.8
LaGrange Pool	80.2–157.6	77.4		

[a] Lockport Pool encompasses river miles both below and above the Electric Dispersal Barrier System. Upstream of the Electric Dispersal Barrier System, the Chicago Sanitary and Ship Canal (CSSC) continues north to the Chicago Lock at Lake Michigan. The Cal-Sag Channel connects with the CSSC at approximately river mile 303, and proceeds eastward toward the T.J. O'Brien Lock and Dam. Lake Michigan is approximately 6 mi north of the T.J. O'Brien Lock and Dam.

Note: River Miles were determined from the U.S. Army Corps of Engineers, Illinois Waterway Navigation Charts from Mississippi River at Grafton, Illinois to Lake Michigan at Chicago and Calumet Harbors, 1998.

PATHWAY 1

BRANDON ROAD LOCK AND DAM TO WILMETTE PUMPING STATION (WPS)

NONSTRUCTURAL ALTERNATIVE: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE PROBABILITY OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Brandon Road Lock and Dam and the WPS over the next 50 years.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Silver carp are active swimmers. The expansion rate of the silver carp is 33.18 km/yr (20.62 river miles/yr) (Jerde et al. 2010). Populations of silver carp appear to be growing exponentially (Kolar et al. 2005) and abundance peaks quickly following establishment. Silver carp range expansion surpasses that of bighead, because silver can more readily bypass locks (Jerde et al. 2010).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp to the Chicago Area Waterway System (CAWS) by natural dispersion.

b. Human-Mediated Transport through Aquatic Pathways

There is commercial vessel and recreational boat traffic between the current location of silver carp and the Brandon Road Lock and Dam. Silver carp eggs, larvae, and fry have the potential to be spread by ballast water if water quality is suitable, although the viability of this ballast water transport is considered to be low (Heilprin et al. 2013).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the CAWS from human-mediated transport through this aquatic pathway.

c. Current Abundance and Reproductive Capacity

T_0: A Monitoring and Response Work Group (MRWG) composed of academic, local, state, and federal agencies was established in 2010 by the Asian Carp Coordinating Committee (ACRCC). The ACRCC's mission statement is to create a sustainable Asian carp control program for protecting the integrity and safety of the Great Lakes ecosystem by preventing introduction of a sustainable Asian carp population into the Great Lakes via all viable pathways (ACRCC 2013d). The MRWG has projects focusing on waterway monitoring, removal efforts, Electric Dispersal Barrier System efficacy, gear catch efficacy, and alternative pathway monitoring. Regular electrofishing and netting efforts have consisted of 16,497 person-hours of sampling from the Starved Rock Pool to Lake Michigan resulting in the capture of 283,290 specimens from 2010 to 2012. Removal efforts below the barrier system include contracted commercial fishermen setting over 643.3 mi of nets through 2012 to remove 698.72 tons of bighead, silver and grass carp. Additional workgroup projects include juvenile, larval, and egg sampling; ichthyoplankton surveys; telemetry studies; hydro-acoustic surveys; and alternative gear development, all of which provide up-to-date information on the status of Asian carp populations and range expansion (ACRCC 2013a).

Based on catch data reported through November 2013, approximately 80 silver carp have been caught in Rock Run Rookery, a backwater in the Dresden Island Pool, approximately 4 mi downstream of the Brandon Road Lock and Dam (ACCRC 2013c). There are no physical barriers between Rock Run Rookery Preserve Lake and the Brandon Road Lock and Dam. It is unknown whether this represents a population increase in this pool since the rookery was not previously sampled.

Silver carp are broadcast spawners that spawn in large aggregates (Kolar et al. 2005). Female egg production is correlated with increased body mass and age. Total fecundity of silver carp from the middle of the Mississippi River in 2003 ranged from 57,283 to 328,538 eggs (Kolar et al. 2005). In 2004 and 2005, fecundity of silver carp ranged from 26,650 to 598,767 and 274,917 to 3,683,150, respectively (Garvey et al. 2006). Eggs are released in the water column and float downstream where they develop in slow-moving waters. Reproduction has not been documented in waters upstream of Marseilles Lock and Dam, which is less than 64 km (40 mi) from the Brandon Road Lock and Dam. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock Pool and none in the Marseilles Pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of silver carp. Controlled harvest and overfishing measures have removed over 1.3 million lbs of Asian carp from the Illinois River between 2010 and 2012 (ACRCC 2013e). However, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The silver carp has been listed as an injurious fish species under the Lacey Act (Federal Register 2011), and federal and state agencies have implemented components of the *National Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States* (Conover et al. 2007). However, ongoing barrier defense monitoring indicates that silver carp remains abundant in the Illinois River (Wyffels et al. 2013) at the current level of harvest, regulation, and management.

Overall, the Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{10}: See T_0. Based on the above information, silver carp seem to have a high reproductive capacity in terms of producing new young per year. Therefore, current populations are expected to increase in abundance. Additionally, future environmental conditions or population genetics have the potential to shift in such a way that would allow a rapid growth and expansion of downstream populations that could lead to increased immigration into the pathway (Kolar et al. 2007); therefore, abundance is expected to increase below the Brandon Road Lock and Dam. This assessment is based on past invasion histories for multiple species (Crooks and Soulé 1996; Williamson 1996; Nico and Fuller 1999; Lockwood et al. 2007); also see the above section *Type of Mobility/Invasion Speed* for more information.

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{25}: See T_{10}. It is expected that, in areas with established populations, natural constraints on population growth would begin to reach a plateau. Thus, reproductive capacity would remain the same, but would no longer result in an exponentially increasing population.

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{50}: See T_{25}.

d. Existing Physical Human/Natural Barriers

T_0: None. There are no barriers to movement of the silver carp from its current position to Brandon Road Lock and Dam. The silver carp has arrived at the pathway.

The Nonstructural Alternative would not affect existing physical human/natural barriers to the pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: The silver carp is established throughout the Illinois River (Nico 2012). Silver carp have been detected as far upstream as Dresden Island Pool. In 2009, one silver carp was observed at the confluence of the Des Plaines River and Chicago Sanitary Ship Canal during routine Asian carp monitoring (ACRCC 2013e).

In addition, there have been multiple positive eDNA detections upstream of electric barriers for silver carp (Jerde et al. 2011). However, there is no evidence to correlate the eDNA detections to an established Asian carp population above the Electric Dispersal Barrier System within the CAWS (ACRCC 2012; Environmental DNA Calibration

Study 2013). Calibration studies are underway to better understand the relationship between positive eDNA and Asian carp populations (ACRCC 2013b).

Below the Brandon Road Pool, silver carp have been detected in the Dresden Island Pool. Based on 2013 catch data reported through November, approximately 80 silver carp have been caught in Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam (ACCRC 2013c). Based on the persistent populations in Marseilles Pool, and the 2013 captures in Rock Run Rookery Preserve Lake approximately 4 mi from Brandon Road Lock and Dam, the silver carp has arrived at the pathway (Brandon Road Lock and Dam).

The Nonstructural Alternative is not expected to affect the silver carp's distance from the aquatic pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Silver carp inhabit freshwater riverine systems and confluent lakes. The species is native to several major Pacific drainages in eastern Asia from the Amur River of far eastern Russia south through much of the eastern half of China to the Pearl River. This species is native from about 54°N southward to 21°N (Xie and Chen 2001; Froese & Pauly 2004). Most of North America falls within these latitudes. Silver carp are tolerant to a wide array of environmental variables (Kolar et al. 2005).

Silver carp are a pelagic, schooling species (Mukhamedova 1977). Silver carp swim just beneath the water surface (Man and Hodgkiss 1981) where it filter-feeds on phytoplankton. Its diet also includes zooplankton, bacteria, and detritus (Leventer 1987). The water temperature range at which larval silver carp can exist is broad: 16–40°C (60.8–104°F) with optimum temperatures reported as 26–30°C (78.8–86°F). Lethal temperature of larval silver carp was 43.5–46.5°C (110.3–115.7°F). Silver carp are quite tolerant to low water temperatures. In Alberta, Canada, silver carp successfully overwinter in ponds that are near 0°C (32°F) from the beginning of November through the end of April (Kolar et al. 2005).

Silver carp eggs are semi-buoyant; spawning typically occurs in water of sufficient flow to keep the eggs from sinking to the bottom and dying (Laird & Page 1996). Currents bring larvae to slow-flowing backwaters, creeks, reservoirs, or other flooded areas that become nursery areas (Nikolsky 1963).

The Nonstructural Alternative is not expected to affect the suitability of habitat for silver carp.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Silver carp have been detected as far upstream as Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway. The silver carp has arrived at the pathway. Therefore, the probability of arrival remains high.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: Based on 2013 catch data reported through November, approximately 80 silver carp have been caught in Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam (ACCRC 2013c).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{10}: See T_0. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) may reduce Asian carp populations. However, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{25}: See T_0. It is uncertain whether Asian carp monitoring and harvesting activities in Dresden Island Pool will continue during this time step. The silver carp population in the Dresden Island Pool is expected, at a minimum, to remain at existing levels; however, an increase in population is more likely through time. The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{50}: See T_0.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Silver carp are active swimmers and can spread upstream naturally. The expansion rate of the silver carp is 33.62 km/yr (20.62 river miles/yr) (Jerde et al. 2010).

Asian carp were first sampled from the Illinois River during the 1990s, and populations have since progressed upstream (Conover et al. 2007; Irons et al. 2009). Monitoring for Asian carp was originally incidental to standard routine sampling by the Illinois Department of Natural Resources (IDNR) and the Illinois Natural History Survey (INHS). Sampling directed toward silver carp in the upper Illinois Waterway began with the U.S. Fish and Wildlife Service's (USFWS's) annual Carp Corral & Round Goby Roundup. Subsequently, the U.S. Army Corps of Engineers (USACE) adopted a plan specifically to monitor Asian carp downstream of the electric barrier system located near Romeoville, Illinois (ACRCC 2013a). By 2010, the ACRCC was formed to coordinate this intensive monitoring effort, which was expanded to include techniques including but not limited to eDNA, electrofishing, netting, sonar, and telemetry above and below the barrier generally between Lake Michigan and the Peoria Lock and Dam (ACRCC 2010).

In 2009, a confirmed sighting of a silver carp during Asian carp routine monitoring efforts at the confluence of the CSSC and Des Plaines River was reported (ACRCC 2013a); however, the silver carp population in Dresden Island Pool has not progressed upstream. Proposed reasons for this halted progression include limited food resources in the CAWS, hydraulic and hydrologic differences, water quality differences, and a habitat shift from natural to manmade. While these assumptions are still under investigation, the exact cause of the delayed expansion is still unknown but can be compared to other species' invasion histories. Numerous invasive species have long documented cases of extended lag periods in range expansion before an unknown cue (environmental or genetic) sparks another boom in population abundance and/or expanded geographical range (Crooks and Soulé 1996; Williamson 1996; Nico and Fuller 1999; Lockwood et al. 2007). Cudmore et al. (2012) rated the probability of the silver carp entering Lake Michigan as very likely.

Within the Marseilles and Dresden Island pools, reproductively mature silver carp have been captured, but no fertilized eggs or larvae have been found. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock Pool and none were caught in the Marseilles Pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. The nearest collection of Asian carp eggs was found near Henry, Illinois, within the Peoria Pool, five locks downstream of the Electric Dispersal Barrier System. Larval Asian carp were only collectd in LaGrange Pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the natural dispersion (i.e., swimming and passive drift) of the silver carp through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Silver carp actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming will likely be the primary mechanism of movement through the CAWS from the Brandon Road Lock and Dam. There is heavy commercial vessel and recreational vessel traffic between the Brandon Road Lock and Dam and the Chicago River (USACE 2011a,b). Silver carp eggs and larvae could also be transported upstream of the Electric Dispersal Barrier System by passive entrainment in a ballast tank (no pumping). Heilprin et al. (2013) found water sampled from barge ballast through a single summer to be within published water quality parameters to sustain juvenile and adult Asian carp. Additionally, survivability of larvae and eggs within ballast water was found to be high for periods up to 144 hours, but a very low percentage of larvae survived pump passage when expelling the ballast water (Heilprin et al. 2013).

USCG has established a regulated navigation area around the Electric Dispersal Barrier System that prohibits vessels from transiting the safety zone with any non-potable water on board if they intend to release that water in any form within or on the other side of the safety zone (USCG, 2011).

Other vessel-related transport mechanisms that may reduce the effectiveness of the Electric Dispersal Barrier System are discussed in section 4c, *Existing Physical Human/Natural Barriers*.

Commercial traffic through the Brandon Road Lock and Dam moves to the T.J. O'Brien Lock and Dam or the Chicago River Controlling Works (CRCW); it does not go to the WPS. Recreational boat fishing occurs on the North Shore Channel leading to the WPS, but boats cannot move from the North Shore Channel into Lake Michigan.

The Nonstructural Alternative includes ballast and bilge water discharge prior to entering the aquatic pathway and is expected to address the human-mediated transport of silver carp through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: There are two lock complexes (Brandon Road Lock and Dam and Lockport Lock and Dam) within the pathway. The Brandon Road and Lockport locks and dams are expected to control the upstream movement of fish except during lockages. The complexity of navigating through the lock may slow the upstream passage of Asian carp. There is some leakage around and through the gates (Ackerson 2012) that small larvae could move through, but the larvae would not be able to swim against the current created by the leakage. It is unlikely larvae or other bigger individuals could move through closed lock gates. However, during normal operations, silver carp is assumed to be able to swim through open gates.

In addition, there is an electrical barrier complex referred to as the Electric Dispersal Barrier System. The Electric Dispersal Barrier System, located approximately 5 mi upstream of Lockport Lock and Dam and 31 mi downstream of Lake Michigan via the Chicago Lock, consists of three electrical barriers: Demonstration Barrier, Barrier IIA, and Barrier IIB (USACE 2011c). The barriers consist of steel electrodes mounted across the bed of the Chicago Sanitary and Ship Canal (CSSC) that pulse direct current into the water at a strength, pulse duration, and frequency that repels and stuns fish.

The Demonstration Barrier has been operational since 2002 and was rehabilitated in 2008, but it was designed and built with materials that were not intended for long-term use because of its demonstration status. Barrier IIA was activated in April 2009 at the same settings as the Demonstration Barrier – 1 volt per in., 5 Hertz, and 4 milliseconds. These settings were increased in August 2009 to 2 volts per in., 15 Hertz, and 6.5 milliseconds in response to eDNA monitoring results that suggested Asian carp were closer to the barriers than previously believed. Barrier IIB was activated in April 2011 at Barrier IIA’s settings, and Barrier IIA was placed into warm standby mode. In October 2011, Barrier II's operational settings were changed to 2.3 volts per in., 30 Hertz and 2.5 milliseconds, based on laboratory research suggesting these settings would be more effective in deterring very small fish. USACE continues to study the optimal operating parameters to deter very small fish.

USFWS is evaluating feral fish populations and their behavior within the electric dispersal barrier using a dual-frequency identification SONAR (DIDSON; Sound Metrics Corp., Bellevue, Washington) unit to evaluate fish populations throughout the entire barrier system (Parker 2013). Results of sampling across the entire barrier system during the summer of 2013, using DIDSON equipment, revealed a large accumulation of fish below the active barrier. Some of the fish that were immediately below the active barrier (either Barrier IIA or IIB) were observed persistently probing and challenging the barrier. DIDSON results showed schools of small fish breaching the barrier. Typically, as the schools of fish penetrated deeper into the zone of ultimate field strength, the size of the school contracted into a tight sphere shape and after they breached, the group expanded again. The sizes of the fish that breached the barrier are estimated to range from approximately 2 to 4 in. in length. To help determine the species of fish most likely observed breaching the barrier, the USFWS performed a limited amount of fish sampling within the narrow array on September 27, 2013, and caught gizzard shad (*Dorosoma cepedianum*), threadfin shad (*Dorosoma petenense*), and skipjack herring (*Alosa chrysochloris*) (USACE 2013). Additional studies are underway to further evaluate operational protocols of the barriers and to identify any potential actions that may be employed to address the findings discussed in this paper.

There are several other mechanisms identified for potential barrier bypass. First, fish could swim through the Dispersal Barrier during times of power outage. According to records through March 2013, the Electric Dispersal Barrier System experienced a loss of power to the water for a total of 4 minutes prior to 2011, and a total of 13 minutes in 2012 (USACE unpublished data, Electric Dispersal Barrier System Power Outage Records, April 1, 2013). Work is underway on a redundant power supply for Barrier IIA and similar work is planned for Barrier IIB. In addition, automatic transfer mechanisms were installed on both Barriers IIA and IIB to maintain power in the water in the event of a power loss. Permanent Barrier I, the upgrade for the Demonstration Barrier, will provide yet another redundant electric field of the Dispersal Barrier System during power outages at Barrier IIA or IIB. In addition, the Electric Dispersal Barrier System would be intentionally shut down completely in emergency situations under a man-overboard scenario; however, there have been no man-overboard scenarios near the Dispersal Barriers as far back as the initialization of the Demonstration Barrier in 2002.

Additional potential barrier aquatic bypass vectors are currently under investigation and include reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage, and fish entrainment within barge-induced water currents across the Electric Dispersal Barrier System. Preliminary research at the USACE Engineer Research and Development Center in Vicksburg, Mississippi, has shown model fish (soft plastic fish lures) to become entrained at numerous surface junctions, to varying degrees, between inter-barge and tow-barge connections on model tow-barge vessels. Additionally, electrical readings taken within the void created between a raked (sloped) bow and a boxed (flat) stern junction show that steel-hulled barges reduce the in-water electrical parameters in this area (USACE 2013).

The USFWS placed live surrogate species of fish in cages alongside and between junctions of barges in the CSSC to evaluate fish-barge interactions and assess the possibility of the fish becoming incapacitated as they traversed the electrical barrier. Fish were incapacitated as they encountered the electrical field at all barge locations except the void space in the rake to box junction. Several feral fish were observed being entrained in two locations around the barges during trial runs, indicating that wild fish do interact with barge traffic near the barriers. In order to determine whether wild fish would stay in this void without a cage, a follow-up study was conducted with externally tagged fish (tethered to a float). Tethered fish placed in barge junctions breached the barrier to some degree in all but one barge configuration tested. When tethered fish were placed below the barriers as barges approached, some degree of fish breaching the barrier occurred with each configuration tested (USACE 2013). Results from these ongoing studies are preliminary. This combination of increased possibility of entrainment and reduced electrical parameters due to barge traffic is expected to lead to an increased possibility of fish being transported over the barrier system. Vessel speed and tow/barge configuration are considered to be primary factors that affect the possible entrainment and transport of fish through the electric barriers (USACE 2013). Further research is being conducted to mitigate this bypass. While preliminary results from these investigations have shown these bypasses to be viable, the possibility of these bypasses occurring in the field is low at this time due to the low or non-existent population of silver carp in the Lockport Pool.

In 2010, lateral barricades were constructed between the CSSC, the Des Plaines River, and the Illinois and Michigan Canal to control upstream bypass of the Electrical Dispersal Barrier System during flooding between these adjacent waterways. The Des Plaines

River Barricade extends approximately 13 mi and consists of concrete barriers and specially fabricated 0.25-in. wire mesh that allows water to flow through the fence but controls the passage juvenile and adult fish, and the Illinois and Michigan Canal is walled off using a stone berm. Small sections of the Des Plaines barricade fence failed during flooding in 2013; however, monitoring crews immediately responded and monitored for the presence of fish along breaches. Although these efforts indicated that fish (common carp) had moved through the breaches, no Asian carp were caught (Barkowski 2013), and prior monitoring efforts in the Des Plaines River had not captured or observed Asian carp, larval fish, or eggs (ACRCC 2013b).

Under current operational protocols, monitoring for Asian carp occurs downstream and upstream of the Electric Dispersal Barrier System. In the event an individual is found upstream of the Lockport Lock and Dam, protocol dictates the use of intensive electrofishing and netting to find and remove individuals or the use of rotenone to immobilize and kill all fish within the reach of concern (ACRCC 2011). It is expected that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp are above the Brandon Road Lock and Dam.

In addition, water control structures separating WPS from Lake Michigan are periodically opened and closed (LimnoTech 2010). When these structures are opened, silver carp would be able to swim into Lake Michigan.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{10}: See T_0. Future operations of the Brandon Road Lock and Dam and Lockport Lock and Dam locks are not expected to change as of the time of this assessment. The Electric Dispersal Barrier System is expected to have additional redundancies in power supply, thereby reducing potential power outage events. A new barrier is currently under construction that will upgrade the Demonstration Barrier to permanent status (Barrier I). Barrier I will be capable of producing higher electrical outputs than those of Barrier II and will add an additional narrow array on the downstream boundary. Barrier I is expected to become operational by 2016. Further study of the current Electric Dispersal Barrier System to address electric field shielding by steel-hulled vessels, fish entrainment within barge-induced water currents, and very small fish would continue and would inform future operations.

Future operations of WPS sluice gate are not predicted to change.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{25}: See T_{10}. Funding for research, monitoring, and removal programs for Asian carp at this time step is highly uncertain. Currently, no funding source has been identified for any one agency to maintain the present level of effort.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{50}: See T_{10} and T_{25}.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Silver carp inhabit freshwater riverine systems and confluent lakes. It is a pelagic, schooling species (Mukhamedova 1977). Silver carp is a filter feeder capable of taking large amounts of phytoplankton. Its diet also includes zooplankton, bacteria, and detritus (Leventer 1987). The CAWS is the recipient of treated wastewater from numerous facilities that produces eutrophic conditions suitable for silver carp. Additionally, recent plankton surveys within the CAWS suggest there are relatively high concentrations of zooplankton available as a food resource (MRRP 2012).

Silver carp are tolerant to a wide array of environmental variables (Kolar et al. 2005). They can tolerate long winters under ice cover as well as temperatures higher than 40°C (104°F) (Opuszynski et al. 1989). In the CAWS, mean annual water temperature ranges from 11.3 to 19.3°C (52.3 to 66.7°F) (MWRD 2010). Fry and fingerlings can survive in waters with a pH of 5.0 to 9.0, dissolved oxygen 1–28 mg/L, and total alkalinity 88–620 mg/L (Singh et al. 1967). Sections of the CAWS also experience seasonally low dissolved oxygen (LimnoTech 2010).

Silver carp eggs are semi-buoyant; spawning typically occurs in water of sufficient flow to keep the eggs from sinking to the bottom and dying (Laird & Page 1996). Reported current velocities required for successful spawning range from 0.3 to 3.0 m/s (0.98 to 9.8 ft/s) (Kolar et al. 2005). The pathway from the Brandon Road Lock and Dam to the mouth of Lake Michigan at the WPS is a slow-moving eutrophic river with a flow of 0.05–0.27 m/s (0.16–0.89 ft/s) (LimnoTech 2010). Currents bring larvae to slow-flowing backwaters, creeks, reservoirs, or other flooded areas that become nursery areas (Nikolsky 1963). The CAWS is a heavily modified channel with little floodplain connection or shallow marshy areas (LimnoTech 2010). Overall, the conditions of the CAWS are not expected to impede movement of silver carp.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for silver carp.

T_{10}: See T_0. Conditions of the CAWS are predicted to change, but not in a way that would affect the likelihood of this species passing through this pathway**.** For example, the Metropolitan Water Reclamation District of Greater Chicago (MWRD) is in the process of evaluating ways to improve the water quality of the CAWS by decreasing the amount of organic materials released into the CAWS. This could potentially decrease the amount of plankton and other food species silver carp would need to survive within the CAWS. In addition, in coordination with the USACE, MWRD will increase the capacity of stormwater catchment and retention in adjacent tunnels and reservoirs, leading to a lower hydrologic peak during storm events. The environmental conditions within the CAWS may change slightly with the closing of two coal-fired power plants (Midwest Generation’s Fisk and Crawford Plants) in August 2012. These plants used canal water in their cooling process and returned heated water back to the canal. As a result, temperature profiles may be reduced significantly in the near vicinity and to a lesser extent downstream. These actions are not expected to significantly affect the silver carp’s ability to pass through this pathway.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for silver carp.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Silver carp would need to pass through the Brandon Road and Lockport locks and dams, the Electric Dispersal Barrier System, and an intermittent sluice gate opening to pass through this pathway. Adults and all life sizes of silver carp would be able to swim through the locks when the lock is in operation; however, the locks may slow passage of silver carp through the pathway.

Based on the sampling and monitoring data, the abundance of individuals within the Lockport Pool below the dispersal barriers is expected to be low to nonexistent at this time step. Since 2007, silver carp were captured in Dresden Island Pool (USGS 2013); however, based on this monitoring data, it appears that few silver carp have expanded past the Brandon Road Lock and Dam. As discussed in *P(arrival)*, *Current and Potential Abundance and Reproductive Capacity*, in 2012, small Asian carp were relatively abundant in the LaGrange Lock and Dam and Peoria Lock and Dam. Only one was caught in the Starved Rock pool. No small age-1 Asian carp were found in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. Adult populations of silver carp are in the Dresden Island Pool (ACRCC 2013a). In an effort to control the Asian carp population downstream of the barrier, fisherman have been contracted to remove these fish from the waterway.

Monitoring and research have found several potential bypass mechanisms for the Electric Barrier System: the man overboard scenario when power to the barrier is intentionally turned off, power outages, bypass during flood events, stunned fish floating through the barrier during reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel-hulled vessels or side wall crevices, small fish passage, and fish entrainment within barge-induced water currents across the Electric Dispersal Barrier System. Bypass due to these various mechanisms is not likely, because the nearest detectable population of swimming silver carp is in Dresden Island Pool and the nearest detected eggs, larvae, and fry are farther downstream (ACRCC 2013a). Additionally, research on these bypasses continues and will inform future operations.

In summary, current propagule pressure of this species immediately downstream of the Dispersal Barriers is considered low or nonexistent as measured by monitoring efforts of local, state, and federal agencies. The probability of passage for the silver carp is low for T_0 because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier

System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier, then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The low passage rating is in conflict with the Canadian Science Advisory Report (2012) that rates passage through the CAWS as highly likely. However, the Canadian report explicitly did not evaluate the effectiveness of the Electric Dispersal Barrier System.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Silver carp are expected to remain in low populations immediately below the Electric Dispersal Barrier System. Contracted fishermen are expected to continue to improve their fishing techniques to increase their catch rates. The Brandon Road and Lockport locks and dams may also slow silver carp passage.

Federal and state natural resource agencies have monitored the upstream progress of Asian carp populations since their arrival in the IWW in the 1990s (Conover et al. 2007; Irons et al. 2009; ACRCC 2013a). Since 2007, silver carp were captured in Dresden Island Pool (USGS 2013); however, based on current monitoring data, it appears that few silver carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences. In addition, it is expected that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp above the Brandon Road Lock and Dam.

Further refinement of the Electric Dispersal Barrier System operations and redundant power sources are expected to decrease the number and length of potential power outages. Additionally, potential transport vectors across the barriers (e.g., vessel entrainment, insufficient operating parameters for small fish, reverse flow events, crevice shielding of electric field) will continue to be analyzed and future operations would be informed by this analysis.

The probability of passage for the silver carp is low for T_{10} because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at T_0. Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}. Funding for monitoring and removal programs for silver carp at this time step is uncertain because there is not a funding source identified to maintain the present level of management. With the continued expected immigration from the lower pools (Tsehaye et al. 2013), the propagule pressure at the Dispersal Barrier System is expected to increase, and thus increase the potential for an individual to move past the barriers. The probability of passage increases to medium.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at T_0. Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's medium probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{50}: See T_{10} and T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	High	High	High
Nonstructural Alternative Rating	Medium	High	High	High

Evidence for Uncertainty Rating

T_0: Although there has been an extraordinary effort from multiple agencies to research potential barrier bypass mechanisms, much of that research is currently underway and only preliminary results have been reported. Each risk assessment was conducted qualitatively under the assumption that bypass is possible but did not address the frequency that it might occur under a set of quantitative conditions. It is also uncertain whether additional bypass mechanisms could still be discovered. Although comprehensive monitoring upstream and downstream of the barrier for Asian carp is ongoing, uncertainty still exists concerning whether monitoring has identified the true abundance of silver carp within upper Illinois River and the CAWS.

The Nonstructural Alternative is expected to affect the passage of silver carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Overall, the uncertainty remains medium.

T_{10}: See T_0. Although empirical tests are underway to see if the potential transport mechanisms across the barriers are viable, at this time uncertainty increases with time because of unknown events and a general lack of published literature discussing future bypass mechanisms. Additionally, funding for management actions that keep the population of Asian carp in check immediately downstream of the Dispersal Barriers are not specified. The factors contributing to the historic absence of range expansion beyond the Brandon Road Lock and Dam are uncertain and may change.

The Nonstructural Alternative is expected to affect the passage of silver carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Overall, the uncertainty remains high.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. **P(spreads) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 2

BRANDON ROAD LOCK AND DAM TO CHICAGO RIVER CONTROLLING WORKS (CRCW)

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE PROBABILITY OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Brandon Road Lock and Dam and the CRCW over the next 50 years.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist. Arrival of an individual specimen is examined here and drives the risk rating.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Silver carp are active swimmers. The expansion rate of the silver carp is 33.18 km/yr (20.62 river miles/yr) (Jerde et al. 2010). Populations of silver carp appear to be growing exponentially (Kolar et al. 2005) and abundance peaks quickly following establishment. Silver carp range expansion surpasses that of bighead, because silver can more readily bypass locks (Jerde et al. 2010).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp to the Chicago Area Waterway System (CAWS) by natural dispersion.

b. Human-Mediated Transport through Aquatic Pathways

There is commercial vessel and recreational boat traffic between the current location of silver carp and the Brandon Road Lock and Dam. Silver carp eggs, larvae, and fry have the potential to be spread by ballast water if water quality is suitable, although the viability of this ballast water transport is considered to be low (Heilprin et al. 2013).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the CAWS from human-mediated transport through this aquatic pathway.

c. Current Abundance and Reproductive Capacity

A MRWG composed of academic, local, state, and federal agencies was established in 2010 by the ACRCC. The ACRCC's mission statement is to create a sustainable Asian carp control program for protecting the integrity and safety of the Great Lakes ecosystem by preventing introduction of a sustainable Asian carp population into the Great Lakes via all viable pathways (ACRCC 2013d). The MRWG has projects focusing on waterway monitoring, removal efforts, Electric Dispersal Barrier System efficacy, gear catch efficacy, and alternative pathway monitoring. Regular electrofishing and netting efforts have consisted of 16,497 person-hours of sampling from the Starved Rock Pool to Lake Michigan resulting in the capture of 283,290 specimens from 2010 to 2012. Removal efforts below the barrier system include contracted commercial fishermen setting over 643.3 mi of nets through 2012 to remove 698.72 tons of bighead, silver and grass carp. Additional workgroup projects include juvenile, larval, and egg sampling;

ichthyoplankton surveys; telemetry studies; hydro-acoustic surveys; and alternative gear development, all of which provide up-to-date information on the status of Asian carp populations and range expansion (ACRCC 2013a).

Based on catch data reported through November 2013, approximately 80 silver carp have been caught in Rock Run Rookery, a backwater in the Dresden Island Pool, approximately 4 mi downstream of the Brandon Road Lock and Dam (ACCRC 2013c). There are no physical barriers between Rock Run Rookery Preserve Lake and the Brandon Road Lock and Dam. It is unknown whether this represents a population increase in this pool since the rookery was not previously sampled.

Silver carp are broadcast spawners that spawn in large aggregates (Kolar et al. 2005). Female egg production is correlated with increased body mass and age. Total fecundity of silver carp from the middle of the Mississippi River in 2003 ranged from 57,283 to 328,538 eggs (Kolar et al. 2005). In 2004 and 2005, fecundity of silver carp ranged from 26,650 to 598,767 and 274,917 to 3,683,150, respectively (Garvey et al. 2006). Eggs are released in the water column and float downstream where they develop in slow-moving waters. Reproduction has not been documented in waters upstream of Marseilles Lock and Dam, which is less than 64 km (40 mi) from the Brandon Road Lock and Dam. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock Pool and none in the Marseilles Pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of silver carp. Controlled harvest and overfishing measures have removed over 1.3 million lbs of Asian carp from the Illinois River between 2010 and 2012 (ACRCC 2013e). However, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The silver carp has been listed as an injurious fish species under the Lacey Act (Federal Register 2011), and federal and state agencies have implemented components of the *National Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States* (Conover et al. 2007). However, ongoing barrier defense monitoring indicates that silver carp remains abundant in the Illinois River (Wyffels et al. 2013) at the current level of harvest, regulation, and management.

Overall, the Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{10}: See T_0. Based on the above information, silver carp seem to have a high reproductive capacity in terms of producing new young per year. Therefore, current populations are expected to increase in abundance. Additionally, future environmental conditions or population genetics have the potential to shift in such a way that would allow a rapid growth and expansion of downstream populations that could lead to increased immigration into the pathway (Kolar et al. 2007); therefore, abundance is expected to increase below the Brandon Road Lock and Dam. This assessment is based on past invasion histories for multiple species (Crooks and Soulé 1996; Williamson 1996; Nico and Fuller 1999; Lockwood et al. 2007); also see the above section *Type of Mobility/Invasion Speed* for more information.

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{25}: See T_{10}. It is expected that, in areas with established populations, natural constraints on population growth would begin to reach a plateau. Thus, reproductive capacity would remain the same, but would no longer result in an exponentially increasing population.

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{50}: See T_{25}.

d. Existing Physical Human/Natural Barriers

T_0: None. There are no barriers to movement of the silver carp from its current position to Brandon Road Lock and Dam. The silver carp has arrived at the pathway.

The Nonstructural Alternative would not affect existing physical human/natural barriers to the pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: The silver carp is established throughout the Illinois River (Nico 2012). Silver carp have been detected as far upstream as Dresden Island Pool. In 2009, one silver carp was observed at the confluence of the Des Plaines River and Chicago Sanitary Ship Canal during routine Asian carp monitoring (ACRCC 2013e).

In addition, there have been multiple positive eDNA detections upstream of electric barriers for silver carp (Jerde et al. 2011). However, there is no evidence to correlate the eDNA detections to an established Asian carp population above the Electric Dispersal Barrier System within the CAWS (ACRCC 2012; Environmental DNA Calibration

Study 2013). Calibration studies are underway to better understand the relationship between positive eDNA and Asian carp populations (ACRCC 2013b).

Below the Brandon Road Pool, silver carp have been detected in the Dresden Island Pool. Based on 2013 catch data reported through November, approximately 80 silver carp have been caught in Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam (ACCRC 2013c). Based on the persistent populations in Marseilles Pool, and the 2013 captures in Rock Run Rookery Preserve Lake approximately 4 mi from Brandon Road Lock and Dam, the silver carp has arrived at the pathway (Brandon Road Lock and Dam).

The Nonstructural Alternative is not expected to affect the silver carp's distance from the aquatic pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Silver carp inhabit freshwater riverine systems and confluent lakes. The species is native to several major Pacific drainages in eastern Asia from the Amur River of far eastern Russia south through much of the eastern half of China to the Pearl River. Native from about 54°N southward to 21°N (Xie & Chen 2001; Froese & Pauly 2004). Most of North America falls within these latitudes. Silver carp are tolerant to a wide array of environmental variables (Kolar et al. 2005).

Silver carp are a pelagic, schooling species (Mukhamedova 1977). Silver carp swims just beneath the water surface (Man & Hodgkiss 1981), where it filter-feeds on phytoplankton. Its diet also includes zooplankton, bacteria, and detritus (Leventer 1987). The water temperature range at which larval silver carp can exist is broad: 16–40°C (60.8–104°F) with optimum temperatures reported as 26–30°C (78.8–86°F). Lethal temperature of larval silver carp was 43.5–46.5°C (110.3–115.7°F). Silver carp is quite tolerant to low water temperatures. In Alberta, Canada, silver carp successfully overwinter in ponds that are near 0°C (32°F) from the beginning of November through the end of April (Kolar et al. 2005).

Silver carp eggs are semi-buoyant; spawning typically occurs in water of sufficient flow to keep the eggs from sinking to the bottom and dying (Laird & Page 1996). Currents bring larvae to slow-flowing backwaters, creeks, reservoirs, or other flooded areas that become nursery areas (Nikolsky 1963).

The Nonstructural Alternative is not expected to affect the suitability of habitat for silver carp.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Silver carp have been detected as far upstream as Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway. The silver carp has arrived at the pathway. Therefore, the probability of arrival remains high.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: Based on 2013 catch data reported through November, approximately 80 silver carp have been caught in Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam (ACCRC 2013c).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{10}: See T_0. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) may reduce Asian carp populations. However, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp to the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{25}: See T_0. It is uncertain whether Asian carp monitoring and harvesting activities in Dresden Island Pool will continue during this time step. The silver carp population in the Dresden Island Pool is expected, at a minimum, to remain at existing levels; however, an increase in population is more likely through time.

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.
T_{50}: See T_0.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Silver carp are active swimmers and can spread upstream naturally. The expansion rate of the silver carp is 33.62 km/yr (20.62 river miles/yr) (Jerde et al. 2010).

Asian carp were first sampled from the Illinois River during the 1990s, and populations have since progressed upstream (Conover et al. 2007; Irons et al. 2009). Monitoring for Asian carp was originally incidental to standard routine sampling by the Illinois Department of Natural Resources (IDNR) and the Illinois Natural History Survey (INHS). Sampling directed toward silver carp in the upper Illinois Waterway began with the USFWS's annual Carp Corral & Round Goby Roundup. Subsequently, USACE adopted a plan specifically to monitor Asian carp downstream of the electric barrier system located near Romeoville, Illinois (ACRCC 2013a). By 2010, the ACRCC was formed to coordinate this intensive monitoring effort, which was expanded to include techniques including but not limited to eDNA, electrofishing, netting, sonar, and telemetry above and below the barrier generally between Lake Michigan and the Peoria Lock and Dam (ACRCC 2010).

In 2009, a confirmed sighting of a silver carp during Asian carp routine monitoring efforts at the confluence of the CSSC and Des Plaines River was reported (ACRCC 2013a); however, the silver carp population in Dresden Island Pool has not progressed upstream. Proposed reasons for this halted progression include limited food resources in the CAWS, hydraulic and hydrologic differences, water quality differences, and a habitat shift from natural to manmade. While these assumptions are still under investigation, the exact cause of the delayed expansion is still unknown but can be compared to other species' invasion histories. Numerous invasive species have long documented cases of extended lag periods in range expansion before an unknown cue (environmental or genetic) sparks another boom in population abundance and/or expanded geographical range (Crooks and Soulé 1996; Williamson 1996; Nico and Fuller 1999; Lockwood et al. 2007). Cudmore et al. (2012) rated the probability of the silver carp entering Lake Michigan as very likely.

Within the Marseilles and Dresden Island pools, reproductively mature silver carp have been captured, but no fertilized eggs or larvae have been found. In 2012, age-1

Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock Pool and none were caught in the Marseilles Pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool (ACRCC 2013a). The nearest collection of Asian carp eggs was found near Henry, Illinois, within the Peoria Pool, five locks downstream of the Electric Dispersal Barrier System. Larval Asian carp were only collected in LaGrange Pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the natural dispersion (i.e., swimming and passive drift) of the silver carp through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Silver carp actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming will likely be the primary mechanism of movement through the CAWS from the Brandon Road Lock and Dam. There is heavy commercial vessel and recreational vessel traffic between the Brandon Road Lock and Dam and the CRCW (USACE 2011a,b) and silver carp eggs and larvae could also be transported upstream of the Electric Dispersal Barrier System by passive entrainment in a ballast tank (no pumping). Heilprin et al. (2013) found water sampled from barge ballast through a single summer to be within published water quality parameters to sustain juvenile and adult Asian carp. Additionally, survivability of larvae and eggs within ballast water was found to be high for periods up to 144 hours, but a very low percentage of larvae survived pump passage when expelling the ballast water (Heilprin et al. 2013).

USCG has established a regulated navigation area around the Electric Dispersal Barrier System that prohibits vessels from transiting the safety zone with any non-potable water on board if they intend to release that water in any form within or on the other side of the safety zone (USCG, 2011).

Other vessel-related transport mechanisms that may reduce the effectiveness of the Electric Dispersal Barrier System are discussed in section 4c, *Existing Physical Human/Natural Barriers*.

The Nonstructural Alternative includes ballast and bilge water discharge prior to entering the aquatic pathway and is expected to address the human-mediated transport of silver carp through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: There are two lock complexes (Brandon Road Lock and Dam and Lockport Lock and Dam) within the pathway. The Brandon Road and Lockport locks and dams are expected to control the upstream movement of fish except during lockages. The complexity of navigating through the lock may slow the upstream passage of Asian carp. There is some leakage around and through the gates (Ackerson 2012) that small larvae could move through, but the larvae would not be able to swim against the current created by the leakage. It is unlikely larvae or other bigger individuals could move through closed lock gates. However, during normal operations, silver carp is assumed to be able to swim through open gates.

In addition, there is an electrical barrier complex referred to as the Electric Dispersal Barrier System. The Electric Dispersal Barrier System, located approximately 5 mi upstream of Lockport Lock and Dam and 31 mi downstream of Lake Michigan via the Chicago Lock, consists of three electrical barriers: Demonstration Barrier, Barrier IIA, and Barrier IIB (USACE 2011c). The barriers consist of steel electrodes mounted across the bed of the CSSC that pulse direct current into the water at a strength, pulse duration, and frequency that repels and stuns fish.

The Demonstration Barrier has been operational since 2002 and was rehabilitated in 2008, but it was designed and built with materials that were not intended for long-term use because of its demonstration status. Barrier IIA was activated in April 2009 at the same settings as the Demonstration Barrier – 1 volt per in., 5 Hertz, and 4 milliseconds. These settings were increased in August 2009 to 2 volts per in., 15 Hertz, and 6.5 milliseconds in response to eDNA monitoring results that suggested Asian carp were closer to the barriers than previously believed. Barrier IIB was activated in April 2011 at Barrier IIA’s settings, and Barrier IIA was placed into warm standby mode. In October 2011, Barrier II's operational settings were changed to 2.3 volts per in., 30 Hertz and 2.5 milliseconds, based on laboratory research suggesting these settings would be more effective in deterring very small fish. USACE continues to study the optimal operating parameters to deter very small fish.

USFWS is evaluating feral fish populations and their behavior within the electric dispersal barrier using a dual-frequency identification SONAR (DIDSON; Sound Metrics Corp., Bellevue, Washington) unit to evaluate fish populations throughout the entire barrier system (Parker 2013). Results of sampling across the entire barrier system during the summer of 2013, using DIDSON equipment, revealed a large accumulation of fish below the active barrier. Some of the fish that were immediately below the active barrier (either Barrier IIA or IIB) were observed persistently probing and challenging the barrier. DIDSON results showed schools of small fish breaching the barrier. Typically, as the schools of fish penetrated deeper into the zone of ultimate field strength, the size of the school contracted into a tight sphere shape and after they breached, the group expanded again. The sizes of the fish that breached the barrier are estimated to range from approximately 2 to 4 in. in length. To help determine the species of fish most likely observed breaching the barrier, the USFWS performed a limited amount of fish sampling within the narrow array on September 27, 2013 and caught gizzard shad (*Dorosoma cepedianum*), threadfin shad (*Dorosoma petenense*), and skipjack herring (*Alosa chrysochloris*) (USACE 2013). Additional studies are underway to further evaluate operational protocols of the barriers and to identify any potential actions that may be employed to address the findings discussed in this paper.

There are several other mechanisms identified for potential barrier bypass. First, fish could swim through the Dispersal Barrier during times of power outage. According to records through March 2013, the Electric Dispersal Barrier System experienced a loss of power to the water for a total of 4 minutes prior to 2011, and a total of 13 minutes in 2012 (USACE unpublished data, Electric Dispersal Barrier System Power Outage Records, April 1, 2013). Work is underway on a redundant power supply for Barrier IIA and similar work is planned for Barrier IIB. In addition, automatic transfer mechanisms were installed on both Barriers IIA and IIB to maintain power in the water in the event of a power loss. Permanent Barrier I, the upgrade for the Demonstration Barrier, will provide yet another redundant electric field of the Dispersal Barrier System during power outages at Barrier IIA or IIB. In addition, the Electric Dispersal Barrier System would be intentionally shut down completely in emergency situations under a man-overboard scenario; however, there have been no man-overboard scenarios near the Dispersal Barriers as far back as the initialization of the Demonstration Barrier in 2002.

Additional potential barrier aquatic bypass vectors are currently under investigation and include reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage, and fish entrainment within barge-induced water currents across the Electric Dispersal Barrier System. Preliminary research at the USACE Engineer Research and Development Center in Vicksburg, Mississippi has shown model fish (soft plastic fish lures) to become entrained at numerous surface junctions, to varying degrees, between inter-barge and tow-barge connections on model tow-barge vessels. Additionally, electrical readings taken within the void created between a raked (sloped) bow and a boxed (flat) stern junction show that steel-hulled barges reduce the in-water electrical parameters in this area (USACE 2013).

The USFWS placed live surrogate species of fish in cages alongside and between junctions of barges in the CSSC to evaluate fish-barge interactions and assess the possibility of the fish becoming incapacitated as they traversed the electrical barrier. Fish were incapacitated as they encountered the electrical field at all barge locations except the void space in the rake to box junction. Several feral fish were observed being entrained in two locations around the barges during trial runs, indicating that wild fish do interact with barge traffic near the barriers. In order to determine whether wild fish would stay in this void without a cage, a follow-up study was conducted with externally tagged fish (tethered to a float). Tethered fish placed in barge junctions breached the barrier to some degree in all but one barge configuration tested. When tethered fish were placed below the barriers as barges approached, some degree of fish breaching the barrier occurred with each configuration tested (USACE 2013). Results from these ongoing studies are preliminary. This combination of increased possibility of entrainment and reduced electrical parameters due to barge traffic is expected to lead to an increased possibility of fish being transported over the barrier system. Vessel speed and tow/barge configuration are considered to be primary factors that affect the possible entrainment and transport of fish through the electric barriers (USACE 2013). Further research is being conducted to mitigate this bypass. While preliminary results from these investigations have shown these bypasses to be viable, the possibility of these bypasses occurring in the field is low at this time due to the low or non-existent population of silver carp in the Lockport Pool.

In 2010, lateral barricades were constructed between the CSSC, the Des Plaines River, and the Illinois and Michigan Canal to control upstream bypass of the Electrical Dispersal

Barrier System during flooding between these adjacent waterways. The Des Plaines River Barricade extends approximately 13 mi and consists of concrete barriers and specially fabricated 0.25-in. wire mesh that allows water to flow through the fence but controls the passage juvenile and adult fish, and the Illinois and Michigan Canal is walled off using a stone berm. Small sections of the Des Plaines barricade fence failed during flooding in 2013; however, monitoring crews immediately responded and monitored for the presence of fish along breaches. Although these efforts indicated that fish (common carp) had moved through the breaches, no Asian carp were caught (Barkowski 2013), and prior monitoring efforts in the Des Plaines River had not captured or observed Asian carp, larval fish, or eggs (ACRCC 2013b).

Under current operational protocols, monitoring for Asian carp occurs downstream and upstream of the Electric Dispersal Barrier System. In the event an individual is found upstream of the Lockport Lock and Dam, protocol dictates the use of intensive electrofishing and netting to find and remove individuals or the use of rotenone to immobilize and kill all fish within the reach of concern (ACRCC 2011). It is expected that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp are above the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{10}: Future operations of the Brandon Road Lock and Dam and Lockport Lock and Dam locks are not expected to change as of the time of this assessment. The Electric Dispersal Barrier System is expected to have additional redundancies in power supply, thereby reducing potential power outage events**.** A new barrier is currently under construction that will upgrade the Demonstration Barrier to permanent status (Barrier I). Barrier I will be capable of producing higher electrical outputs than those of Barrier II and will add an additional narrow array on the downstream boundary. Barrier I is expected to become operational by 2016. Further study of the current Electric Dispersal Barrier System to address electric field shielding by steel-hulled vessels, fish entrainment within barge-induced water currents and very small fish would continue and would inform future operations.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{25}: See T_{10}. Funding for research, monitoring, and removal programs for Asian carp at this time step is highly uncertain. Currently, no funding source has been identified for any one agency to maintain the present level of effort.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{50}: See T_{10} and T_{25}.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: Silver carp inhabit freshwater riverine systems and confluent lakes. It is a pelagic, schooling species (Mukhamedova 1977). Silver carp is a filter-feeder capable of taking large amounts of phytoplankton. Its diet also includes zooplankton, bacteria, and detritus (Leventer 1987). The CAWS is the recipient of treated wastewater from numerous facilities that produces eutrophic conditions suitable for silver carp. Additionally, recent plankton surveys within the CAWS suggest there are relatively high concentrations of zooplankton available as a food resource (MRRP 2012).

Silver carp are tolerant to a wide array of environmental variables (Kolar et al. 2005). They can tolerate long winters under ice cover as well as temperatures higher than 40°C (104°F) (Opuszynski et al. 1989). In the CAWS, mean annual water temperature ranges from 11.3–19.3°C (52.3–66.7°F) (MWRD 2010). Fry and fingerlings can survive in waters with a pH of 5.0 to 9.0, dissolved oxygen 1–28 mg/L, and total alkalinity 88–620 mg/L (Singh et al. 1967; Tripathu 1989). Sections of the CAWS also experiences seasonally low dissolved oxygen (LimnoTech 2010).

Silver carp eggs are semi-buoyant; spawning typically occurs in water of sufficient flow to keep the eggs from sinking to the bottom and dying (Laird & Page 1996). Reported current velocities required for successful spawning range from 0.3 to 3.0 m/s (0.98 to 9.8 ft/s) (Kolar et al. 2005). The pathway from the Brandon Road Lock and Dam to the mouth of Lake Michigan at the CRCW is a slow-moving eutrophic river with a flow of 0.05–0.27 m/s (0.16–0.89 ft/s) (LimnoTech 2010). Currents bring larvae to slow-flowing backwaters, creeks, reservoirs, or other flooded areas that become nursery areas (Nikolsky 1963). The CAWS is a heavily modified channel with little floodplain connection or shallow marshy areas (LimnoTech 2010). Overall, the conditions of the CAWS are not expected to impede movement of silver carp.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for silver carp.

T_{10}: See T_0. Conditions of the CAWS are predicted to change, but not in a way that would affect the likelihood of this species passing through this pathway**.** For example, the Metropolitan Water Reclamation District of Greater Chicago (MWRD) is in the process of evaluating ways to improve the water quality of the CAWS by decreasing the amount of organic materials released into the CAWS. This could potentially decrease the amount of plankton and other food species silver carp would need to survive within the CAWS. In addition, in coordination with the USACE, MWRD will increase capacity of stormwater catchment and retention in adjacent tunnels and reservoirs. This will lead to a lower hydrologic peak during storm events. The environmental conditions within the CAWS may change slightly with the closing of two coal-fired power plants (Midwest Generation’s Fisk and Crawford Plants) in August 2012. These plants used canal water in their cooling process and returned heated water back to the canal. As a result, temperature profiles may be reduced significantly in the near vicinity and to a lesser extent downstream. These actions are not expected to significantly affect the silver carp’s ability to pass through this pathway.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for silver carp.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Silver carp would need to pass through the Brandon Road and Lockport locks and dams, the Electric Dispersal Barrier System and an intermittent sluice gate opening to pass through this pathway. Adults and all life sizes of silver carp would be able to swim through the locks when the lock is in operation; however, the locks may slow passage of silver carp through the pathway.

Based on the sampling and monitoring data, the abundance of individuals within the Lockport Pool below the dispersal barriers is expected to be low to nonexistent at this time step. Since 2007, silver carp were captured in Dresden Island Pool (USGS 2013); however, based on this monitoring data, it appears that few silver carp have expanded past the Brandon Road Lock and Dam. As discussed in *P(arrival)*, *Current and Potential Abundance and Reproductive Capacity*, in 2012, small Asian carp were relatively abundant in the LaGrange Lock and Dam and Peoria Lock and Dam. Only one was caught in the Starved Rock pool. No small age-1 Asian carp were found in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. Adult populations of silver carp are in the Dresden Island Pool (ACRCC 2013a). In an effort to control the Asian carp population downstream of the barrier, fisherman have been contracted to remove these fish from the waterway.

Monitoring and research have found several potential bypass mechanisms for the Electric Barrier System: the man overboard scenario when power to the barrier is intentionally turned off, power outages, bypass during flood events, stunned fish floating through the barrier during reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel-hulled vessels or side wall crevices, small fish passage and fish entrainment within barge-induced water currents across the Electric Dispersal Barrier System. Bypass due to these various mechanisms is not likely, because the nearest detectable population of swimming silver carp is in Dresden Island Pool and the nearest detected eggs, larvae, and fry are farther downstream (ACRCC 2013a). Additionally, research on these bypasses continues and will inform future operations.

In summary, current propagule pressure of this species immediately downstream of the Dispersal Barriers is considered low or nonexistent as measured by monitoring efforts of local, state, and federal agencies. The probability of passage for the silver carp is low for T_0 because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier, then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The low passage rating is in conflict with the Canadian Science Advisory Report (2012) that rates passage through the CAWS as highly likely. However, the Canadian report explicitly did not evaluate the effectiveness of the Electric Dispersal Barrier System.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Silver carp are expected to remain in low populations immediately below the Electric Dispersal Barrier System. Contracted fishermen are expected to continue to improve their fishing techniques to increase their catch rates. The Brandon Road and Lockport locks and dams may also slow silver carp passage.

Federal and state natural resource agencies have monitored the upstream progress of Asian carp populations since their arrival in the IWW in the 1990s (Conover et al. 2007; Irons et al. 2009; ACRCC 2013a). Since 2007, silver carp were captured in Dresden Island Pool (USGS 2013); however, based on current monitoring data, it appears that few silver carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences. In addition, it is expected that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp above the Brandon Road Lock and Dam.

Further refinement of the Electric Dispersal Barrier System operations and redundant power sources are expected to decrease the number and length of potential power outages. Additionally, potential transport vectors across the barriers (e.g., vessel entrainment, insufficient operating parameters for small fish, reverse flow events, crevice shielding of electric field) will continue to be analyzed and future operations would be informed by this analysis.

The probability of passage for the silver carp is low for T_{10} because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at $T_{0.}$ Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not

expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}. Funding for monitoring and removal programs for silver carp at this time step is uncertain because there is not a funding source identified to maintain the present level of management. With the continued expected immigration from the lower pools (Tsehaye et al. 2013), the propagule pressure at the Dispersal Barrier System is expected to increase, and thus increase the potential for an individual to move past the Barriers.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at T_0. Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's medium probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{50}: See T_{10} and T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	High	High	High
Nonstructural Alternative Rating	Medium	High	High	High

Evidence for Uncertainty Rating

T_0: Although there has been an extraordinary effort from multiple agencies to research potential barrier bypass mechanisms, much of that research is currently underway and only preliminary results have been reported. Each risk assessment was conducted qualitatively under the assumption that bypass is possible but did not address the frequency that it might occur under a set of quantitative conditions. It is also uncertain whether additional bypass mechanisms could still be discovered. Although comprehensive monitoring upstream and downstream of the barrier for Asian carp is ongoing, uncertainty still exists concerning whether monitoring has identified the true abundance of silver carp within upper Illinois River and the CAWS.

The Nonstructural Alternative is expected to affect the passage of silver carp through the aquatic pathway by human-mediated transport; however, these measures are not

expected to affect the natural dispersion of silver carp through the aquatic pathway. Overall, the uncertainty remains medium.

T_{10}: See T_0. Although empirical tests are underway to see if the potential transport mechanisms across the barriers are viable, at this time uncertainty increases with time because of unknown events and a general lack of published literature discussing future bypass mechanisms. Additionally, funding for management actions that keep the population of Asian carp in check immediately downstream of the Dispersal Barriers are not specified. The factors contributing to the historic absence of range expansion beyond the Brandon Road Lock and Dam are uncertain and may change.

The Nonstructural Alternative is expected to affect the passage of silver carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Overall, the uncertainty remains high.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 3

BRANDON ROAD LOCK AND DAM TO CALUMET HARBOR

NONSTRUCTURAL ALTERNATIVE: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE PROBABILITY OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Brandon Road Lock and Dam and Calumet Harbor over the next 50 years.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Silver carp are active swimmers. The expansion rate of the silver carp is 33.18 km/yr (20.62 river miles/yr) (Jerde et al. 2010). Populations of silver carp appear to be growing exponentially (Kolar et al. 2005) and abundance peaks quickly following establishment. Silver carp range expansion surpasses that of bighead, because silver can more readily bypass locks (Jerde et al. 2010).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp to the Chicago Area Waterway System (CAWS) by natural dispersion.

b. Human-Mediated Transport through Aquatic Pathways

There is commercial vessel and recreational boat traffic between the current location of silver carp and the Brandon Road Lock and Dam. Silver carp eggs, larvae, and fry have the potential to be spread by ballast water if water quality is suitable, although the viability of this ballast water transport is considered to be low (Heilprin et al. 2013).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the CAWS from human-mediated transport through this aquatic pathway.

c. Current Abundance and Reproductive Capacity

T_0: A MRWG composed of academic, local, state, and federal agencies was established in 2010 by the ACRCC. The ACRCC's mission statement is to create a sustainable Asian carp control program for protecting the integrity and safety of the Great Lakes ecosystem by preventing introduction of a sustainable Asian carp population into the Great Lakes via all viable pathways (ACRCC 2013d). The MRWG has projects focusing on waterway monitoring, removal efforts, Electric Dispersal Barrier System efficacy, gear catch efficacy, and alternative pathway monitoring. Regular electrofishing and netting efforts have consisted of 16,497 person-hours of sampling from the Starved Rock Pool to Lake Michigan resulting in the capture of 283,290 specimens from 2010 to 2012. Removal efforts below the barrier system include contracted commercial fishermen setting over 643.3 mi of nets through 2012 to remove 698.72 tons of bighead, silver, and grass carp. Additional workgroup projects include juvenile, larval, and egg sampling; ichthyoplankton surveys; telemetry studies; hydro-acoustic surveys; and alternative gear development, all of which provide up-to-date information on the status of Asian carp populations and range expansion (ACRCC 2013a).

Based on catch data reported through November 2013, approximately 80 silver carp have been caught in Rock Run Rookery, a backwater in the Dresden Island Pool, approximately 4 mi downstream of the Brandon Road Lock and Dam (ACCRC 2013c). There are no physical barriers between Rock Run Rookery Preserve Lake and the Brandon Road Lock and Dam. It is unknown whether this represents a population increase in this pool since the rookery was not previously sampled.

Silver carp are broadcast spawners that spawn in large aggregates (Kolar et al. 2005). Female egg production is correlated with increased body mass and age. Total fecundity of silver carp from the middle of the Mississippi River in 2003 ranged from 57,283 to 328,538 eggs (Kolar et al. 2005). In 2004 and 2005, fecundity of silver carp ranged from 26,650 to 598,767 and 274,917 to 3,683,150, respectively (Garvey et al. 2006). Eggs are released in the water column and float downstream where they develop in slow-moving waters. Reproduction has not been documented in waters upstream of Marseilles Lock and Dam, which is less than 64 km (40 mi) from the Brandon Road Lock and Dam. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock Pool and none in the Marseilles Pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of silver carp. Controlled harvest and overfishing measures have removed over 1.3 million lbs of Asian carp from the Illinois River between 2010 and 2012 (ACRCC 2013e). However, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The silver carp has been listed as an injurious fish species under the Lacey Act (Federal Register 2011), and federal and state agencies have implemented components of the *National Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States* (Conover et al. 2007). However, ongoing barrier defense monitoring indicates that silver carp remains abundant in the Illinois River (Wyffels et al. 2013) at the current level of harvest, regulation, and management.

Overall, the Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{10}: See T_0. Based on the above information, silver carp seem to have a high reproductive capacity in terms of producing new young per year. Therefore, current populations are expected to increase in abundance. Additionally, future environmental conditions or population genetics have the potential to shift in such a way that would allow a rapid growth and expansion of downstream populations that could lead to increased immigration into the pathway (Kolar et al. 2007); therefore, abundance is expected to increase below the Brandon Road Lock and Dam. This assessment is based on past invasion histories for multiple species (Crooks and Soulé 1996; Williamson 1996;

Nico and Fuller 1999; Lockwood et al. 2007); also see the above section *Type of Mobility/Invasion Speed* for more information.

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{25}: See T_{10}. It is expected that, in areas with established populations, natural constraints on population growth would begin to reach a plateau. Thus, reproductive capacity would remain the same, but would no longer result in an exponentially increasing population.

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{50}: See T_{25}.

d. Existing Physical Human/Natural Barriers

T_0: None. There are no barriers to movement of the silver carp from its current position to Brandon Road Lock and Dam. The silver carp has arrived at the pathway.

The Nonstructural Alternative would not affect existing physical human/natural barriers to the pathway.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: The silver carp is established throughout the Illinois River (USGS 2012). Silver carp have been detected as far upstream as Dresden Island Pool. In 2009, one silver carp was observed at the confluence of the Des Plaines River and Chicago Sanitary Ship Canal during routine Asian carp monitoring (ACRCC 2013e).

In addition, there have been multiple positive eDNA detections upstream of electric barriers for silver carp (Jerde et al. 2011). However, there is no evidence to correlate the eDNA detections to an established Asian carp population above the Electric Dispersal Barrier System within the CAWS (ACRCC 2012; Environmental DNA Calibration Study 2013). Calibration studies are underway to better understand the relationship between positive eDNA and Asian carp populations (ACRCC 2013b).

Below the Brandon Road Pool, silver carp have been detected in the Dresden Island Pool. Based on 2013 catch data reported through November, approximately 80 silver carp have been caught in Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam (ACCRC 2013c). Based on the persistent populations in

Marseilles Pool, and the 2013 captures in Rock Run Rookery Preserve Lake approximately 4 mi from Brandon Road Lock and Dam, the silver carp has arrived at the pathway (Brandon Road Lock and Dam).

The Nonstructural Alternative is not expected to affect the silver carp's distance from the aquatic pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Silver carp inhabit freshwater riverine systems and confluent lakes. The species is native to several major Pacific drainages in eastern Asia from the Amur River of far eastern Russia south through much of the eastern half of China to the Pearl River. The species is native from about 54°N southward to 21°N (Xie & Chen 2001; Froese & Pauly 2004). Most of North America falls within these latitudes. Silver carp are tolerant to a wide array of environmental variables (Kolar et al. 2005).

Silver carp are pelagic, schooling species (Mukhamedova 1977). Silver carp swim just beneath the water surface (Man & Hodgkiss 1981), where it filter-feeds on phytoplankton. Its diet also includes zooplankton, bacteria, and detritus (Leventer 1987). The water temperature range at which larval silver carp can exist is broad: 16–40°C (60.8–104°F), with optimum temperatures reported as 26–30°C (87.8–86°F). Lethal temperature of larval silver carp was 43.5–46.5°C (110.3–115.7°F). Silver carp is quite tolerant to low water temperatures. In Alberta, Canada, silver carp successfully overwinter in ponds that are near 0°C (32°F) from the beginning of November through the end of April (Kolar et al. 2005).

Silver carp eggs are semi-buoyant; spawning typically occurs in water of sufficient flow to keep the eggs from sinking to the bottom and dying (Laird & Page 1996). Currents bring larvae to slow-flowing backwaters, creeks, reservoirs, or other flooded areas that become nursery areas (Nikolsky 1963).

The Nonstructural Alternative is not expected to affect the suitability of habitat for silver carp.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Silver carp have been detected as far upstream as Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of the silver carp to the aquatic pathway. The silver carp has arrived at the pathway. Therefore, the probability of arrival remains high.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: Based on 2013 catch data reported through November, approximately 80 silver carp have been caught in Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam (ACCRC 2013c).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{10}: See T_0. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) may reduce Asian carp populations. However, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp to the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{25}: See T_0. It is uncertain whether Asian carp monitoring and harvesting activities in Dresden Island Pool will continue during this time step. The silver carp population in the Dresden Island Pool is expected, at a minimum, to remain at existing levels; however, an increase in population is more likely through time.

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{50}: See T_0.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Silver carp are active swimmers and can spread upstream naturally. The expansion rate of the silver carp is 33.62 km/yr (20.62 river miles/yr) (Jerde et al. 2010).

Asian carp were first sampled from the Illinois River during the 1990s, and populations have since progressed upstream (Conover et al. 2007; Irons et al. 2009). Monitoring for Asian carp was originally incidental to standard routine sampling by the Illinois Department of Natural Resources (IDNR) and the Illinois Natural History Survey (INHS). Sampling directed toward silver carp in the upper Illinois Waterway began with the USFWS's annual Carp Corral & Round Goby Roundup. Subsequently, USACE adopted a plan specifically to monitor Asian carp downstream of the electric barrier system located near Romeoville, Illinois (ACRCC 2013a). By 2010, the ACRCC was formed to coordinate this intensive monitoring effort which was expanded to include techniques including but not limited to eDNA, electrofishing, netting, sonar, and telemetry above and below the barrier generally between Lake Michigan and the Peoria Lock and Dam (ACRCC 2010).

In 2009, a confirmed sighting of a silver carp during Asian carp routine monitoring efforts at the confluence of the CSSC and Des Plaines River was reported (ACRCC 2013a); however, the silver carp population in Dresden Island Pool has not progressed upstream. Proposed reasons for this halted progression include limited food resources in the CAWS, hydraulic and hydrologic differences, water quality differences, and a habitat shift from natural to manmade. While these assumptions are still under investigation, the exact cause of the delayed expansion is still unknown but can be compared to other species' invasion histories. Numerous invasive species have long documented cases of extended lag periods in range expansion before an unknown cue (environmental or genetic) sparks another boom in population abundance and/or expanded geographical range (Crooks and Soulé 1996; Williamson 1996; Nico and Fuller 1999; Lockwood et al. 2007). Cudmore et al. (2012) rated the probability of the silver carp entering Lake Michigan as very likely.

Within the Marseilles and Dresden Island pools, reproductively mature silver carp have been captured, but no fertilized eggs or larvae have been found. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock Pool and none were caught in the Marseilles Pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool (ACRCC 2013a).

The nearest collection of Asian carp eggs were found near Henry, Illinois, within the Peoria Pool, five locks downstream of the Electric Dispersal Barrier System. Larval Asian carp were only collected in LaGrange Pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the natural dispersion (i.e., swimming and passive drift) of the silver carp through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Silver carp actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming will likely be the primary mechanism of movement through the CAWS from the Brandon Road Lock and Dam. There is heavy commercial vessel and recreational vessel traffic between the Brandon Road Lock and Dam and the Chicago River (USACE 2011a,b). Silver carp eggs and larvae could also be transported upstream of the Electric Dispersal Barrier System by passive entrainment in a ballast tank (no pumping). Heilprin et al. (2013) found water sampled from barge ballast through a single summer to be within published water quality parameters to sustain juvenile and adult Asian carp. Additionally, survivability of larvae and eggs within ballast water was found to be high for periods up to 144 hours, but a very low percentage of larvae survived pump passage when expelling the ballast water (Heilprin et al. 2013).

USCG has established a regulated navigation area around the Electric Dispersal Barrier System that prohibits vessels from transiting the safety zone with any non-potable water on board if they intend to release that water in any form within, or on the other side of the safety zone (USCG 2011).

Other vessel-related transport mechanisms that may reduce the effectiveness of the Electric Dispersal Barrier System are discussed in section 4c, *Existing Physical Human/Natural Barriers*.

The Nonstructural Alternative includes ballast and bilge water discharge prior to entering the aquatic pathway and is expected to address the human-mediated transport of silver carp through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: There are two lock complexes (Brandon Road Lock and Dam and Lockport Lock and Dam) within the pathway.

The Brandon Road and Lockport locks and dams are expected to control the upstream movement of fish except during lockages. The complexity of navigating through the lock may slow the upstream passage of Asian carp. There is some leakage around and through the gates (Ackerson 2012) that small larvae could move through, but the larvae would not be able to swim against the current created by the leakage. It is unlikely larvae or other bigger individuals could move through closed lock gates. However, during normal operations, silver carp is assumed to be able to swim through open gates.

In addition, there is an electrical barrier complex referred to as the Electric Dispersal Barrier System. The Electric Dispersal Barrier System, located approximately 5 mi upstream of Lockport Lock and Dam and 31 mi downstream of Lake Michigan via the Chicago Lock, consists of three electrical barriers: Demonstration Barrier, Barrier IIA, and Barrier IIB (USACE 2011c). The barriers consist of steel electrodes mounted across the bed of the CSSC that pulse direct current into the water at a strength, pulse duration, and frequency that repels and stuns fish.

The Demonstration Barrier has been operational since 2002 and was rehabilitated in 2008, but it was designed and built with materials that were not intended for long-term use because of its demonstration status. Barrier IIA was activated in April 2009 at the same settings as the Demonstration Barrier – 1 volt per in., 5 Hertz, and 4 milliseconds. These settings were increased in August 2009 to 2 volts per in., 15 Hertz, and 6.5 milliseconds in response to eDNA monitoring results that suggested Asian carp were closer to the barriers than previously believed. Barrier IIB was activated in April 2011 at Barrier IIA's settings, and Barrier IIA was placed into warm standby mode. In October 2011, Barrier II's operational settings were changed to 2.3 volts per in., 30 Hertz and 2.5 milliseconds, based on laboratory research suggesting these settings would be more effective in deterring very small fish. USACE continues to study the optimal operating parameters to deter very small fish.

USFWS is evaluating feral fish populations and their behavior within the electric dispersal barrier using a dual-frequency identification SONAR (DIDSON; Sound Metrics Corp., Bellevue, Washington) unit to evaluate fish populations throughout the entire barrier system (Parker 2013). Results of sampling across the entire barrier system during the summer of 2013, using DIDSON equipment, revealed a large accumulation of fish below the active barrier. Some of the fish that were immediately below the active barrier (either Barrier IIA or IIB) were observed persistently probing and challenging the barrier. DIDSON results showed schools of small fish breaching the barrier. Typically, as the schools of fish penetrated deeper into the zone of ultimate field strength, the size of the school contracted into a tight sphere shape and after they breached, the group expanded again. The sizes of the fish that breached the barrier are estimated to range from approximately 2 to 4 in. in length. To help determine the species of fish most likely observed breaching the barrier, the USFWS performed a limited amount of fish sampling within the narrow array on September 27, 2013, and caught gizzard shad (*Dorosoma cepedianum*), threadfin shad (*Dorosoma petenense*), and skipjack herring (*Alosa chrysochloris*) (USACE 2013). Additional studies are underway to further evaluate operational protocols of the barriers and to identify any potential actions that may be employed to address the findings discussed in this paper.

There are several other mechanisms identified for potential barrier bypass. First, fish could swim through the Dispersal Barrier during times of power outage. According to records through March 2013, the Electric Dispersal Barrier System experienced a loss of power to the water for a total of 4 minutes prior to 2011, and a total of 13 minutes in 2012 (USACE unpublished data, Electric Dispersal Barrier System Power Outage Records, April 1, 2013). Work is underway on a redundant power supply for Barrier IIA and similar work is planned for Barrier IIB. In addition, automatic transfer mechanisms were installed on both Barriers IIA and IIB to maintain power in the water in the event of a power loss. Permanent Barrier I, the upgrade for the Demonstration Barrier, will provide yet another redundant electric field of the Dispersal Barrier System during power outages at Barrier IIA or IIB. In addition, the Electric Dispersal Barrier System would be intentionally shut down completely in emergency situations under a man-overboard scenario; however, there have been no man-overboard scenarios near the Dispersal Barriers as far back as the initialization of the Demonstration Barrier in 2002.

Additional potential barrier aquatic bypass vectors are currently under investigation and include reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel-hulled vessels or side wall crevices, small fish passage and fish entrainment within barge-induced water currents across the Electric Dispersal Barrier System. Preliminary research at the USACE Engineer Research and Development Center in Vicksburg, Mississippi, has shown model fish (soft plastic fish lures) to become entrained at numerous surface junctions, to varying degrees, between inter-barge and tow-barge connections on model tow-barge vessels. Additionally, electrical readings taken within the void created between a raked (sloped) bow and a boxed (flat) stern junction show that steel-hulled barges reduce the in-water electrical parameters in this area (USACE 2013).

The USFWS placed live surrogate species of fish in cages alongside and between junctions of barges in the CSSC to evaluate fish-barge interactions and assess the possibility of the fish becoming incapacitated as they traversed the electrical barrier. Fish were incapacitated as they encountered the electrical field at all barge locations except the void space in the rake to box junction. Several feral fish were observed being entrained in two locations around the barges during trial runs, indicating that wild fish do interact with barge traffic near the barriers. In order to determine whether wild fish would stay in this void without a cage, a follow-up study was conducted with externally tagged fish (tethered to a float). Tethered fish placed in barge junctions breached the barrier to some degree in all but one barge configuration tested. When tethered fish were placed below the barriers as barges approached, some degree of fish breaching the barrier occurred with each configuration tested (USACE 2013). Results from these ongoing studies are preliminary. This combination of increased possibility of entrainment and reduced electrical parameters due to barge traffic is expected to lead to an increased possibility of fish being transported over the barrier system. Vessel speed and tow/barge configuration are considered to be primary factors that affect the possible entrainment and transport of fish through the electric barriers (USACE 2013). Further research is being conducted to mitigate this bypass. While preliminary results from these investigations have shown these bypasses to be viable, the possibility of these bypasses occurring in the field is low at this time due to the low or non-existent population of silver carp in the Lockport Pool.

In 2010, lateral barricades were constructed between the CSSC, the Des Plaines River, and the Illinois and Michigan Canal to control upstream bypass of the Electrical Dispersal Barrier System during flooding between these adjacent waterways. The Des Plaines River Barricade extends approximately 13 mi and consists of concrete barriers and specially fabricated 0.25-in. wire mesh that allows water to flow through the fence but controls the passage juvenile and adult fish, and the Illinois and Michigan Canal is walled off using a stone berm. Small sections of the Des Plaines barricade fence failed during flooding in 2013; however, monitoring crews immediately responded and monitored for the presence of fish along breaches. Although these efforts indicated that fish (common carp) had moved through the breaches, no Asian carp were caught (Barkowski 2013), and prior monitoring efforts in the Des Plaines River had not captured or observed Asian carp, larval fish, or eggs (ACRCC 2013b).

Under current operational protocols, monitoring for Asian carp occurs downstream and upstream of the Electric Dispersal Barrier System. In the event an individual is found upstream of the Lockport Lock and Dam, protocol dictates the use of intensive electrofishing and netting to find and remove individuals or the use of rotenone to immobilize and kill all fish within the reach of concern (ACRCC 2011). It is expected that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp are above the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{10}: Future operations of the Brandon Road Lock and Dam and Lockport Lock and Dam locks are not expected to change as of the time of this assessment. The Electric Dispersal Barrier System is expected to have additional redundancies in power supply, thereby reducing potential power outage events. A new barrier is currently under construction that will upgrade the Demonstration Barrier to permanent status (Barrier I). Barrier I will be capable of producing higher electrical outputs than those of Barrier II and will add an additional narrow array on the downstream boundary. Barrier I is expected to become operational by 2016. Further study of the current Electric Dispersal Barrier System to address electric field shielding by steel-hulled vessels, fish entrainment within barge-induced water currents and very small fish would continue and would inform future operations.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{25}: See T_{10}. Funding for research, monitoring and removal programs for Asian carp at this time step is highly uncertain. Currently, no funding source has been identified for any one agency to maintain the present level of effort.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{50}: See T_{10} and T_{25}.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Silver carp inhabit freshwater riverine systems and confluent lakes. It is a pelagic, schooling species (Mukhamedova 1977). Silver carp is a filter feeder capable of taking large amounts of phytoplankton. Its diet also includes zooplankton, bacteria, and detritus (Leventer 1987). The CAWS is the recipient of treated wastewater from numerous facilities that produces eutrophic conditions suitable for silver carp. Additionally, recent plankton surveys within the CAWS suggest there are relatively high concentrations of zooplankton available as a food resource (MRRP 2012).

Silver carp are tolerant to a wide array of environmental variables (Kolar et al. 2005). They can tolerate long winters under ice cover as well as temperatures higher than 40°C (104°F) (Opuszynski et al. 1989). In the CAWS, mean annual water temperature ranges from 11.3 to 19.3°C (52.3 to 66.7°F) (MWRD 2010). Fry and fingerlings can survive in waters with a pH of 5.0 to 9.0, dissolved oxygen 1–28 mg/L, and total alkalinity 88–620 mg/L (Singh et al. 1967). Sections of the CAWS also experience seasonally low dissolved oxygen (LimnoTech 2010).

Silver carp eggs are semi-buoyant; spawning typically occurs in water of sufficient flow to keep the eggs from sinking to the bottom and dying (Laird & Page 1996). Reported current velocities required for successful spawning range from 0.3 to 3.0 m/s (0.98 to 9.8 ft/s) (Kolar et al. 2005). The pathway from the Brandon Road Lock and Dam to the mouth of Lake Michigan at Calumet Harbor is a slow-moving eutrophic river with a flow of 0.05–0.27 m/s (0.16–0.89 ft/s) (LimnoTech 2010). Currents bring larvae to slow-flowing backwaters, creeks, reservoirs, or other flooded areas that become nursery areas (Nikolsky 1963). The CAWS is a heavily modified channel with little floodplain connection or shallow marshy areas (LimnoTech 2010). Overall, the conditions of the CAWS are not expected to impede movement of silver carp.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for silver carp.

T_{10}: See T_0. Conditions of the CAWS are predicted to change, but not in a way that would affect the likelihood of this species passing through this pathway**.** For example, the Metropolitan Water Reclamation District of Greater Chicago (MWRD) is in the process of evaluating ways to improve the water quality of the CAWS by decreasing the amount of organic materials released into the CAWS. This could potentially decrease the amount of plankton and other food species silver carp would need to survive within the CAWS. In addition, in coordination with the USACE, MWRD will increase capacity of stormwater catchment and retention in adjacent tunnels and reservoirs; this will lead to a lower hydrologic peak during storm events. The environmental conditions with the CAWS may change slightly with the closing of two coal-fired power plants (Midwest Generation’s Fisk and Crawford Plants) in August 2012. These plants used canal water in their cooling process and returned heated water back to the canal. As a result, temperature profiles may be reduced significantly in the near vicinity and to a lesser extent downstream. These actions are not expected to significantly affect the silver carp’s ability to pass through this pathway.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for silver carp.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Silver carp would need to pass through the Brandon Road and Lockport locks and dams, the Electric Dispersal Barrier System, and an intermittent sluice gate opening to pass through this pathway. Adults and all life sizes of silver carp would be able to swim through the locks when the lock is in operation; however, the locks may slow passage of silver carp through the pathway.

Based on the sampling and monitoring data, the abundance of individuals within the Lockport Pool below the dispersal barriers is expected to be low to nonexistent at this time step. Since 2007, silver carp were captured in Dresden Island Pool (USGS 2013); however, based on this monitoring data, it appears that few silver carp have expanded past the Brandon Road Lock and Dam. As discussed in *P(arrival)*, *Current and Potential Abundance and Reproductive Capacity*, in 2012, small Asian carp were relatively abundant in the LaGrange Lock and Dam and Peoria Lock and Dam. Only one was caught in the Starved Rock pool. No small age-1 Asian carp were found in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. Adult populations of silver carp are in the Dresden Island Pool (ACRCC 2013a). In an effort to control the Asian carp population downstream of the barrier, fisherman have been contracted to remove these fish from the waterway.

Monitoring and research have found several potential bypass mechanisms for the Electric Barrier System: the man overboard scenario when power to the barrier is intentionally turned off, power outages, bypass during flood events, stunned fish floating through the barrier during reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel-hulled vessels or side wall crevices, small fish passage and fish entrainment within barge-induced water currents across the Electric Dispersal Barrier System. Bypass due to these various mechanisms is not likely, because the nearest detectable population of swimming silver carp is in Dresden Island Pool and the nearest detected eggs, larvae, and fry are farther downstream (ACRCC 2013a). Additionally, research on these bypasses continues and will inform future operations.

In summary, current propagule pressure of this species immediately downstream of the Dispersal Barriers is considered low or nonexistent as measured by monitoring efforts of local, state, and federal agencies. The probability of passage for the silver carp is low for T_0 because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier, then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The low passage rating is in conflict with the Canadian Science Advisory Report (2012) that rates passage through the CAWS as highly likely. However, the Canadian report explicitly did not evaluate the effectiveness of the Electric Dispersal Barrier System.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at T_0. Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Silver carp are expected to remain in low populations immediately below the Electric Dispersal Barrier System. Contracted fishermen are expected to continue to improve their fishing techniques to increase their catch rates. The Brandon Road and Lockport locks and dams may also slow silver carp passage.

Federal and state natural resource agencies have monitored the upstream progress of Asian carp populations since their arrival in the IWW in the 1990s (Conover et al. 2007; Irons et al. 2009; ACRCC 2013a). Since 2007, silver carp were captured in Dresden Island Pool (USGS 2013); however, based on current monitoring data, it appears that few silver carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences. In addition, it is expected that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp above the Brandon Road Lock and Dam.

Further refinement of the Electric Dispersal Barrier System operations and redundant power sources are expected to decrease the number and length of potential power outages. Additionally, potential transport vectors across the barriers (e.g., vessel entrainment, insufficient operating parameters for small fish, reverse flow events, crevice shielding of electric field) will continue to be analyzed and future operations would be informed by this analysis.

The probability of passage for the silver carp is low for T_{10} because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at T_0. Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}. Funding for monitoring and removal programs for silver carp at this time step is uncertain because there is not a funding source identified to maintain the present level of management. With the continued expected immigration from the lower pools (Tsehaye et al. 2013), the propagule pressure at the Dispersal Barrier System is expected to increase, and thus increase the potential for an individual to move past the barriers. The probability of passage increases to medium.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at T_0. Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's medium probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{50}: See T_{10} and T_{25}.

Uncertainty of Passages

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	High	High	High
Nonstructural Alternative Rating	Medium	High	High	High

Evidence for Uncertainty Rating

T_0: Although there has been an extraordinary effort from multiple agencies to research potential barrier bypass mechanisms, much of that research is currently underway and only preliminary results have been reported. Each risk assessment was conducted qualitatively under the assumption that bypass is possible but did not address the frequency that it might occur under a set of quantitative conditions. It is also uncertain whether additional bypass mechanisms could still be discovered. Although comprehensive monitoring upstream and downstream of the barrier for Asian carp is ongoing, uncertainty still exists concerning whether monitoring has identified the true abundance of silver carp within upper Illinois River and the CAWS.

The Nonstructural Alternative is expected to affect the passage of silver carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Overall, the uncertainty remains medium.

T_{10}: See T_0. Although empirical tests are underway to see if the potential transport mechanisms across the barriers are viable, at this time uncertainty increases with time because of unknown events and a general lack of published literature discussing future bypass mechanisms. Additionally, funding for management actions that keep the populations of Asian carp in check immediately downstream of the Dispersal Barriers are not specified beyond 2016. The factors contributing to the historic absence of range expansion beyond the Brandon Road Lock and Dam are uncertain and may change.

The Nonstructural Alternative is expected to affect the passage of silver carp through the aquatic pathway by human-mediated transport; however, these measures are not

expected to affect the natural dispersion of silver carp through the aquatic pathway. Overall, the uncertainty remains high.
T_{25}: See T_{10}.
T_{50}: See T_{10}.

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. **P(spreads) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 4

BRANDON ROAD LOCK AND DAM TO INDIANA HARBOR

NONSTRUCTURAL ALTERNATIVE: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE PROBABILITY OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are anticipated that would reduce or eliminate the hydrologic connection between Indiana Harbor and the Brandon Road Lock and Dam over the next 50 years.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Silver carp are active swimmers. The expansion rate of the silver carp is 33.18 km/yr (20.62 river miles/yr) (Jerde et al. 2010). Populations of silver carp appear to be growing exponentially (Kolar et al. 2005) and abundance peaks quickly following establishment. Silver carp range expansion surpasses that of bighead, because silver can more readily bypass locks (Jerde et al. 2010).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp to the Chicago Area Waterway System (CAWS) by natural dispersion.

b. Human-Mediated Transport through Aquatic Pathways

There is commercial vessel and recreational boat traffic between the current location of silver carp and the Brandon Road Lock and Dam. Silver carp eggs, larvae, and fry have the potential to be spread by ballast water if water quality is suitable, although the viability of this ballast water transport is considered to be low (Heilprin et al. 2013).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the CAWS from human-mediated transport through this aquatic pathway.

c. Current Abundance and Reproductive Capacity

T_0: A MRWG composed of academic, local, state and federal agencies was established in 2010 by the ACRCC. The ACRCC's mission statement is to create a sustainable Asian carp control program for protecting the integrity and safety of the Great Lakes ecosystem by preventing introduction of a sustainable Asian carp population into the Great Lakes via all viable pathways (ACRCC 2013d). The MRWG has projects focusing on waterway monitoring, removal efforts, Electric Dispersal Barrier System efficacy, gear catch efficacy, and alternative pathway monitoring. Regular electrofishing and netting efforts have consisted of 16,497 person-hours of sampling from the Starved Rock Pool to Lake Michigan resulting in the capture of 283,290 specimens from 2010 to 2012. Removal efforts below the barrier system include contracted commercial fishermen setting over 643.3 mi of nets through 2012 to remove 698.72 tons of bighead, silver and grass carp. Additional workgroup projects include juvenile, larval, and egg sampling; ichthyoplankton surveys; telemetry studies; hydro-acoustic surveys; and alternative gear development, all of which provide up-to-date information on the status of Asian carp populations and range expansion (ACRCC 2013a).

Based on catch data reported through November 2013, approximately 80 silver carp have been caught in Rock Run Rookery, a backwater in the Dresden Island Pool, approximately 4 mi downstream of the Brandon Road Lock and Dam (ACCRC 2013c). There are no physical barriers between Rock Run Rookery Preserve Lake and the Brandon Road Lock and Dam. It is unknown whether this represents a population increase in this pool since the rookery was not previously sampled.

Silver carp are broadcast spawners that spawn in large aggregates (Kolar et al. 2005). Female egg production is correlated with increased body mass and age. Total fecundity of silver carp from the middle of the Mississippi River in 2003 ranged from 57,283 to 328,538 eggs (Kolar et al. 2005). In 2004 and 2005, fecundity of silver carp ranged from 26,650 to 598,767 and 274,917 to 3,683,150, respectively (Garvey et al. 2006). Eggs are released in the water column and float downstream where they develop in slow-moving waters. Reproduction has not been documented in waters upstream of Marseilles Lock and Dam. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock Pool and none in the Marseilles Pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of silver carp. Controlled harvest and overfishing measures have removed over 1.3 million lbs of Asian carp from the Illinois River between 2010 and 2012 (ACRCC 2013e). However, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The silver carp has been listed as an injurious fish species under the Lacey Act (Federal Register 2011), and federal and state agencies have implemented components of the *National Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States* (Conover et al. 2007). However, ongoing barrier defense monitoring indicates that silver carp remains abundant in the Illinois River (Wyffels et al. 2013) at the current level of harvest, regulation, and management.

Overall, the Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{10}: See T_0. Based on the above information, silver carp seem to have a high reproductive capacity in terms of producing new young per year. Therefore, current populations are expected to increase in abundance. Additionally, future environmental conditions or population genetics have the potential to shift in such a way that would allow a rapid growth and expansion of downstream populations that could lead to increased immigration into the pathway (Kolar et al. 2007); therefore, abundance is expected to increase below the Brandon Road Lock and Dam. This assessment is based on past invasion histories for multiple species (Crooks and Soulé 1996; Williamson 1996; Nico and Fuller 1999; Lockwood et al. 2007); also see the above section *Type of Mobility/Invasion Speed* for more information.

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{25}: See T_{10}. It is expected that, in areas with established populations, natural constraints on population growth would begin to reach a plateau. Thus, reproductive capacity would remain the same, but would no longer result in an exponentially increasing population.

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{50}: See T_{25}.

d. Existing Physical Human/Natural Barriers

T_0: None. There are no barriers to movements of the silver carp from its current position to Brandon Road Lock and Dam. The silver carp has arrived at the pathway.

The Nonstructural Alternative would not affect existing physical human/natural barriers to the pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: The silver carp is established throughout the Illinois River (USGS 2012). Silver carp have been detected as far upstream as Dresden Island Pool. In 2009, one silver carp was observed at the confluence of the Des Plaines River and Chicago Sanitary Ship Canal during routine Asian carp monitoring (ACRCC 2013e).

In addition, there have been multiple positive eDNA detections upstream of electric barriers for silver carp (Jerde et al. 2011). However, there is no evidence to correlate the eDNA detections to an established Asian carp population above the Electric Dispersal Barrier System within the CAWS (ACRCC 2012; Environmental DNA Calibration Study 2013). Calibration studies are underway to better understand the relationship between positive eDNA and Asian carp populations (ACRCC 2013b).

Below the Brandon Road Pool, silver carp have been detected in the Dresden Island Pool. Based on 2013 catch data reported through November, approximately 80 silver carp have been caught in Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam (ACCRC 2013c). Based on the persistent populations in Marseilles Pool, and the 2013 captures in Rock Run Rookery Preserve Lake approximately 4 mi from Brandon Road Lock and Dam, the silver carp has arrived at the pathway (Brandon Road Lock and Dam).

The Nonstructural Alternative is not expected to affect the silver carp's distance from the aquatic pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Silver carp inhabit freshwater riverine systems and confluent lakes. The species is native to several major Pacific drainages in eastern Asia, from the Amur River in far eastern Russia south through much of the eastern half of China to the Pearl River. The species is native from about 54°N southward to 21°N (Xie & Chen 2001; Froese & Pauly 2004). Most of North America falls within these latitudes. Silver carp are tolerant to a wide array of environmental variables (Kolar et al. 2005).

Silver carp are pelagic, schooling species (Mukhamedova 1977). Silver carp swims just beneath the water surface (Man & Hodgkiss 1981), where it filter-feeds on phytoplankton. Its diet also includes zooplankton, bacteria, and detritus (Leventer 1987). The water temperature range at which larval silver carp can exist is broad: 16–40°C (60.8–104°F) with optimum temperatures reported as 26–30°C (78.8–86°F). Lethal temperature of larval silver carp was 43.5–46.5°C (110.3–115.7°F) (Kolar et al. 2005). Silver carp is quite tolerant to low water temperatures. In Alberta, Canada, silver carp successfully overwinter in ponds that are near 0°C (32°F) from the beginning of November through the end of April (Kolar et al. 2005).

Silver carp eggs are semi-buoyant; spawning typically occurs in water of sufficient flow to keep the eggs from sinking to the bottom and dying (Laird & Page 1996). Currents bring larvae to slow-flowing backwaters, creeks, reservoirs, or other flooded areas that become nursery areas (Nikolsky 1963).

The Nonstructural Alternative is not expected to affect the suitability of habitat for silver carp.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Silver carp have been detected as far upstream as Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of the silver carp to the aquatic pathway. The silver carp has arrived at the pathway. Therefore, the probability of arrival remains high.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: Based on 2013 catch data reported through November, approximately 80 silver carp have been caught in Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam (ACCRC 2013c).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{10}: See T_0. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) may reduce Asian carp populations. However, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp to the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{25}: See T_{10}. It is uncertain whether Asian carp monitoring and harvesting activities in Dresden Island Pool will continue during this time step. The silver carp population in the Dresden Island Pool is expected, at a minimum, to remain at existing levels; however, an increase in population is more likely through time.

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{50}: See T_{25}.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Silver carp are active swimmers and can spread upstream naturally. The expansion rate of the silver carp is 33.62 km/yr (20.62 river miles/yr) (Jerde et al. 2010). Asian carp were first sampled from the Illinois River during the 1990's and populations have since progressed upstream (Conover et al. 2007; Irons et al. 2009). Monitoring for Asian carp was originally incidental to standard routine sampling by the IDNR and the INHS. Sampling directed toward silver carp in the upper Illinois Waterway began with the USFWS's annual Carp Corral & Round Goby Roundup. Subsequently, USACE adopted a plan specifically to monitor Asian carp downstream of the electric barrier system located near Romeoville, Illinois (ACRCC 2013a). By 2010, the ACRCC was formed to coordinate this intensive monitoring effort which was expanded to include techniques including but not limited to eDNA, electrofishing, netting, sonar, and telemetry above and below the barrier generally between Lake Michigan and the Peoria Lock and Dam (ACRCC 2010).

In 2009, a confirmed sighting of a silver carp during Asian carp routine monitoring efforts at the confluence of the CSSC and Des Plaines River was reported (ACRCC 2013a); however, the silver carp population in Dresden Island Pool has not progressed upstream. Proposed reasons for this halted progression include limited food resources in the CAWS, hydraulic and hydrologic differences, water quality differences, and a habitat shift from natural to manmade. While these assumptions are still under investigation, the exact cause of the delayed expansion is still unknown but can be compared to other species' invasion histories. Numerous invasive species have long documented cases of extended lag periods in range expansion before an unknown cue (environmental or genetic) sparks another boom in population abundance and/or expanded geographical range (Crooks and Soulé 1996; Williamson 1996; Nico and Fuller 1999; Lockwood et al. 2007). Cudmore et al. (2012) rated the probability of the silver carp entering Lake Michigan as very likely.

Within the Marseilles and Dresden Island pools, reproductively mature silver carp have been captured but no fertilized eggs or larvae have been found. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock Pool and none were caught in the Marseilles Pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. The nearest collection of Asian carp eggs was found near Henry, Illinois, within the Peoria Pool, five locks downstream of the Electric Dispersal Barrier System. Larval Asian carp were only collected in LaGrange Pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the natural dispersion (i.e., swimming and passive drift) of the silver carp through the aquatic pathway.

b. *Human-Mediated Transport through Aquatic Pathways*

Vessel traffic to Indiana Harbor is lakewide (USACE 2011a,b). Silver carp actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming will likely be the primary mechanism of movement through the CAWS from the Brandon Road Lock and Dam. There is heavy commercial vessel and recreational vessel traffic between the Brandon Road Lock and Dam and the Little Calumet River, but this traffic does not go to Indiana Harbor (USACE 2011a,b). Silver carp eggs and larvae could also be transported upstream of the Electric Dispersal Barrier System by passive entrainment in a ballast tank (no pumping). Heilprin et al. (2013) found water sampled from barge ballast through a single summer to be within published water quality parameters to sustain juvenile and adult Asian carp. Additionally, survivability of larvae and eggs within ballast water was found to be high for periods up to 144 hours, but a very low percentage of larvae survived pump passage when expelling the ballast water (Heilprin et al. 2013).

USCG has established a regulated navigation area around the Electric Dispersal Barrier System that prohibits vessels from transiting the safety zone with any non-potable water on board if they intend to release that water in any form within, or on the other side of the safety zone (USCG 2011).

Other vessel-related transport mechanisms that may reduce the effectiveness of the Electric Dispersal Barrier System are discussed in section 4c, *Existing Physical Human/Natural Barriers*.

The Nonstructural Alternative includes ballast and bilge water discharge prior to entering the aquatic pathway and is expected to address the human-mediated transport of silver carp through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: There are two lock complexes (Brandon Road Lock and Dam and Lockport Lock and Dam) within the pathway. The Brandon Road and Lockport locks and dams are expected to control the upstream movement of fish except during lockages. The complexity of navigating through the lock may slow the upstream passage of Asian carp. There is some leakage around and through the gates (Ackerson 2012) that small larvae could move through, but the larvae would not be able to swim against the current created by the leakage. It is unlikely larvae or other bigger individuals could move through closed lock gates. However, during normal operations, silver carp is assumed to be able to swim through open gates.

In addition, there is an electrical barrier complex referred to as the Electric Dispersal Barrier System. The Electric Dispersal Barrier System, located approximately 5 mi upstream of Lockport Lock and Dam and 31 mi downstream of Lake Michigan via the Chicago Lock, consists of three electrical barriers: Demonstration Barrier, Barrier IIA, and Barrier IIB (USACE 2011c). The barriers consist of steel electrodes mounted across the bed of the CSSC that pulse direct current into the water at a strength, pulse duration, and frequency that repels and stuns fish.

The Demonstration Barrier has been operational since 2002 and was rehabilitated in 2008, but it was designed and built with materials that were not intended for long-term use because of its demonstration status. Barrier IIA was activated in April 2009 at the same settings as the Demonstration Barrier – 1 volt per in., 5 Hertz, and 4 milliseconds. These settings were increased in August 2009 to 2 volts per in., 15 Hertz, and 6.5 milliseconds in response to eDNA monitoring results that suggested Asian carp were closer to the barriers than previously believed. Barrier IIB was activated in April 2011 at Barrier IIA’s settings, and Barrier IIA was placed into warm standby mode. In October 2011, Barrier II's operational settings were changed to 2.3 volts per in., 30 Hertz and 2.5 milliseconds, based on laboratory research suggesting these settings would be more effective in deterring very small fish. USACE continues to study the optimal operating parameters to deter very small fish.

USFWS is evaluating feral fish populations and their behavior within the electric dispersal barrier using a dual-frequency identification SONAR (DIDSON; Sound Metrics Corp., Bellevue, Washington) unit to evaluate fish populations throughout the entire barrier system (Parker 2013). Results of sampling across the entire barrier system during the summer of 2013, using DIDSON equipment, revealed a large accumulation of fish below the active barrier. Some of the fish that were immediately below the active barrier (either Barrier IIA or IIB) were observed persistently probing and challenging the barrier. DIDSON results showed schools of small fish breaching the barrier. Typically, as the schools of fish penetrated deeper into the zone of ultimate field strength, the size of the school contracted into a tight sphere shape and after they breached, the group expanded again. The sizes of the fish that breached the barrier are estimated to range from approximately 2 to 4 in. in length. To help determine the species of fish that we most likely observed breaching the barrier, the USFWS performed a limited amount of fish sampling within the narrow array on September 27, 2013, and caught gizzard shad (*Dorosoma cepedianum*), threadfin shad (*Dorosoma petenense*), and skipjack herring (*Alosa chrysochloris*) (USACE 2013). Additional studies are underway to further evaluate operational protocols of the barriers and to identify any potential actions that may be employed to address the findings discussed in this paper.

There are several other mechanisms identified for potential barrier bypass. First, fish could swim through the Dispersal Barrier during times of power outage. According to records through March 2013, the Electric Dispersal Barrier System experienced a loss of power to the water for a total of 4 minutes prior to 2011, and a total of 13 minutes in 2012 (USACE unpublished data, Electric Dispersal Barrier System Power Outage Records, April 1, 2013). Work is underway on a redundant power supply for Barrier IIA and similar work is planned for Barrier IIB. In addition, automatic transfer mechanisms were installed on both Barriers IIA and IIB to maintain power in the water in the event of a power loss. Permanent Barrier I, the upgrade for the Demonstration Barrier, will provide yet another redundant electric field of the Dispersal Barrier System during power outages at Barrier IIA or IIB. In addition, the Electric Dispersal Barrier System would be intentionally shut down completely in emergency situations under a man-overboard scenario; however, there have been no man-overboard scenarios near the Dispersal Barriers as far back as the initialization of the Demonstration Barrier in 2002.

Additional potential barrier aquatic bypass vectors are currently under investigation and include reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage, and fish entrainment within barge-induced water currents across the Electric Dispersal Barrier System. Preliminary research at the USACE Engineer Research and Development Center in Vicksburg, Mississippi, has shown model fish (soft plastic fish lures) to become entrained at numerous surface junctions, to varying degrees, between inter-barge and tow-barge connections on model tow-barge vessels. Additionally, electrical readings taken within the void created between a raked (sloped) bow and a boxed (flat) stern junction show that steel-hulled barges reduce the in-water electrical parameters in this area (USACE 2013).

The USFWS placed live surrogate species of fish in cages alongside and between junctions of barges in the CSSC to evaluate fish-barge interactions and assess the possibility of the fish becoming incapacitated as they traversed the electrical barrier. Fish were incapacitated as they encountered the electrical field at all barge locations except the void space in the rake to box junction. Several feral fish were observed being entrained in two locations around the barges during trial runs, indicating that wild fish do interact with barge traffic near the barriers. In order to determine whether wild fish would stay in this void without a cage, a follow-up study was conducted with externally tagged fish (tethered to a float). Tethered fish placed in barge junctions breached the barrier to some degree in all but one barge configuration tested. When tethered fish were placed below the barriers as barges approached, some degree of fish breaching the barrier occurred with each configuration tested (USACE 2013). Results from these ongoing studies are preliminary. This combination of increased possibility of entrainment and reduced electrical parameters due to barge traffic is expected to lead to an increased possibility of fish being transported over the barrier system. Vessel speed and tow/barge configuration are considered to be primary factors that affect the possible entrainment and transport of fish through the electric barriers (USACE 2013). Further research is being conducted to mitigate this bypass. While preliminary results from these investigations have shown these bypasses to be viable, the possibility of these bypasses occurring in the field is low at this time due to the low or non-existent population of silver carp in the Lockport Pool.

In 2010, lateral barricades were constructed between the CSSC, the Des Plaines River, and the Illinois and Michigan Canal to control upstream bypass of the Electrical Dispersal Barrier System during flooding between these adjacent waterways. The Des Plaines River Barricade extends approximately 13 mi and consists of concrete barriers and specially fabricated 0.25-in. wire mesh that allows water to flow through the fence but controls the passage juvenile and adult fish, and the Illinois and Michigan Canal is walled off using a stone berm. Small sections of the Des Plaines barricade fence failed during flooding in 2013; however, monitoring crews immediately responded and monitored for the presence of fish along breaches. Although these efforts indicated that fish (common carp) had moved through the breaches, no Asian carp were caught (Barkowski 2013), and prior monitoring efforts in the Des Plaines River had not captured or observed Asian carp, larval fish, or eggs (ACRCC 2013b).

Under current operational protocols, monitoring for Asian carp occurs downstream and upstream of the Electric Dispersal Barrier System. In the event an individual is found upstream of the Lockport Lock and Dam, protocol dictates the use of intensive electrofishing and netting to find and remove individuals or the use of rotenone to immobilize and kill all fish within the reach of concern (ACRCC 2011). It is expected that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp are above the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{10}: See T_0. Future operations of the Brandon Road Lock and Dam and Lockport Lock and Dam locks are not expected to change as of the time of this assessment. The Electric Dispersal Barrier System is expected to have additional redundancies in power supply, thereby reducing potential power outage events**.** A new barrier is currently under construction that will upgrade the Demo Barrier to permanent status (Barrier I). Barrier I will be capable of producing higher electrical outputs than those of Barrier II and will add an additional narrow array on the downstream boundary. Barrier I is expected to become operational by 2016. Further study of the current Electric Dispersal Barrier System to address electric field shielding by steel-hulled vessels, fish entrainment within barge-induced water currents and very small fish would continue and would inform future operations.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{25}: See T_{10}. Funding for research, monitoring and removal programs for Asian carp at this time step is highly uncertain. Currently, no funding source has been identified for any one agency to maintain the present level of effort.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{50}: See T_{10} and T_{25}.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Silver carp inhabits freshwater riverine systems and confluent lakes. It is a pelagic, schooling species (Mukhamedova 1977). Silver carp is a filter-feeder capable of taking large amounts of phytoplankton. Its diet also includes zooplankton, bacteria, and detritus (Leventer 1987). The CAWS is the recipient of treated wastewater from numerous facilities that produces eutrophic conditions suitable for silver carp.

Additionally, recent plankton surveys within the CAWS suggest there are relatively high concentrations of zooplankton available as a food resource (MRRP 2012).

Silver carp are tolerant to a wide array of environmental variables (Kolar et al. 2005). They can tolerate long winters under ice cover as well as temperatures higher than 40°C (104°F) (Opuszynski et al. 1989). In the CAWS, the mean annual water temperature ranges from 11.3 to 19.3°C (52.3 to 66.7°F) (MWRD 2010). Fry and fingerlings can survive in waters with a pH of 5.0 to 9.0, dissolved oxygen 1–28 mg/L, and total alkalinity 88–620 mg/L (Singh et al. 1967). Sections of the CAWS also experience seasonally low dissolved oxygen (LimnoTech 2010).

Silver carp eggs are semi-buoyant; spawning typically occurs in water of sufficient flow to keep the eggs from sinking to the bottom and dying (Laird & Page 1996). Reported current velocities required for successful spawning range from 0.3 to 3.0 m/s (0.98 to 9.8 ft/s) (Kolar et al. 2005). The pathway from the Brandon Road Lock and Dam to the mouth of Lake Michigan at Indiana Harbor is a slow-moving eutrophic river with a flow of 0.05–0.27 m/s (0.16–0.89 ft/s) (LimnoTech 2010). Currents bring larvae to slow-flowing backwaters, creeks, reservoirs, or other flooded areas that become nursery areas (Nikolsky 1963). The CAWS is a heavily modified channel with little floodplain connection or shallow marshy areas (LimnoTech 2010). Overall, the conditions of the CAWS are not expected to impede movement of silver carp.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for silver carp.

T_{10}: See T_0. Conditions of the CAWS are predicted to change but not in a way that would affect the likelihood of this species passing through this pathway**.** For example, the Metropolitan Water Reclamation District of Greater Chicago (MWRD) is in the process of evaluating ways to improve the water quality of the CAWS by decreasing the amount of organic materials released into the CAWS. This could potentially decrease the amount of plankton and other food species silver carp would need to survive within the CAWS. In addition, in coordination with the USACE, MWRD will increase capacity of stormwater catchment and retention in adjacent tunnels and reservoirs; this will lead to a lower hydrologic peak during storm events. The environmental conditions within the CAWS may change slightly with the closing of two coal-fired power plants (Midwest Generation's Fisk and Crawford Plants) in August 2012. These plants used canal water in their cooling process and returned heated water back to the canal. As a result, temperature profiles may be reduced significantly in the near vicinity and to a lesser extent downstream. These actions are not expected to significantly affect the silver carp's ability to pass through this pathway.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for silver carp.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Silver carp would need to pass through the Brandon Road and Lockport locks and dams, the Electric Dispersal Barrier System and an intermittent sluice gate opening to pass through this pathway. Adults and all life sizes of silver carp would be able to swim through the locks when the lock is in operation; however, the locks may slow passage of silver carp through the pathway.

Based on the sampling and monitoring data, the abundance of individuals within the Lockport Pool below the dispersal barriers is expected to be low to nonexistent at this time step. Since 2007, silver carp were captured in Dresden Island Pool (USGS 2013); however, based on this monitoring data, it appears that few silver carp have expanded past the Brandon Road Lock and Dam. As discussed in *P(arrival)*, *Current and Potential Abundance and Reproductive Capacity*, in 2012, small Asian carp were relatively abundant in the LaGrange Lock and Dam and Peoria Lock and Dam. Only one was caught in the Starved Rock pool. No small age-1 Asian carp were found in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. Adult populations of silver carp are in the Dresden Island Pool (ACRCC 2013a). In an effort to control the Asian carp population downstream of the barrier, fisherman have been contracted to remove these fish from the waterway.

Monitoring and research have found several potential bypass mechanisms for the Electric Barrier System: the man overboard scenario when power to the barrier is intentionally turned off, power outages, bypass during flood events, stunned fish floating through the barrier during reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel-hulled vessels or side wall crevices, small fish passage and fish entrainment within barge-induced water currents across the Electric Dispersal Barrier System. Bypass due to these various mechanisms is not likely, because the nearest detectable population of swimming silver carp is in Dresden Island Pool and the nearest detected eggs, larvae, and fry are farther downstream (ACRCC 2013a). Additionally, research on these bypasses continues and will inform future operations.

In summary, current propagule pressure of this species immediately downstream of the Dispersal Barriers is considered low or nonexistent as measured by monitoring efforts of local, state, and federal agencies. The probability of passage for the silver carp is low for T_0 because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier, then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The low passage rating is in conflict with the Canadian Science Advisory Report (2012) that rates passage through the CAWS as highly likely. However, the Canadian report explicitly did not evaluate the effectiveness of the Electric Dispersal Barrier System.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at T_0. Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Silver carp are expected to remain in low populations immediately below the Electric Dispersal Barrier System. Contracted fishermen are expected to continue to improve their fishing techniques to increase their catch rates. The Brandon Road and Lockport locks and dams may also slow silver carp passage.

Federal and state natural resource agencies have monitored the upstream progress of Asian carp populations since their arrival in the IWW in the 1990s (Conover et al. 2007; Irons et al. 2009; ACRCC 2013a). Since 2007, silver carp were captured in Dresden Island Pool (USGS 2013); however, based on current monitoring data, it appears that few silver carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences. In addition, it is expected that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp above the Brandon Road Lock and Dam.

Further refinement of the Electric Dispersal Barrier System operations and redundant power sources are expected to decrease the number and length of potential power outages. Additionally, potential transport vectors across the barriers (e.g., vessel entrainment, insufficient operating parameters for small fish, reverse flow events, crevice shielding of electric field) will continue to be analyzed and future operations would be informed by this analysis.

The probability of passage for the silver carp is low for T_{10} because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at T_0. Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not

expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}. Funding for monitoring and removal programs for silver carp at this time step is uncertain because there is not a funding source identified to maintain the present level of management. With the continued expected immigration from the lower pools (Tsehaye et al. 2013), the propagule pressure at the Dispersal Barrier System is expected to increase, and thus increase the potential for an individual to move past the barriers.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at T_0. Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's medium probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{50}: See T_{10} and T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	High	High	High
Nonstructural Alternative Rating	Medium	High	High	High

Evidence for Uncertainty Rating

T_0: Although there has been an extraordinary effort from multiple agencies to research potential barrier bypass mechanisms, much of that research is currently underway and only preliminary results have been reported. Each risk assessment was conducted qualitatively under the assumption that bypass is possible but did not address the frequency that it might occur under a set of quantitative conditions. It is also uncertain whether additional bypass mechanisms could still be discovered. Although comprehensive monitoring upstream and downstream of the barrier for Asian carp is ongoing, uncertainty still exists concerning whether monitoring has identified the true abundance of silver carp within upper Illinois River and the CAWS.

The Nonstructural Alternative is expected to affect the passage of silver carp through the aquatic pathway by human-mediated transport; however, these measures are not

expected to affect the natural dispersion of silver carp through the aquatic pathway. Overall, the uncertainty remains medium.

T_{10}: See T_0. Although empirical tests are underway to see if the potential transport mechanisms across the barriers are viable, at this time uncertainty increases with time because of unknown events and a general lack of published literature discussing future bypass mechanisms. Additionally, funding for management actions that keep the populations of Asian carp in check immediately downstream of the Dispersal Barriers are not specified. The factors contributing to the historic absence of range expansion beyond the Brandon Road Lock and Dam are uncertain and may change.

The Nonstructural Alternative is expected to affect the passage of silver carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Overall, the uncertainty remains high.

T_{25}: See T_0.

T_{50}: See T_0.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 5

BRANDON ROAD LOCK AND DAM TO BURNS SMALL BOAT HARBOR (BSBH)

NONSTRUCTURAL ALTERNATIVE: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	Low	Medium	Low	High	Medium	High	Medium	High
P(colonizes)	High	Medium	High	Medium	High	Medium	High	Medium
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE PROBABILITY OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are anticipated that would reduce or eliminate the hydrologic connection between the BSBH and the Brandon Road Lock and Dam over the next 50 years.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Silver carp are active swimmers. The expansion rate of the silver carp is 33.18 km/yr (20.62 river miles/yr) (Jerde et al. 2010). Populations of silver carp appear to be growing exponentially (Kolar et al. 2005) and abundance peaks quickly following establishment. Silver carp range expansion surpasses that of bighead, because silver can more readily bypass locks (Jerde et al. 2010).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp to the Chicago Area Waterway System (CAWS) by natural dispersion.

b. Human-Mediated Transport through Aquatic Pathways

There is commercial vessel and recreational boat traffic between the current location of silver carp and the Brandon Road Lock and Dam. Silver carp eggs, larvae, and fry have the potential to be spread by ballast water if water quality is suitable, although the viability of this ballast water transport is considered to be low (Heilprin et al. 2013).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the CAWS from human-mediated transport through this aquatic pathway.

c. Current Abundance and Reproductive Capacity

T_0: A MRWG composed of academic, local, state and federal agencies was established in 2010 by the ACRCC. The ACRCC's mission statement is to create a sustainable Asian carp control program for protecting the integrity and safety of the Great Lakes ecosystem by preventing introduction of a sustainable Asian carp population into the Great Lakes via all viable pathways (ACRCC 2013d). The MRWG has projects focusing on waterway monitoring, removal efforts, Electric Dispersal Barrier System efficacy, gear catch efficacy, and alternative pathway monitoring. Regular electrofishing and netting efforts have consisted of 16,497 person-hours of sampling from the Starved Rock Pool to Lake Michigan resulting in the capture of 283,290 specimens from 2010 to 2012. Removal efforts below the barrier system include contracted commercial fishermen setting over 643.3 mi of nets through 2012 to remove 698.72 tons of bighead, silver, and grass carp. Additional workgroup projects include juvenile, larval, and egg sampling; ichthyoplankton surveys; telemetry studies; hydro-acoustic surveys; and alternative gear development, all of which provide up-to-date information on the status of Asian carp populations and range expansion (ACRCC 2013a).

Based on catch data reported through November 2013, approximately 80 silver carp have been caught in Rock Run Rookery, a backwater in the Dresden Island Pool, approximately 4 mi downstream of the Brandon Road Lock and Dam (ACCRC 2013c). There are no physical barriers between Rock Run Rookery Preserve Lake and the Brandon Road Lock and Dam. It is unknown whether this represents a population increase in this pool since the rookery was not previously sampled.

Silver carp are broadcast spawners that spawn in large aggregates (Kolar et al. 2005). Female egg production is correlated with increased body mass and age. Total fecundity of silver carp from the middle of the Mississippi River in 2003 ranged from 57,283 to 328,538 eggs (Kolar et al. 2005). In 2004 and 2005, fecundity of silver carp ranged from 26,650 to 598,767 and 274,917 to 3,683,150, respectively (Garvey et al. 2006). Eggs are released in the water column and float downstream where they develop in slow-moving waters. Reproduction has not been documented in waters upstream of Marseilles Lock and Dam. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock Pool and none in the Marseilles Pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of silver carp. Controlled harvest and overfishing measures have removed over 1.3 million lbs of Asian carp from the Illinois River between 2010 and 2012 (ACRCC 2013e). However, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The silver carp has been listed as an injurious fish species under the Lacey Act (Federal Register 2011), and federal and state agencies have implemented components of the *National Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States* (Conover et al. 2007). However, ongoing barrier defense monitoring indicates that silver carp remains abundant in the Illinois River (Wyffels et al. 2013) at the current level of harvest, regulation, and management.

Overall, the Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are not expected to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{10}: See T_0. Based on the above information, silver carp seems to have a high reproductive capacity in terms of producing new young per year. Therefore, current populations are expected to increase in abundance. Additionally, future environmental conditions or population genetics have the potential to shift in such a way that would allow a rapid growth and expansion of downstream populations that could lead to increased immigration into the pathway (Kolar et al. 2007); therefore, abundance is expected to increase below the Brandon Road Lock and Dam. This assessment is based on past invasion histories for multiple species (Crooks and Soulé 1996; Williamson, 1996; Nico and Fuller 1999; Lockwood et al. 2007); also see the above section *Type of Mobility/Invasion Speed* for more information.

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{25}: See T_{10}. It is expected that, in areas with established populations, natural constraints on population growth would begin to reach a plateau. Thus, reproductive capacity would remain the same, but would no longer result in an exponentially increasing population.

The Nonstructural Alternative is not expected to affect the abundance or reproductive capacity of this species. Although monitoring and overfishing techniques are expected to improve, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

T_{50}: See T_{25}.

d. Existing Physical Human/Natural Barriers

T_0: None. There are no barriers to movements of the silver carp from its current position to Brandon Road Lock and Dam. The silver carp has arrived at the pathway.

The Nonstructural Alternative would not affect existing physical human/natural barriers to the pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: The silver carp is established throughout the Illinois River (Nico 2012). Silver carp have been detected as far upstream as Dresden Island Pool. In 2009, one silver carp was observed at the confluence of the Des Plaines River and Chicago Sanitary Ship Canal during routine Asian carp monitoring (ACRCC 2013e).

In addition, there have been multiple positive eDNA detections upstream of electric barriers for silver carp (Jerde et al. 2011). However, there is no evidence to correlate the eDNA detections to an established Asian carp population above the Electric Dispersal Barrier System within the CAWS (ACRCC 2012; Environmental DNA Calibration Study 2013). Calibration studies are underway to better understand the relationship between positive eDNA and Asian carp populations (ACRCC 2013b).

Below the Brandon Road Pool, silver carp have been detected in the Dresden Island Pool. Based on 2013 catch data reported through November, approximately 80 silver carp have been caught in Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam (ACCRC 2013c). Based on the persistent populations in Marseilles Pool, and the 2013 captures in Rock Run Rookery Preserve Lake approximately 4 mi from Brandon Road Lock and Dam, the silver carp has arrived at the pathway (Brandon Road Lock and Dam).

The Nonstructural Alternative is not expected to affect the silver carp's distance from the aquatic pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Silver carp inhabit freshwater riverine systems and confluent lakes. The species is native to several major Pacific drainages in eastern Asia, from the Amur River of far eastern Russia south through much of the eastern half of China to the Pearl River. This species is native from about 54°N southward to 21°N (Xie & Chen 2001; Froese & Pauly 2004). Most of North America falls within these latitudes. Silver carp are tolerant to a wide array of environmental variables (Kolar et al. 2005).

Silver carp are pelagic, schooling species (Mukhamedova 1977). Silver carp swim just beneath the water surface (Man & Hodgkiss 1981), where it filter-feeds on phytoplankton. Its diet also includes zooplankton, bacteria, and detritus (Leventer 1987). The water temperature range at which larval silver carp can exist is broad, 16–40°C (60.8–104°F), with optimum temperatures reported as 26–30°C (87.8–86°F). Lethal temperature of larval silver carp was 43.5–46.5°C (110.3–115.7°F) (Kolar et al. 2005). Silver carp is quite tolerant to low water temperatures. In Alberta, Canada, silver carp successfully overwinters in ponds that are near 0°C (32°F) from the beginning of November through the end of April (Kolar et al. 2005).

Silver carp eggs are semi-buoyant; spawning typically occurs in water of sufficient flow to keep the eggs from sinking to the bottom and dying (Laird & Page 1996). Currents bring larvae to slow-flowing backwaters, creeks, reservoirs, or other flooded areas that become nursery areas (Nikolsky 1963).

The Nonstructural Alternative is not expected to affect the suitability of habitat for silver carp.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Silver carp have been detected as far upstream as Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway. The silver carp has arrived at the pathway. Therefore, the probability of arrival remains high.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: Based on 2013 catch data reported through November, approximately 80 silver carp have been caught in Rock Run Rookery, approximately 4 mi downstream of Brandon Road Lock and Dam (ACCRC 2013c).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{10}: See T_0. Existing data indicate that harvesting in the upper pools (above Starved Rock Lock and Dam) may reduce Asian carp populations. However, the removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{25}: See T_{10}. It is uncertain whether Asian carp monitoring and harvesting activities in Dresden Island Pool will continue during this time step. The silver carp population in the Dresden Island Pool is expected, at a minimum, to remain at existing levels; however an increase in population is more likely through time.

The Nonstructural Alternative is not expected to affect the arrival of the silver carp at the aquatic pathway because the species has already arrived at the aquatic pathway. Therefore, uncertainty remains none.

T_{50}: See T_{25}.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Silver carp are active swimmers and can spread upstream naturally. The expansion rate of the silver carp is 33.62 km/yr (20.62 river miles/yr) (Jerde et al. 2010).

Asian carp were first sampled from the Illinois River during the 1990s, and populations have since progressed upstream (Conover et al. 2007; Irons et al. 2009). Monitoring for Asian carp was originally incidental to standard routine sampling by the IDNR and the INHS. Sampling directed toward silver carp in the upper Illinois Waterway began with the USFWS's annual Carp Corral & Round Goby Roundup. Subsequently, USACE adopted a plan specifically to monitor Asian carp downstream of the electric barrier system located near Romeoville, Illinois (ACRCC 2013a). By 2010, the ACRCC was formed to coordinate this intensive monitoring effort, which was expanded to include techniques including but not limited to eDNA, electrofishing, netting, sonar, and telemetry above and below the barrier generally between Lake Michigan and the Peoria Lock and Dam (ACRCC 2010).

In 2009, a confirmed sighting of a silver carp during Asian carp routine monitoring efforts at the confluence of the CSSC and Des Plaines River was reported (ACRCC 2013a); however, the silver carp population in Dresden Island Pool has not progressed upstream. Proposed reasons for this halted progression include limited food resources in the CAWS, hydraulic and hydrologic differences, water quality differences, and a habitat shift from natural to manmade. While these assumptions are still under investigation, the exact cause of the delayed expansion is still unknown but can be compared to other species' invasion histories. Numerous invasive species have long documented cases of extended lag periods in range expansion before an unknown cue (environmental or genetic) sparks another boom in population abundance and/or expanded geographical range (Crooks and Soulé 1996; Williamson 1996; Nico and Fuller 1999; Lockwood et al. 2007). Cudmore et al. (2012) rated the probability of the silver carp entering Lake Michigan as very likely.

Within the Marseilles and Dresden Island pools, reproductively mature silver carp have been captured, but no fertilized eggs or larvae have been found. In 2012, age-1 Asian carp were relatively abundant in the LaGrange and Peoria pools, but only one was caught in the Starved Rock Pool and none were caught in the Marseilles Pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. The nearest collection of Asian carp eggs was found near Henry, Illinois, within the Peoria Pool, five locks downstream of the Electric Dispersal Barrier System. Larval Asian carp were only collected in LaGrange Pool (ACRCC 2013a).

The Nonstructural Alternative is not expected to affect the natural dispersion (i.e., swimming and passive drift) of the silver carp through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Silver carp actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming will likely be the primary mechanism of movement through the CAWS from the Brandon Road Lock and Dam. There is heavy commercial vessel and recreational vessel traffic between the Brandon Road Lock and Dam and the Chicago River (USACE 2011a,b). Silver carp eggs and larvae could also be transported upstream of the Electric Dispersal Barrier System by passive entrainment in a ballast tank (no pumping). Heilprin et al. (2013) found water sampled from barge ballast through a single summer to be within published water quality parameters to sustain juvenile and adult Asian carp. Additionally, survivability of larvae and eggs within ballast water was found to be high for periods up to 144 hours, but a very low percentage of larvae survived pump passage when expelling the ballast water (Heilprin et al. 2013).

USCG has established a regulated navigation area around the Electric Dispersal Barrier System that prohibits vessels from transiting the safety zone with any non-potable water on board if they intend to release that water in any form within or on the other side of the safety zone (USCG 2011).

Other vessel-related transport mechanisms that may reduce the effectiveness of the Electric Dispersal Barrier System are discussed in section 4c, *Existing Physical Human/Natural Barriers*.

The Nonstructural Alternative includes ballast and bilge water discharge prior to entering the aquatic pathway and is expected to address the human-mediated transport of silver carp through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: The Brandon Road and Lockport locks and dams are expected to control the upstream movement of fish except during lockages. The complexity of navigating through the lock may slow the upstream passage of Asian carp. There is some leakage around and through the gates (Ackerson 2012) that small larvae could move through, but the larvae would not be able to swim against the current created by the leakage. It is unlikely larvae or other bigger individuals could move through closed lock gates. However, during normal operations, silver carp is assumed to be able to swim through open gates.

In addition, there is an electrical barrier complex referred to as the Electric Dispersal Barrier System. The Electric Dispersal Barrier System, located approximately 5 mi upstream of Lockport Lock and Dam and 31 mi downstream of Lake Michigan via the

Chicago Lock, consists of three electrical barriers: Demonstration Barrier, Barrier IIA, and Barrier IIB (USACE 2011c). The barriers consist of steel electrodes mounted across the bed of the CSSC that pulse direct current into the water at a strength, pulse duration, and frequency that repels and stuns fish.

The Demonstration Barrier has been operational since 2002 and was rehabilitated in 2008, but it was designed and built with materials that were not intended for long-term use because of its demonstration status. Barrier IIA was activated in April 2009 at the same settings as the Demonstration Barrier – 1 volt per in., 5 Hertz, and 4 milliseconds. These settings were increased in August 2009 to 2 volts per in., 15 Hertz, and 6.5 milliseconds in response to eDNA monitoring results that suggested Asian carp were closer to the barriers than previously believed. Barrier IIB was activated in April 2011 at Barrier IIA's settings, and Barrier IIA was placed into warm standby mode. In October 2011, Barrier II's operational settings were changed to 2.3 volts per in., 30 Hertz and 2.5 milliseconds, based on laboratory research suggesting these settings would be more effective in deterring very small fish. USACE continues to study the optimal operating parameters to deter very small fish.

USFWS is evaluating feral fish populations and their behavior within the electric dispersal barrier using a dual-frequency identification SONAR (DIDSON; Sound Metrics Corp., Bellevue, Washington) unit to evaluate fish populations throughout the entire barrier system (Parker 2013). Results of sampling across the entire barrier system during the summer of 2013, using DIDSON equipment, revealed a large accumulation of fish below the active barrier. Some of the fish that were immediately below the active barrier (either Barrier IIA or IIB) were observed persistently probing and challenging the barrier. DIDSON results showed schools of small fish breaching the barrier. Typically, as the schools of fish penetrated deeper into the zone of ultimate field strength, the size of the school contracted into a tight sphere shape and after they breached, the group expanded again. The sizes of the fish that breached the barrier are estimated to range from approximately 2 to 4 in. in length. To help determine the species of fish most likely observed breaching the barrier, the USFWS performed a limited amount of fish sampling within the narrow array on September 27, 2013 and caught gizzard shad (*Dorosoma cepedianum*), threadfin shad (*Dorosoma petenense*), and skipjack herring (*Alosa chrysochloris*) (USACE 2013). Additional studies are underway to further evaluate operational protocols of the barriers and to identify any potential actions that may be employed to address the findings discussed in this paper.

There are several other mechanisms identified for potential barrier bypass. First, fish could swim through the Dispersal Barrier during times of power outage. According to records through March 2013, the Electric Dispersal Barrier System experienced a loss of power to the water for a total of 4 minutes prior to 2011, and a total of 13 minutes in 2012 (USACE unpublished data, Electric Dispersal Barrier System Power Outage Records, April 1, 2013). Work is underway on a redundant power supply for Barrier IIA and similar work is planned for Barrier IIB. In addition, automatic transfer mechanisms were installed on both Barriers IIA and IIB to maintain power in the water in the event of a power loss. Permanent Barrier I, the upgrade for the Demonstration Barrier, will provide yet another redundant electric field of the Dispersal Barrier System during power outages at Barrier IIA or IIB. In addition, the Electric Dispersal Barrier System would be intentionally shut down completely in emergency situations under a man-overboard scenario; however, there have been no man-overboard scenarios near the Dispersal Barriers as far back as the initialization of the Demonstration Barrier in 2002.

Additional potential barrier aquatic bypass vectors are currently under investigation and include reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage and fish entrainment within barge-induced water currents across the Electric Dispersal Barrier System. Preliminary research at the USACE Engineer Research and Development Center in Vicksburg, Mississippi, has shown model fish (soft plastic fish lures) to become entrained at numerous surface junctions, to varying degrees, between inter-barge and tow-barge connections on model tow-barge vessels. Additionally, electrical readings taken within the void created between a raked (sloped) bow and a boxed (flat) stern junction show that steel-hulled barges reduce the in-water electrical parameters in this area (USACE 2013).

The USFWS placed live surrogate species of fish in cages alongside and between junctions of barges in the CSSC to evaluate fish-barge interactions and assess the possibility of the fish becoming incapacitated as they traversed the electrical barrier. Fish were incapacitated as they encountered the electrical field at all barge locations except the void space in the rake to box junction. Several feral fish were observed being entrained in two locations around the barges during trial runs, indicating that wild fish do interact with barge traffic near the barriers. In order to determine whether wild fish would stay in this void without a cage, a follow-up study was conducted with externally tagged fish (tethered to a float). Tethered fish placed in barge junctions breached the barrier to some degree in all but one barge configuration tested. When tethered fish were placed below the barriers as barges approached, some degree of fish breaching the barrier occurred with each configuration tested (USACE 2013). Results from these ongoing studies are preliminary. This combination of increased possibility of entrainment and reduced electrical parameters due to barge traffic is expected to lead to an increased possibility of fish being transported over the barrier system. Vessel speed and tow/barge configuration are considered to be primary factors that affect the possible entrainment and transport of fish through the electric barriers (USACE 2013). Further research is being conducted to mitigate this bypass. While preliminary results from these investigations have shown these bypasses to be viable, the possibility of these bypasses occurring in the field is low at this time due to the low or non-existent population of silver carp in the Lockport Pool.

In 2010, lateral barricades were constructed between the CSSC, the Des Plaines River, and the Illinois and Michigan Canal to control upstream bypass of the Electrical Dispersal Barrier System during flooding between these adjacent waterways. The Des Plaines River Barricade extends approximately 13 mi and consists of concrete barriers and specially fabricated 0.25-in. wire mesh that allows water to flow through the fence but controls the passage juvenile and adult fish, and the Illinois and Michigan Canal is walled off using a stone berm. Small sections of the Des Plaines barricade fence failed during flooding in 2013; however, monitoring crews immediately responded and monitored for the presence of fish along breaches. Although these efforts indicated that fish (common carp) had moved through the breaches, no Asian carp were caught (Barkowski 2013), and prior monitoring efforts in the Des Plaines River had not captured or observed Asian carp, larval fish, or eggs (ACRCC 2013b).

Under current operational protocols, monitoring for Asian carp occurs downstream and upstream of the Electric Dispersal Barrier System. In the event an individual is found upstream of the Lockport Lock and Dam, protocol dictates the use of intensive electrofishing and netting to find and remove individuals or the use of rotenone to immobilize and kill all fish within the reach of concern (ACRCC 2011). It is expected that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp are above the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{10}: See $T_{0.}$ Future operations of the Brandon Road Lock and Dam and Lockport Lock and Dam locks are not expected to change as of the time of this assessment. The Electric Dispersal Barrier System is expected to have additional redundancies in power supply, thereby reducing potential power outage events. A new barrier is currently under construction that will upgrade the Demonstration Barrier to permanent status (Barrier I). Barrier I will be capable of producing higher electrical outputs than those of Barrier II and will add an additional narrow array on the downstream boundary. Barrier I is expected to become operational by 2016. Further study of the current Electric Dispersal Barrier System to address electric field shielding by steel-hulled vessels, fish entrainment within barge-induced water currents and very small fish would continue and would inform future operations.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{25}: See T_{10}. Funding for research, monitoring, and removal programs for Asian carp at this time step is highly uncertain. Currently, no funding source has been identified for any one agency to maintain the present level of effort.

The Nonstructural Alternative is not expected to affect the existing physical human and natural barriers for the silver carp.

T_{50}: See T_{10} and T_{25}.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Silver carp inhabit freshwater riverine systems and confluent lakes. It is a pelagic, schooling species (Mukhamedova 1977). Silver carp is a filter-feeder capable of taking large amounts of phytoplankton. Its diet also includes zooplankton, bacteria, and detritus (Leventer 1987). The CAWS is the recipient of treated wastewater from numerous facilities that produce eutrophic conditions suitable for silver carp.

Additionally, recent plankton surveys within the CAWS suggest there are relatively high concentrations of zooplankton available as a food resource (MRRP 2012).

Silver carp are tolerant to a wide array of environmental variables (Kolar et al. 2005). They can tolerate long winters under ice cover as well as temperatures higher than 40°C (104°F) (Opuszynski et al. 1989). In the CAWS, the mean annual water temperature ranges from 11.3 to 19.3°C (52.3 to 66.7° F) (MWRD 2010). Fry and fingerlings can survive in waters with a pH of 5.0 to 9.0, dissolved oxygen 1–28 mg/L, and total alkalinity 88–620 mg/L (Singh et al. 1967). Sections of the CAWS also experience seasonally low DO (LimnoTech 2010).

Silver carp eggs are semi-buoyant; spawning typically occurs in water of sufficient flow to keep the eggs from sinking to the bottom and dying (Laird & Page 1996). Reported current velocities required for successful spawning range from 0.3 to 3.0 m/s (0.98 to 9.8 ft/s) (Kolar et al. 2005). The pathway from the Brandon Road Lock and Dam to the mouth of Lake Michigan at the BSBH is a slow-moving eutrophic river with a flow of 0.05–0.27 m/s (0.16–0.89 ft/s) (LimnoTech 2010). Currents bring larvae to slow-flowing backwaters, creeks, reservoirs, or other flooded areas that become nursery areas (Nikolsky 1963). The CAWS is a heavily modified channel with little floodplain connection or shallow marshy areas (LimnoTech 2010). The south branch of the Little Calumet River is small and shallow (Gallagher et al. 2011) and may not be preferred habitat for the silver carp. Overall, the conditions of the CAWS are not expected to impede movement of silver carp.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for silver carp.

T_{10}: See T_0. Conditions of the CAWS are predicted to change but not in a way that would affect the likelihood of this species passing through this pathway**.** For example, the Metropolitan Water Reclamation District of Greater Chicago (MWRD) is in the process of evaluating ways to improve the water quality of the CAWS by decreasing the amount of organic materials released into the CAWS. This could potentially decrease the amount of plankton and other food species silver carp would need to survive within the CAWS. In addition, in coordination with the USACE, MWRD will increase capacity of stormwater catchment and retention in adjacent tunnels and reservoirs. This increased capacity will lead to a lower hydrologic peak during storm events. The environmental conditions within the pools may change slightly with the closing of two coal-fired power plants (Midwest Generation's Fisk and Crawford Plants) in August 2012. These plants used canal water in their cooling process and returned heated water back to the canal. As a result, temperature profiles may be reduced significantly in the near vicinity and to a lesser extent downstream. These actions are not expected to significantly affect the silver carp's ability to pass through this pathway.

The Nonstructural Alternative is not expected to affect the suitability of the habitat within the CAWS for silver carp.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Silver carp would need to pass through the Brandon Road and Lockport locks and dams, the Electric Dispersal Barrier System and an intermittent sluice gate opening to pass through this pathway. Adults and all life sizes of silver carp would be able to swim through the locks when the lock is in operation; however, the locks may slow passage of silver carp through the pathway.

Based on the sampling and monitoring data, the abundance of individuals within the Lockport Pool below the dispersal barriers is expected to be low to nonexistent at this time step. Since 2007, silver carp were captured in Dresden Island Pool (USGS 2013); however, based on this monitoring data, it appears that few silver carp have expanded past the Brandon Road Lock and Dam. As discussed in *P(arrival)*, *Current and Potential Abundance and Reproductive Capacity*, in 2012, small Asian carp were relatively abundant in the LaGrange Lock and Dam and Peoria Lock and Dam. Only one was caught in the Starved Rock pool. No small age-1 Asian carp were found in the Marseilles pool. Only one age-0 Asian carp was captured at Peoria Lock and Dam, LaGrange pool. Adult populations of silver carp are in the Dresden Island Pool (ACRCC 2013a). In an effort to control the Asian carp population downstream of the barrier, fisherman have been contracted to remove these fish from the waterway.

Monitoring and research have found several potential bypass mechanisms for the Electric Barrier System: the man overboard scenario when power to the barrier is intentionally turned off, power outages, bypass during flood events, stunned fish floating through the barrier during reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel-hulled vessels or side wall crevices, small fish passage and fish entrainment within barge-induced water currents across the Electric Dispersal Barrier System. Bypass due to these various mechanisms is not likely, because the nearest detectable population of swimming silver carp is in Dresden Island Pool and the nearest detected eggs, larvae, and fry are farther downstream (ACRCC 2013a). Additionally, research on these bypasses continues and will inform future operations.

In summary, current propagule pressure of this species immediately downstream of the Dispersal Barriers is considered low or nonexistent as measured by monitoring efforts of local, state, and federal agencies. The probability of passage for the silver carp is low for T_0 because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier, then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The low passage rating is in conflict with the Canadian Science Advisory Report (2012) that rates passage through the CAWS as highly likely. However, the Canadian report explicitly did not evaluate the effectiveness of the Electric Dispersal Barrier System.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at T_0. Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Silver carp are expected to remain in low populations immediately below the Electric Dispersal Barrier System. Contracted fishermen are expected to continue to improve their fishing techniques to increase their catch rates. The Brandon Road and Lockport locks and dams may also slow silver carp passage.

Federal and state natural resource agencies have monitored the upstream progress of Asian carp populations since their arrival in the IWW in the 1990s (Conover et al. 2007; Irons et al. 2009; ACRCC 2013a). Since 2007, silver carp were captured in Dresden Island Pool (USGS 2013); however, based on current monitoring data, it appears that few silver carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam. The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences. In addition, it is expected that the ACRCC Monitoring and Response Group would evaluate and respond to any evidence of Asian carp above the Brandon Road Lock and Dam.

Further refinement of the Electric Dispersal Barrier System operations and redundant power sources are expected to decrease the number and length of potential power outages. Additionally, potential transport vectors across the barriers (e.g., vessel entrainment, insufficient operating parameters for small fish, reverse flow events, crevice shielding of electric field) will continue to be analyzed and future operations would be informed by this analysis.

The probability of passage for the silver carp is low for T_{10} because (1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, (2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and (3) if a low population of adults approaches the barrier then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at T_0. Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not

expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's low probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}. Funding for monitoring and removal programs for silver carp at this time step is uncertain because there is not a funding source identified to maintain the present level of management. With the continued expected immigration from the lower pools (Tsehaye et al. 2013), the propagule pressure at the Dispersal Barrier System is expected to increase, and thus increase the potential for an individual to move past the barriers.

The Nonstructural Alternative includes nonstructural measures such as ballast and bilge water discharge that could be implemented at T_0. Although ballast and bilge water discharge prior to entering the pathway is expected to address the human-mediated transport of silver carp through the aquatic pathway, these measures alone are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Additionally, although monitoring and overfishing techniques are expected to improve, removal efforts are unlikely to amount to a total extirpation from a single pool because removed fish could be replenished by reproducing populations (Tsehaye et al. 2013) and immigration from the lower pools (ACRCC 2013a).

Overall, the Nonstructural Alternative's medium probability of passage rating does not differ from that reported in the No New Federal Action Risk Assessment.

T_{50}: See T_{10} and T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	High	High	High
Nonstructural Alternative Rating	Medium	High	High	High

Evidence for Uncertainty Rating

T_0: Although there has been an extraordinary effort from multiple agencies to research potential barrier bypass mechanisms, much of that research is currently underway and only preliminary results have been reported. Each risk assessment was conducted qualitatively under the assumption that bypass is possible but did not address the frequency that it might occur under a set of quantitative conditions. It is also uncertain whether additional bypass mechanisms could still be discovered. Although comprehensive monitoring upstream and downstream of the barrier for Asian carp is ongoing, uncertainty still exists concerning whether monitoring has identified the true abundance of silver carp within upper Illinois River and the CAWS.

The Nonstructural Alternative is expected to affect the passage of silver carp through the aquatic pathway by human-mediated transport; however, these measures are not

expected to affect the natural dispersion of silver carp through the aquatic pathway. Overall, the uncertainty remains medium.

T_{10}: See T_0. Although empirical tests are underway to see if the potential transport mechanisms across the barriers are viable, at this time uncertainty increases with time because of unknown events and a general lack of published literature discussing future bypass mechanisms. Additionally, funding for management actions that keep the populations of Asian carp in check immediately downstream of the Dispersal Barriers are not specified. The factors contributing to the historic absence of range expansion beyond the Brandon Road Lock and Dam are uncertain and may change.

The Nonstructural Alternative is expected to affect the passage of silver carp through the aquatic pathway by human-mediated transport; however, these measures are not expected to affect the natural dispersion of silver carp through the aquatic pathway. Overall, the uncertainty remains high.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

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E.2.2 ANS Potentially Invading the Mississippi River Basin

E.2.2.1 Algae

E.2.2.1.1 Grass Kelp (*Enteromorpha flexuosa*)

NONSTRUCTURAL ALTERNATIVE

This alternative would potentially include a combination of the following measures that may be implemented at time step 0 (T_0, in units of years) by local, state, and federal agencies and the public. The Nonstructural Alternative would include the development of a monitoring and response program.

Nonstructural Alternative Measures for *Enteromorpha flexuosa*

Option or Technology	Description	
Education & Outreach	• Education of recreational waterway users • Signage, pamphlets, brochures on how to identify ANS and control the spread of ANS; promotion of national campaigns (e.g., "Stop Aquatic Hitchhikers") • Management of nutrient loads to waterways (e.g., grass buffer zones, limited fertilizer use, and voluntary improvements to waterway discharges)	
Anti-fouling Hull Paints	• Education of vessel owners and operators to promote use of anti-fouling paints	
Ballast/Bilge-Water Exchange	• Ballast/bilge-water exchange	
Monitoring	• Agency monitoring • Voluntary occurrence reporting	
Laws & Regulations	• Quarantine – restricted site access • Prohibition of sale, cultivation, transport, release/planting • Local, state, and USDA Federal Noxious Weed listing • Mandatory watercraft and trailer inspection and decontamination • Restrictions on nutrient loads to waterways	
	ANS Controls	**ANS Factsheet**[a]
ANS Control Methods	Algaecides	Algaecides
	Dredging	Manual Harvest & Mechanical Control Methods
	Desiccation (Water Drawdown)	Lethal Temperature
	Alteration of Water Quality (Alum)	Alteration of Water Quality

[a] For more information, refer to *Inventory of Available Controls for Aquatic Nuisance Species of Concern – Chicago Area Waterway System* (http://glmris.anl.gov/documents/interim/anscontrol/index.cfm).

PATHWAY 1

WILMETTE PUMPING STATION (WPS) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(passage)	High	Medium	High	Medium	High	Medium	High	Medium
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary[a]

	T_0		**T_{10}**		**T_{25}**		**T_{50}**	
Probability Element	**P**	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Medium	***Low***	Medium	***Low***	Medium	***Low***	***High***
P(passage)	High	Medium	High	Medium	High	Medium	High	Medium
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[b]	***Low***	–	***Low***	–	***Low***	–

[a] The highlighted table cells indicate a rating change in the probability element.

[b] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Wilmette Pumping Station (WPS) and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative is not expected to impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

E. flexuosa is a marine attached alga with a worldwide distribution. Its spores are released into the water daily and can float for 8–11 days (Beach et al. 1995). The species is highly invasive, has a rapid growth rate, and can tolerate a wide range of environmental conditions (Lougheed and Stevenson 2004). The ecological success of *E. flexuosa* is attributable in part to the readily available pool of motile unicells that are able to rapidly colonize new areas (Hill 2001). The chance for successful settlement of these cells is greatly enhanced because gametes and zoospores of this species remain viable for 10 or more days after release due to their ability to photosynthesize (Beach et al. 1995). The adults are attached unless they become dislodged, in which case they can be transported as floating mats (John et al. 2002).

The Nonstructural Alternative is expected to affect the invasion speed of *E. flexuosa* from natural dispersion (i.e., current-driven passage) through aquatic pathways to the Chicago Area Waterway System (CAWS). The Nonstructural Alternative includes aquatic nuisance species (ANS) control methods such as algaecides, dredging, water drawdown, and alum application, which may impact the invasion speed of *E. flexuosa* by reducing its existing population.

b. Human-Mediated Transport through Aquatic Pathways

E. flexuosa is documented to be transported by boat hulls (Lougheed and Stevenson 2004). WPS is not a port with cargo vessel use; however, there is recreational boat use in the Wilmette Harbor that could potentially transport this species from the Great Lakes to the WPS.

Anti-fouling hull paints are a possible measure for controlling *E. flexuosa* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS because of wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use

of biocide-based hull paints because of their impact on biodiversity as a result of leaching.

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS by human-mediated transport through aquatic pathways. Agency monitoring and voluntary occurrence reporting in combination with education and outreach may be used to determine where to target nonstructural control measures, in particular, algaecides. The implementation of a ballast/bilge water exchange program, education and outreach, as well as and laws and regulations, may reduce the human-mediated transport of *E. flexuosa* through aquatic pathways to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: *E. flexuosa* is highly fecund (Beach et al. 1995); propagule release via mitotic spores and meiotic gametes occurs on a daily basis in lower latitudes (Hill 2001). Spores and gametes of this species are photosynthetically competent upon release into the water column, with unicells remaining motile for up to 11 days (Hill 2001). A 2003 study indicated *E. flexuosa* was present in Muskegon Lake and in 2 of 11 nearby inland lakes and lagoons that were surveyed (Sturtevant 2011). Overall, the results suggested that, although *E. flexuosa* may not be widespread, local abundance can be high (Lougheed and Stevenson 2004). *E. flexuosa* is an excellent pioneer species, able to colonize newly available strata year-round (Emerson and Zedler 1978). Yet it is not good at competing with other successional species. In an experimental study of the recolonization of intertidal algae following disturbance, Emerson and Zedler (1978) showed that *E. flexuosa* tends to be present at low densities (as measured in percent cover) throughout the year in undisturbed zones. After disturbance to an area, the density of this species increases dramatically within 2–3 weeks (Emerson and Zedler 1978). However, as other algae become established, the percent cover for this species declines (Emerson and Zedler 1978). This observation suggests that *E. flexuosa* may be unable to maintain dominance in the presence of later successional species such as *Ulva* spp. and other perennial algae that are present in the Great Lakes (Emerson and Zedler 1978).

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS from natural dispersion and human-mediated transport through aquatic pathways. The Nonstructural Alternative would include agency monitoring to locate areas where *E. flexuosa* is established. Additionally, outreach and education may be used to inform the public of *E. flexuosa* management efforts, and voluntary occurrence reporting may supplement agency monitoring. Data collected through agency monitoring and voluntary occurrence reporting would focus management efforts on locations where *E. flexuosa* is abundant. Managing nutrient loads to waterways may reduce habitat suitability for this species at current infestations and may reduce the ability for species establishment near the CAWS. Overall, the Nonstructural Alternative may reduce the current abundance and distribution of *E. flexuosa*.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.
T_{10}: None.
T_{25}: None.
T_{50}: None.

e. Distance from Pathway

T_0: The closest that *E. flexuosa* has been recorded to the WPS was on the beaches of Muskegon Lake in 2003 (Lougheed and Stevenson 2004). Muskegon Lake is a coastal lake on the eastern shore of, and with a hydrologically connected to, Lake Michigan (Lougheed and Stevenson 2004). Muskegon Lake is approximately 290 km (180 mi) from the pathway entrance. Water circulation in Lake Michigan is typically counterclockwise (Beletsky and Schwab 2001). Therefore, currents would transport the species north, away from the pathway entrance.

The Nonstructural Alternative includes ANS control methods such as algaecides, dredging, water drawdown, and alum application, which may control the expansion of *E. flexuosa* from its current location.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The species is widespread around the world in inland and coastal waters (Lougheed and Stevenson 2004). The native range of *E. flexuosa* is unknown, but the species is found worldwide; therefore, the climate in southern Lake Michigan is likely to be suitable. *E. flexuosa* is primarily a marine species, but it is highly tolerant of freshwater conditions. Lougheed and Stevenson (2004) state that industrial activity resulting in increased nutrients and salinity in associated waters may have facilitated the invasion of this marine taxon. It is found at depths ranging from the intertidal zone to approximately 5 m (16.4 ft) below the surface (Beach et al. 1995). Species of this weedy genus are often the first to colonize open substrata (Beach et al. 1995). Growth of this species in outdoor ponds in India showed that *E. flexuosa* was able to sustain growth in water temperatures as high as 30°C (86°F) (Mairh et al. 1986; Hill 2001). Favorable growth was maintained at temperatures ranging from 15.5 to 30°C (59.9 to 86°F) (Hill 2001). Optimal reproduction occurs at temperatures under 30°C (86°F) in waters with a pH of approximately 8.2 (Hill 2001). Historically, urban runoff has allowed the establishment of several eutrophic and/or marine species offshore of the Chicago area, including *Bangia atrpurpurea* and *Cyclotella cryptica*.

E. flexuosa typically grows in clusters on plant roots, rocks, or wood, or as an epiphyte on other plants (Beach et al. 1995). In Muskegon Lake it was primarily found growing on submerged aquatic macrophytes in windswept, littoral areas of eutrophic and mesotrophic lakes (Lougheed and Stevenson 2004). Although submerged macrophytes are not common along the shoreline of southern Lake Michigan, there are scattered macroalgal beds (*Cladophora*) near the WPS (MTRI 2012). Wilmette Harbor, on the lake side of the WPS, has generally sandy beaches and riprap, which are suitable for the species to colonize. There are no emergent wetlands near the WPS (unpublished data from the U.S. Army Corps of Engineers).

The Nonstructural Alternative includes measures such as managing nutrient loads to waterways. Such measures may reduce habitat suitability for *E. flexuosa* at its current location at Muskegon Lake.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. The Nonstructural Alternative is expected to manage nutrient loads to waterways where *E. flexuosa* is currently located. Additionally, future climate change or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes Basin for *E. flexuosa*. In particular, mean water temperature is expected to increase (Wuebbles et al. 2010). However, *E. flexuosa* is found in a wide range of water temperatures and is globally distributed (Hill 2001). Therefore, temperature is expected to remain species suitable. However, changes in nutrients and conductivity related to future climate change or new environmental regulations may affect the suitability of southern Lake Michigan for this species.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Low	***Low***	***Low***	***Low***

[a] The highlighted table cells indicate a rating change in the probability element.

Evidence for Probability Rating (Considering All Life Stages)

T_0: *E. flexuosa* is a highly invasive, highly fecund species (sections 2a and 2c) that can be transferred by boats (section 2b). The WPS does not receive cargo vessels, but there is recreational boat activity in the area. *E. flexuosa* has been established in Muskegon Lake since 2003, but it has yet to be identified at the WPS (section 2e). The habitat near the WPS is likely suitable for the species to establish due to the higher energy shoreline of Lake Michigan, which has rocky shoals and hard substrate. The species is opportunistic and may be able to populate disturbed areas that remove competitors such as *Cladophora* (section 2f). Historically, urban runoff has supported marine algal species in the vicinity of the WPS (section 2e). Currently, *E. flexuosa* has only been recorded along the eastern shoreline of central Lake Michigan.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *E. flexuosa*. Until additional study is completed and these issues are addressed, anti-fouling

hull paints are considered ineffective at controlling the arrival of *E. flexuosa* at the CAWS via fouled vessels.

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS from natural dispersion and human-mediated transport through aquatic pathways. The Nonstructural Alternative would also include agency monitoring to locate areas where *E. flexuosa* is established. Additionally, outreach and education may be used to inform the public of *E. flexuosa* management efforts, and voluntary occurrence reporting may supplement agency monitoring. Informed by monitoring information, management efforts may be directed at controlling *E. flexuosa* abundance. Data collected through agency monitoring and voluntary occurrence reporting may be used to target dense populations of *E. flexuosa* and implement algaecide treatments to reduce biomass and population density. Additionally, managing nutrient loads to waterways may reduce habitat suitability for this species. The Nonstructural Alternative may reduce the current abundance and distribution of *E. flexuosa*.

The Nonstructural Alternative reduces the likelihood of *E. flexuosa* arriving at the pathway by reducing the current abundance and distribution of *E. flexuosa*. However, the Nonstructural Alternative's low probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. The current of the lake may transport the species away from the pathway entrance; however, transport by boat is possible.

The Nonstructural Alternative is expected to manage the spread and distribution of *E. flexuosa*, thereby reducing the likelihood of the species arriving at the aquatic pathway. Therefore, the probability of arrival is reduced to low.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Medium	Medium	Medium	***High***

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Uncertainty Rating

T_0: *E. flexuosa* is considered to be a rapid invader (section 2a), and the latest record of its presence is from 2003. Therefore, the current location of the species is uncertain (section 2e). In addition, this is a marine species, and the suitability of nutrient and conductivity levels in the vicinity of the WPS is uncertain.

The Nonstructural Alternative is expected to manage the spread and distribution of *E. flexuosa*. However, it is uncertain whether *E. flexuosa* has spread past the locations identified in 2003; therefore, the overall uncertainty is medium.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. The future effects of climate change on *E. flexuosa* and habitat suitability in Lake Michigan are uncertain.

In addition, the uncertainty revolving around the effectiveness of the Nonstructural Alternative to control the arrival of *E. flexuosa* at the CAWS is thought to increase with time. Therefore, uncertainty is high.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

E. flexuosa must move more than 64 km (40 mi) downstream from WPS to reach the Brandon Road Lock and Dam. The species is highly invasive, has a rapid growth rate, and can tolerate a wide range of environmental conditions (Lougheed and Stevenson 2004). Its spores are transported by currents, but the adults are attached, unless they become dislodged, in which case it can be transported as floating mats (John et al. 2002).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., current-driven passage) of *E. flexuosa* spores and filaments through the aquatic pathway. Therefore, the Nonstructural Alternative is not expected to control the natural dispersion of *E. flexuosa* as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

E. flexuosa is documented to have been transported by boat hulls (Lougheed and Stevenson 2004). There is no cargo traffic and limited recreational vessel traffic in the North Shore Channel (USACE 2011a,b); therefore, natural downstream dispersal through the North Shore Channel would likely be required for *E. flexuosa* to reach Brandon Road Lock and Dam. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the *E. flexuosa* into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Anti-fouling hull paints are a possible measure for controlling *E. flexuosa* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS because of wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use

of biocide-based hull paints because of their impact on biodiversity as a result of leaching.

The Nonstructural Alternative is not expected to control the human-mediated transport of *E. flexuosa* spores and filaments through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: The sluice gate at the WPS is a barrier that could retard natural dispersion. However, water that could transport the species is pumped from Lake Michigan into the North Shore Channel.
The Nonstructural Alternative does not include physical human/natural barriers.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: *E. flexuosa* has been found in drainage channels with slow water currents (Fernandez et al. 1998), as well as in reservoirs, ponds, and fast- and slow-flowing rivers (John et al. 2002). Most flows in the CAWS were less than 0.15 m/s (0.49 ft/s); the highest was 0.27 m/s (0.89 ft/s) (LimnoTech 2010). Spores and gametes of this species are photosynthetically competent upon release into the water column, and unicells remain motile for up to 11 days (Hill 2001). The CAWS is a heavily modified channel with little floodplain connection and few shallow marshy areas. The species is found at depths ranging from the intertidal zone to approximately 5 m (16.4 ft) below the surface (Beach et al. 1995). The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically around 5 m (16.4 ft) (LimnoTech 2010), suggesting that the depth there is suitable. Growth of the species is maintained at temperatures ranging from 15.5 to 30°C (59.9 to 86°F) (Hill 2001). The water temperature in the CAWS averages from 11.3 to 19.3°C (52.3 to 66.7°F) (MWRDGC 2010). The species has been found in turbid water (Sand-Jenson et al. 2008), and turbidity is high in the CAWS (LimnoTech 2010). *E. flexuosa* may be abundant in rivers and tributaries with hard water and high nutrient levels (Holmes and Whitton 1977). Portions of the CAWS flow through limestone bedrock, and there is heavy municipal water discharge into the CAWS; these sources may provide nutrients and carbonates required by *E. flexuosa*.

Species of this weedy genus are often the first to colonize open substrata (Beach et al. 1995). *E. flexuosa* typically grows in clusters on plant roots, rocks, or wood, or as an epiphyte on other plants (Beach et al. 1995). The banks of the CAWS are typically a mix of stone blocks, steel sheet piling, and earthen banks with vegetation; riprap banks are common. In the North Shore Channel and the upper North Branch of the Chicago River there are partly shaded banks with aquatic plants, tree roots, and brush debris jams, and sediments consist of silt and sand. Further downstream in the Chicago River and in the Chicago Sanitary and Ship Canal (CSSC) there is suitable hard substrate in the form of concrete, riprap, pilings, bridges, and sheet pile (LimnoTech 2010). Toxic organic and inorganic pollutants are present in the Chicago

River (Gallagher et al. 2009). Aguilar-Rosas and Pacheco-Ruiz (1989) showed that *Enteromorpha* species develop abundantly in zones directly affected by pollution, even as the abundance of other genera decreases. In areas affected by polluted discharge, *E. flexuosa* can be a highly successful invader (Lougheed and Stevenson 2004).

The Nonstructural Alternative includes managing nutrient loads to waterways, which may affect *E. flexuosa* establishing in the CAWS and thereby reducing the abundance of spores and filaments in the CAWS. However, the transport of spores and filaments through the CAWS would not be affected.

T_{10}: See T_0.

T_{25}: See T_0. The discharge of common municipal contaminants such as nutrients, metals, total dissolved solids, and sewage may decrease due to the adoption of water quality standards and effluent discharge limitations currently proposed for the CAWS (Raber 2012; Illinois Pollution Control Board 2012). These changes may reduce habitat suitability for *E. flexuosa* in the CAWS.

T_{50}: See T_{25}.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: *E. flexuosa* is thought to have a rapid invasion speed (section 3a) and could move from Lake Michigan to the North Shore Channel by water pumping through a sluice gate (section 3c). The planktonic spore stage may facilitate downstream transport to Brandon Road Lock and Dam (section 3a). There is a low potential for human-mediated transport in the North Shore Channel (section 3b), but spores or fragments could float downstream through this portion of the CAWS. Habitat is suitable for *E. flexuosa* throughout much of the CAWS (section 3d), and this species has been found in rivers and tributaries where suitable water quality conditions are present (section 3d). The urban runoff entering the CAWS may provide the high nutrient and conductivity levels that this species prefers. There is low submerged aquatic macrophyte cover in the CAWS, which is a preferred habitat for this species (section 3d). Within the current time step, *E. flexuosa* spores or fragments may drift from WPS to Brandon Road Lock and Dam by natural dispersion or attached to vessels in portion of the pathway with vessel traffic.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *E. flexuosa*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of *E. flexuosa* through the aquatic pathway via fouled vessels.

The Nonstructural Alternative is not expected to reduce the likelihood of *E. flexuosa* passing through the aquatic pathway. The alternative does not include measures to address the passage of *E. flexuosa* by the Lake Michigan diversion and the downstream passive transport of *E. flexuosa* spores and filaments to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating	Medium	Medium	Medium	Medium

Evidence for Uncertainty Rating

T_0: Although this species is commonly found in waters that are heavily affected by human uses, it is a marine species, and the ability of hydraulic and chemical conditions in the inland portions of the CAWS to support *E. flexuosa* is uncertain. *E. flexuosa* is an opportunistic species and would invade areas in the CAWS where a disturbance opens up space for the species. The potential rate of spread of this species through the CAWS is uncertain.

The Nonstructural Alternative includes managing nutrient loads to waterways. The effect of nutrient management on *E. flexuosa* abundance and its natural rate of spread is uncertain. Overall, the Nonstructural Alternative is not expected to affect the passage of *E. flexuosa* through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the uncertainty remains medium.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

4. **P(colonizes) T_0-T_{50}: MEDIUM**

   The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

   Uncertainty: MEDIUM

5. **P(spreads) T_0-T_{50}: MEDIUM**

   The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

   Uncertainty: HIGH

PATHWAY 2

CHICAGO RIVER CONTROLLING WORKS (CRCW) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(passage)	High	Medium	High	Medium	High	Medium	High	Medium
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary[a]

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Medium	***Low***	Medium	***Low***	Medium	***Low***	***High***
P(passage)	High	Medium	High	Medium	High	Medium	High	Medium
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[b]	***Low***	–	***Low***	–	***Low***	–

[a] The highlighted table cells indicate a rating change in the probability element.

[b] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Chicago River Controlling Works (CRCW) and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative is not expected to impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

E. flexuosa is a marine attached alga with a worldwide distribution. The spores are released into the water daily and can float for 8–11 days (Beach et al. 1995). The species is considered highly invasive, has a rapid growth rate, and can tolerate a wide range of environmental conditions (Lougheed and Stevenson 2004). The ecological success of *E. flexuosa* is, in part, attributable to the readily available pool of motile unicells that are able to rapidly colonize new areas (Hill 2001). The chance for successful settlement of these cells is greatly enhanced because gametes and zoospores of this species remain viable for 10 or more days after release due to their ability to photosynthesize (Beach et al. 1995). The adults are attached unless they become dislodged, in which case they can be transported as floating mats (John et al. 2002).

The Nonstructural Alternative is expected to impact the arrival of *E. flexuosa* to the CAWS by natural dispersion (i.e., current-driven passage) through aquatic pathways. The Nonstructural Alternative includes ANS control methods such as algaecides, dredging, water drawdown, and alum application, which may impact the invasion speed of *E. flexuosa* by reducing its existing population.

b. Human-Mediated Transport through Aquatic Pathways

E. flexuosa has been documented to be transported by boat hulls (Lougheed and Stevenson 2004). There is recreational and commercial boat traffic between the CRCW and multiple ports in Lake Michigan (USACE 2011a,b), including Muskegon, Michigan, where grass kelp can be found (NBIC 2012).

Anti-fouling hull paints are a possible measure for controlling *E. flexuosa* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS because of wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity as a result of leaching.

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS by human-mediated transport through aquatic pathways. Agency monitoring and voluntary occurrence reporting in combination with education and outreach may be used to determine where to target nonstructural control measures, in particular, algaecides. The implementation of a ballast/bilge water exchange program, education and outreach, as well as laws and regulations, may reduce the human-mediated transport of *E. flexuosa* to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: *E. flexuosa* is highly fecund (Beach et al. 1995); propagule release via mitotic spores and meiotic gametes occurs on a daily basis in lower latitudes (Hill 2001). Spores and gametes of this species are photosynthetically competent upon release into the water column, and unicells remain motile for up to 11 days (Hill 2001). A 2003 study indicated *E. flexuosa* was present in Muskegon Lake and in 2 of 11 nearby inland lakes and lagoons that were surveyed (Sturtevant 2011). Overall, these results suggest that, although *E. flexuosa* may not be widespread, local abundance can be high (Lougheed and Stevenson 2004). *E. flexuosa* is an excellent pioneer species, able to colonize newly available strata year-round (Emerson and Zedler 1978). However, it is not good at competing with other successional species. In an experimental study of recolonization of intertidal algae following disturbance, Emerson and Zedler (1978) showed that *E. flexuosa* tends to be present at low densities (as measured in percent cover) throughout the year in undisturbed zones. Following disturbance to an area, the density of this species increases dramatically within 2–3 weeks (Emerson and Zedler 1978). However, as other algae become established, the percent cover for this species declines (Emerson and Zedler 1978). This observation suggests that *E. flexuosa* may be unable to maintain dominance in the presence of later successional species such as *Ulva* spp. and other perennial algae that are present in the Great Lakes (Emerson and Zedler 1978).

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS from natural dispersion through aquatic pathways. The Nonstructural Alternative would include agency monitoring to locate areas where *E. flexuosa* is established. Additionally, outreach and education may be used to inform the public of *E. flexuosa* management efforts, and voluntary occurrence reporting may supplement agency monitoring. Data collected through agency monitoring and voluntary occurrence reporting would focus management efforts on locations where *E. flexuosa* is abundant. Managing nutrient loads to waterways may reduce habitat suitability for this species at current infestations and may reduce the ability for species establishment near CAWS. The Nonstructural Alternative may reduce the current abundance and distribution of *E. flexuosa*.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: The closest that *E. flexuosa* has been recorded to the CRCW was on the beaches of Muskegon Lake in 2003 (Lougheed and Stevenson 2004). Muskegon Lake is a coastal lake on the eastern shore of, and hydrologically connected to, Lake Michigan (Lougheed and Stevenson 2004). Muskegon Lake is approximately 290 km (180 mi) from the pathway entrance. Water circulation in Lake Michigan is typically counterclockwise (Beletsky and Schwab 2001). Therefore, currents would transport the species north, away from the pathway entrance.

The Nonstructural Alternative includes ANS control methods such as algaecides, dredging, water drawdown, and alum application, which are expected to control the expansion of *E. flexuosa* from its current location.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The species is widespread around the world in inland and coastal waters (Lougheed and Stevenson 2004). The native range of *E. flexuosa* is unknown, but the species is found worldwide; therefore, the climate in southern Lake Michigan is likely to be suitable. *E. flexuosa* is primarily a marine species, but it is highly tolerant of freshwater conditions. Lougheed and Stevenson (2004) state that industrial activity resulting in increased nutrients and salinity of associated waters may have facilitated the invasion of this marine taxon. It is found at depths ranging from the intertidal zone to approximately 5 m (16.4 ft) below the surface (Beach et al. 1995). Species of this weedy genus are often the first to colonize open substrata (Beach et al. 1995). Growth of *E. flexuosa* in outdoor ponds in India showed that this species was able to sustain growth in water temperatures as high as 30°C (86°F) (Mairh et al. 1986). Favorable growth was maintained at temperatures ranging from 15.5 to 30°C (59.9 to 86°F) (Hill 2001). Optimal reproduction occurs at temperatures under 30°C (86°F), in waters with a pH of approximately 8.2 (Hill 2001). Historically, urban runoff has allowed the establishment of several eutrophic and/or marine species offshore of the Chicago area, including *Bangia atrpurpurea* and *Cyclotella cryptica*.

E. flexuosa typically grows in clusters on plant roots, rocks, or wood, or as an epiphyte on other plants (Beach et al. 1995). In Muskegon Lake it was primarily found growing on submerged aquatic macrophytes in windswept, littoral areas of eutrophic and mesotrophic lakes (Lougheed and Stevenson 2004). Submerged macrophytes are

not common along the shoreline of southern Lake Michigan, but there are extensive *Cladophora* beds that may provide a suitable habitat (MTRI 2012). CRCW has generally sandy beaches and riprap, which are suitable for the species to colonize.

The Nonstructural Alternative includes measures such as managing nutrient loads to waterways. Such measures may reduce habitat suitability for *E. flexuosa* at its current location at Muskegon Lake*.*

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. The Nonstructural Alternative is expected to manage nutrient loads to waterways where *E. flexuosa* is currently located. Additionally, future climate change or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for *E. flexuosa*. In particular, mean water temperature is expected to increase (Wuebbles et al. 2010). However, *E. flexuosa* can be found in a wide range of water temperatures and is globally distributed (Hill 2001). Therefore, water temperature is expected to remain suitable. However, changes in nutrients and conductivity related to future climate change or new environmental regulations may affect the suitability of southern Lake Michigan for this species.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Low	***Low***	***Low***	***Low***

[a] The highlighted table cells indicate a rating change in the probability element.

Evidence for Probability Rating (Considering All Life Stages)

T_0: *E. flexuosa* is a highly invasive, highly fecund species (sections 2a, 2c) that can be transferred by boats (section 2b). The CRCW receives recreational boat activity from Lake Michigan and cargo vessels from many ports in the Great Lakes, including Muskegon, Michigan, where grass kelp can be found. The species has been established in Lake Michigan since 2003, but it has yet to be identified at the CRCW (section 2e). The habitat near the CRCW is likely suitable for *E. flexuosa* due to the higher energy shoreline of Lake Michigan, which has rocky shoals and hard substrate. The species is opportunistic and may be able to inhabit disturbed areas that remove competitors such as *Cladophora* (section 2f). Historically, urban runoff has supported marine algal species in the vicinity of the CRCW (section 2e). Currently, *E. flexuosa* has only been recorded along the eastern shoreline of central Lake Michigan.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *E. flexuosa*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of *E. flexuosa* at the CAWS via fouled vessels.

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS from natural dispersion and human-mediated transport through aquatic pathways. The Nonstructural Alternative would also include agency monitoring to locate areas where *E. flexuosa* is established. Additionally, outreach and education may be used to inform the public of *E. flexuosa* management efforts, and voluntary occurrence reporting may supplement agency monitoring. Informed by monitoring information, management efforts may be directed at controlling *E. flexuosa* abundance. Data collected through agency monitoring and voluntary occurrence reporting may be used to target dense populations of *E. flexuosa* and implement algaecide treatments to reduce biomass and population density. Additionally, managing nutrient loads to waterways may reduce habitat suitability for this species.

The Nonstructural Alternative reduces the likelihood of *E. flexuosa* arriving at the pathway by reducing the current abundance and distribution of *E. flexuosa*. However, the Nonstructural Alternative's low probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. *E. flexuosa* is highly invasive, and a suitable physical habitat is present in the vicinity of the CRCW. The current of the lake may transport the species away from the pathway entrance; however, transport by boat is also possible.

The Nonstructural Alternative includes measures that are expected to manage the spread of *E. flexuosa*, thereby reducing the likelihood of the species arriving at the aquatic pathway. Therefore, the probability of arrival is reduced to low.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Medium	Medium	Medium	***High***

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Uncertainty Rating

T_0: *E. flexuosa* is considered to be a rapid invader (section 2a), and the latest record of its presence is from 2003. Therefore, the current location of the species is uncertain (section 2e). In addition, this is a marine species, and the suitability of nutrient and conductivity levels in the vicinity of the CRCW is uncertain.

The Nonstructural Alternative is expected to manage the spread and distribution of *E. flexuosa*. However, it is uncertain whether *E. flexuosa* has spread past the locations identified in 2003; therefore, the overall uncertainty is medium.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. The future effects of climate change on *E. flexuosa* and habitat suitability in Lake Michigan are uncertain. In addition, the uncertainty revolving around the effectiveness of the Nonstructural Alternative to control the arrival of *E. flexuosa* at the CAWS is thought to increase with time. Therefore, uncertainty is high.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

E. flexuosa must move more than 64 km (40 mi) downstream from CRCW to reach Brandon Road Lock and Dam. The species is highly invasive, has a rapid growth rate, and can tolerate a wide range of environmental conditions (Lougheed and Stevenson 2004). Its spores are transported by currents, but the adults are attached unless they become dislodged, in which case they can be transported as floating mats (John et al. 2002).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., current-driven passage) of *E. flexuosa* spores and filaments through the aquatic pathway. Therefore, the Nonstructural Alternative is not expected to control the natural dispersion of the species through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

E. flexuosa has been documented to be transported by boat hulls (Lougheed and Stevenson 2004). There is recreational and commercial vessel traffic between the CRCW and Brandon Road Lock and Dam (USACE 2011a, b). The discharge of ballast water originating from the Great Lakes would not likely occur within the CAWS (NBIC 2012), but hull transport to Brandon Road Lock and Dam is possible. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the *E. flexuosa* into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Anti-fouling hull paints are a possible measure for controlling *E. flexuosa* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS because of wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity as a result of leaching.

The Nonstructural Alternative is not expected to control the human-mediated transport of *E. flexuosa* spores and filaments through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: *E. flexuosa* has been found in drainage channels with slow water currents (Fernandez et al. 1998), as well as reservoirs, ponds, and fast- and slow-flowing rivers (John et al. 2002). Most flows in the CAWS were less than 0.15 m/s (0.49 ft/s); the highest was 0.27 m/s (0.89 ft/s) (LimnoTech 2010). The CAWS is a heavily modified channel with little floodplain connection and few shallow marshy areas. The species is found at depths ranging from the intertidal zone to approximately 5 m (16.4 ft) below the surface (Beach et al. 1995). The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically around 5 m (16.4 ft) (LimnoTech 2010), suggesting that the depth there is suitable. Growth of the species is maintained at temperatures ranging from 15.5 to 30°C (59.9 to 86°F) (Hill 2001), and the water temperature in the CAWS averages from 11.3 to 19.3°C (52.3 to 66.7°F) (MWRDGC 2010). The species has been found in turbid water (Sand-Jenson et al. 2008), and turbidity is high in the CAWS (LimnoTech 2010). *E. flexuosa* can be abundant in rivers and tributaries with hard water and high nutrient levels (Holmes and Whitton 1977). Portions of the CAWS flow through limestone bedrock, and there is heavy municipal water discharge into the CAWS; these sources may provide the nutrients and carbonates required by *E. flexuosa*.

Species of this weedy genus are often the first to colonize open substrata (Beach et al. 1995). *E. flexuosa* typically grows in clusters on plant roots, rocks, or wood, or as an epiphyte on other plants (Beach et al. 1995). The banks of the CAWS are typically a mix of stone blocks, steel sheet piling, and earthen banks with vegetation, and riprap banks are common. In the Chicago River and the CSSC, there is suitable hard substrate in the form of concrete, riprap, pilings, bridges, and sheet pile (LimnoTech 2010). Toxic organic and inorganic pollutants are present in the Chicago River (Gallagher et al. 2009). Aguilar-Rosas and Pacheco-Ruiz (1989) showed that *Enteromorpha* species develop abundantly in zones directly affected by pollution, even as the abundance of other genera decreases. In areas affected by polluted discharge, *E. flexuosa* can be a highly successful invader (Lougheed and Stevenson 2004).

The Nonstructural Alternative includes managing nutrient loads to waterways, which may affect *E. flexuosa* establishing in the CAWS and thereby reducing the abundance of spores and filaments in the CAWS. However, the transport of spores and filaments through the CAWS would not be affected.
T_{10}: See T_0.

T_{25}: See T_0. The discharge of common municipal contaminants such as nutrients, metals, total dissolved solids, and sewage may decrease due to the adoption of water quality standards and effluent discharge limitations currently proposed for the CAWS (Raber 2012; Illinois Pollution Control Board 2012). These changes may reduce habitat suitability for *E. flexuosa* in the CAWS.
T_{50}: See T_{25}.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: *E. flexuosa* is thought to have a rapid invasion speed (section 3a) and can move from Lake Michigan to the Chicago River on boat hulls or by floating through the locks (section 3b). The planktonic spore stage may facilitate downstream transport to Brandon Road Lock and Dam (section 3a). Habitat is suitable for *E. flexuosa* throughout much of the CAWS (section 3d), and the species has been found in rivers and tributaries where suitable water quality conditions are present (section 3d). The urban runoff entering the CAWS may provide the high nutrient and conductivity levels that this species prefers. However, this opportunistic species may require uncolonized habitat. There is low submerged aquatic macrophyte cover in the CAWS, which is a preferred habitat for this species (section 3d). Within the current time step, *E. flexuosa* spores or fragments may drift from CRCW to Brandon Road Lock and Dam as a result of natural dispersion or attached to vessels.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *E. flexuosa*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at reducing the passage of *E. flexuosa* via fouled vessels.

The Nonstructural Alternative is not expected to reduce the likelihood of *E. flexuosa* passing through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of *E. flexuosa* by the Lake Michigan diversion and the downstream passive transport of *E. flexuosa* spores and filaments to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating	Medium	Medium	Medium	Medium

Evidence for Uncertainty Rating

T_0: Although this species is commonly found in waters that are heavily affected by human uses, it is a marine species, and the ability of hydraulic and chemical conditions in the inland portions of the CAWS to support *E. flexuosa* is uncertain. *E. flexuosa* is an opportunistic species that could grow where a disturbance opens up space. The potential rate of spread of this species through the CAWS is uncertain.
The Nonstructural Alternative includes managing nutrient loads to waterways. The effect of nutrient management on *E. flexuosa* abundance and its natural rate of spread is uncertain. Therefore, the Nonstructural Alternative is not expected to control the passage of *E. flexuosa* through the aquatic pathway. Overall, the uncertainty remains medium.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

PATHWAY 3

CALUMET HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(passage)	High	Medium	High	Medium	High	Medium	High	Medium
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Medium	–	Medium	–	Medium	–

[a] “–” Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary[a]

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Medium	***Low***	Medium	***Low***	Medium	***Low***	***High***
P(passage)	High	Medium	High	Medium	High	Medium	High	Medium
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[b]	***Low***	–	***Low***	–	***Low***	–

[a] The highlighted table cells indicate a rating change in the probability element.

[b] “–” Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Calumet Harbor and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative is not expected to impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. **P(arrival) T_0-T_{50}: LOW**

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

E. flexuosa is a marine attached alga with a worldwide distribution. The spores are released into the water daily and can float for 8 to 11 days (Beach et al. 1995). The species is highly invasive, has a rapid growth rate, and can tolerate a wide range of environmental conditions (Lougheed and Stevenson 2004). The ecological success of *E. flexuosa* is, in part, attributable to the readily available pool of motile unicells that are able to rapidly colonize new areas (Hill 2001). The chance for successful settlement of these cells is greatly enhanced because gametes and zoospores of this species remain viable for 10 or more days after release due to their ability to photosynthesize (Beach et al. 1995). The adults are attached unless they become dislodged, in which case they can be transported as floating mats (John et al. 2002).

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* to the CAWS from natural dispersion (i.e., current-driven passage) through aquatic pathways. The Nonstructural Alternative includes ANS control methods such as algaecides, dredging, water drawdown, and alum application, which may impact the invasion speed of *E. flexuosa* by reducing its existing population.

b. Human-Mediated Transport through Aquatic Pathways

E. flexuosa has been documented to be transported by boat hulls (Lougheed and Stevenson 2004). There is recreational and commercial boat traffic between the Calumet Harbor and multiple ports in Lake Michigan (USACE 2011a,b), including Muskegon, Michigan, where grass kelp can be found (NBIC 2012).

Anti-fouling hull paints are a possible measure for controlling *E. flexuosa* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS because of wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use

of biocide-based hull paints because of their impact on biodiversity as a result of leaching.

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS by human-mediated transport through aquatic pathways. Agency monitoring and voluntary occurrence reporting in combination with education and outreach may be used to determine where to target nonstructural control measures, in particular, algaecides. The implementation of a ballast/bilge water exchange program, education and outreach, as well as laws and regulations, may reduce the human-mediated transport of *E. flexuosa* to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: *E. flexuosa* is highly fecund (Beach et al. 1995); propagule release via mitotic spores and meiotic gametes occurs on a daily basis in lower latitudes (Hill 2001). Spores and gametes of this species are photosynthetically competent upon release into the water column, and unicells remain motile for up to 11 days (Hill 2001). A 2003 study indicated *E. flexuosa* was present in Muskegon Lake and in 2 of 11 nearby inland lakes and lagoons that were surveyed (Sturtevant 2011). Overall, the results suggested that, although *E. flexuosa* may not be widespread, local abundance can be high (Lougheed and Stevenson 2004). *E. flexuosa* is an excellent pioneer species, able to colonize newly available strata year-round (Emerson and Zedler 1978). However, it is not good at competing with other successional species. In an experimental study of the recolonization of intertidal algae following a disturbance, Emerson and Zedler (1978) showed that *E. flexuosa* tends to be present at low densities (as measured in percent cover) throughout the year in undisturbed zones. Following disturbance to an area, the density of this species increases dramatically within 2–3 weeks (Emerson and Zedler 1978). However, as other algae become established, the percent cover for this species declines (Emerson and Zedler 1978). This observation suggests that *E. flexuosa* may be unable to maintain dominance in the presence of later successional species such as *Ulva* spp. and other perennial algae that are present in the Great Lakes (Emerson and Zedler 1978).

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS from natural dispersion and human-mediated transport through aquatic pathways. The Nonstructural Alternative would include agency monitoring to locate areas where *E. flexuosa* is established. Additionally, outreach and education may be used to inform the public of *E. flexuosa* management efforts, and voluntary occurrence reporting may supplement agency monitoring. Data collected through agency monitoring and voluntary occurrence reporting would focus management efforts on locations where *E. flexuosa* is abundant. Managing nutrient loads to waterways may reduce habitat suitability for this species at current infestations and may reduce the ability for species establishment near CAWS. The Nonstructural Alternative may reduce the current abundance and distribution of *E. flexuosa*.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: The closest that *E. flexuosa* has been recorded to Calumet Harbor was on the beaches of Muskegon Lake in 2003 (Lougheed and Stevenson 2004). Muskegon Lake is a coastal lake on the eastern shore of, and hydrologically connected to, Lake Michigan (Lougheed and Stevenson 2004). Muskegon Lake is approximately 290 km (180 mi) from the pathway entrance. Water circulation in Lake Michigan is typically counterclockwise (Beletsky and Schwab 2001). Therefore, currents would transport the species north, away from the pathway entrance.

The Nonstructural Alternative includes ANS control methods such as algaecides, dredging, water drawdown, and alum application, which are expected to control the expansion of *E. flexuosa* from its current location.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The species is widespread around the world in inland and coastal waters (Lougheed and Stevenson 2004). The native range of *E. flexuosa* is unknown, but the species is found worldwide; therefore, the climate in southern Lake Michigan is likely to be suitable. *E. flexuosa* is primarily a marine species that is highly tolerant of freshwater conditions. Lougheed and Stevenson (2004) state that industrial activity resulting in increased nutrients and salinity of associated waters may have facilitated the invasion of this marine taxon. It is found at depths ranging from the intertidal zone to approximately 5 m (16.4 ft) below the surface (Beach et al. 1995). Species of this weedy genus are often the first to colonize open substrata (Beach et al. 1995). Growth of *E. flexuosa* in outdoor ponds in India showed that this species was able to sustain growth in water temperatures as high as 30°C (86°F) (Mairh et al. 1986). Favorable growth was maintained at temperatures ranging from 15.5 to 30°C (59.9 to 8°F) (Hill 2001). Optimal reproduction occurs at temperatures under 30°C (86°F) in waters with a pH of approximately 8.2 (Hill 2001). Historically, urban runoff has allowed the establishment of several eutrophic and/or marine species offshore of the Chicago area, including *Bangia atropurpurea* and *Cyclotella cryptica*.

E. flexuosa typically grows in clusters on plant roots, rocks, or wood, or as an epiphyte on other plants (Beach et al. 1995). In Muskegon Lake it was primarily found growing on submerged aquatic macrophytes in windswept, littoral areas of eutrophic and mesotrophic lakes (Lougheed and Stevenson 2004). Submerged macrophytes are

not common along the shoreline of southern Lake Michigan, but there are extensive *Cladophora* beds that may provide suitable habitat (MTRI 2012). Calumet Harbor has generally sandy beaches and riprap, which are suitable for the species to colonize.

The Nonstructural Alternative includes measures such as managing nutrient loads to waterways. These measures may reduce habitat suitability for *E. flexuosa* at its current location at Muskegon Lake.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

The Nonstructural Alternative is expected to manage nutrient loads to waterways where *E. flexuosa* is currently located. Additionally, future climate change or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes Basin for *E. flexuosa*. In particular, mean water temperature is expected to increase (Wuebbles et al. 2010). However, *E. flexuosa* is found in a wide range of water temperatures and is globally distributed (Hill 2001). Therefore, temperature is expected to remain suitable. However, changes in nutrients and conductivity related to future climate change or new environmental regulations may affect the suitability of southern Lake Michigan for this species.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Low	***Low***	***Low***	***Low***

[a] The highlighted table cells indicate a rating change in the probability element.

Evidence for Probability Rating (Considering All Life Stages)

T_0: *E. flexuosa* is a highly invasive, highly fecund species (sections 2a, 2c) that can be transferred by boats (section 2b). Calumet Harbor receives cargo vessels and recreational boat activity from Lake Michigan, as well as cargo vessels from many ports in the Great Lakes, including Muskegon, Michigan, where grass kelp can be found. The species has been established in Lake Michigan since 2003, but it has yet to be identified at Calumet Harbor (section 2e). The habitat near Calumet Harbor is likely suitable for *E. flexuosa* due to the higher energy shoreline of Lake Michigan with rocky shoals and hard substrate. The species is opportunistic and may be able to inhabit disturbed areas that lack competitors such as *Cladophora* (section 2f). Historically, urban runoff has supported marine algal species in the vicinity of Calumet Harbor (section 2e). Currently, however, *E. flexuosa* has only been recorded along the eastern shoreline of central Lake Michigan.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *E. flexuosa*. Until additional study is completed and these issues are addressed, anti-fouling

hull paints are considered ineffective at controlling the arrival of *E. flexuosa* at the CAWS via fouled vessels.

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS by natural dispersion and human-mediated transport through aquatic pathways. The Nonstructural Alternative would also include agency monitoring to locate areas where *E. flexuosa* is established. Additionally, outreach and education may be used to inform the public of *E. flexuosa* management efforts, and voluntary occurrence reporting may supplement agency monitoring. Informed by monitoring information, management efforts may be directed at controlling *E. flexuosa* abundance. Data collected through agency monitoring and voluntary occurrence reporting may be used to target dense populations of *E. flexuosa* and implement algaecide treatments to reduce biomass and population density. Additionally, managing nutrient loads to waterways may reduce habitat suitability for this species.

The Nonstructural Alternative reduces the likelihood of *E. flexuosa* arriving at the pathway by reducing the current abundance and distribution of *E. flexuosa*. However, the Nonstructural Alternative's low probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. *E. flexuosa* is highly invasive, and a suitable physical habitat is present in the vicinity of Calumet Harbor. The current of the lake may transport the species away from the pathway entrance; however, transport by boat is also possible.

The Nonstructural Alternative is expected to manage the spread of *E. flexuosa*, thereby reducing the likelihood of the species arriving at the aquatic pathway. Therefore, the probability of arrival is reduced to low.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Medium	Medium	Medium	***High***

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Uncertainty Rating

T_0: *E. flexuosa* is considered to be a rapid invader (section 2a), and the latest record of its presence is from 2003. Therefore, the current location of the species is uncertain (section 2e). In addition, this is a marine species, and the suitability of nutrient and conductivity levels in the vicinity of Calumet Harbor is uncertain.

The Nonstructural Alternative is expected to manage the spread and distribution of *E. flexuosa*. However, it is uncertain whether *E. flexuosa* has spread past the locations identified in 2003; therefore, the overall uncertainty is medium.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. In addition, the future effects of climate change on *E. flexuosa* and habitat suitability in Lake Michigan are uncertain.

The uncertainty revolving around the effectiveness of the Nonstructural Alternative to control the arrival of *E. flexuosa* at the CAWS is thought to increase with time. Therefore, uncertainty is high.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

E. flexuosa must move downstream to reach Brandon Road Lock and Dam. The species is highly invasive, has a rapid growth rate, and is tolerant to a wide range of environmental conditions (Lougheed and Stevenson 2004). Its spores are transported by currents, but the adults are attached unless they become dislodged, in which case they can be transported as floating mats (John et al. 2002).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., current-driven passage) of *E. flexuosa* spores and filaments through the aquatic pathway; therefore, this alternative is not expected to control the natural dispersion of *E. flexuosa* through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

E. flexuosa is documented to be transported by boat hulls (Lougheed and Stevenson 2004). Commercial vessel traffic to the Calumet Harbor is via the lake, but there is vessel traffic between Brandon Road Lock and Dam and the T.J. O'Brien Lock and Dam, which is located just below the Calumet Harbor (USACE 2011a,b). The discharge of ballast water originating from the Great Lakes would not be likely to occur within the CAWS (NBIC 2012), but hull transport to Brandon Road Lock and Dam is possible. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the *E. flexuosa* into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Anti-fouling hull paints are a possible measure for controlling *E. flexuosa* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS because of wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use

of biocide-based hull paints because of their impact on biodiversity as a result of leaching.

The Nonstructural Alternative is not expected to control the human-mediated transport of *E. flexuosa* spores and filaments through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: *E. flexuosa* has been found in drainage channels with slow water currents (Fernandez et al. 1998), as well as in reservoirs, ponds, and fast- and slow-flowing rivers (John et al. 2002). Most flows in the CAWS were less than 0.15 m/s (0.49 ft/s); the highest was 0.27 m/s (0.89 ft/s) (LimnoTech 2010). The CAWS is a heavily modified channel with little floodplain connection and few shallow marshy areas. The species is found at depths ranging from the intertidal zone to approximately 5 m (16.4 ft) below the surface (Beach et al. 1995). The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically around 5 m (16.4 ft) (LimnoTech 2010), suggesting that the depth there is suitable. Growth of the species is maintained at temperatures ranging from 15.5 to 30°C (59.9 to 86°F) (Hill 2001). The water temperature in the CAWS averages from 11.3 to 19.3°C (52.3 to 66.7°F) (MWRDGC 2010). The species has been found in turbid water (Sand-Jenson et al. 2008), and turbidity is high in the CAWS (LimnoTech 2010). *E. flexuosa* can be abundant in rivers and tributaries with hard water and high nutrient levels (Holmes and Whitton 1977). Aguilar-Rosas and Pacheco-Ruiz (1989) showed that *Enteromorpha* species develop abundantly in zones directly affected by pollution, even as the abundance of other genera decreases. In areas affected by polluted discharge, *E. flexuosa* can be a highly successful invader (Lougheed and Stevenson 2004). Portions of the CAWS flow through limestone bedrock, and there is heavy municipal water discharge into the CAWS; these sources may provide the nutrients and carbonates required by *E. flexuosa*.

Species of this weedy genus are often the first to colonize open substrata (Beach et al. 1995). *E. flexuosa* typically grows in clusters on plant roots, rocks, or wood, or as an epiphyte on other plants (Beach et al. 1995). The banks of the CAWS are typically a mix of stone blocks, steel sheet piling, and earthen banks with vegetation, and riprap banks are common. In the Calumet River, the Calumet Sag Channel, and the CSSC, there is suitable hard substrate in the form of concrete, riprap, pilings, bridges, and sheet pile (LimnoTech 2010). There are also ditches and tributaries along the Calumet Sag Channel that may provide suitable habitat.

The Nonstructural Alternative includes managing nutrient loads to waterways, which may affect *E. flexuosa* establishing in the CAWS and thereby reduce the abundance of

spores and filaments in the CAWS. However, the transport of spores and filaments through the CAWS would not be affected.
T_{10}: See T_0.
T_{25}: See T_0. The discharge of common municipal contaminants such as nutrients, metals, total dissolved solids, and sewage may decrease due to the adoption of water quality standards and effluent discharge limitations currently proposed for the CAWS (Raber 2012; Illinois Pollution Control Board 2012). These changes may reduce habitat suitability in the CAWS.
T_{50}: See T_{25}.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: *E. flexuosa* is thought to have a rapid invasion speed (section 3a) and can move from Lake Michigan to the Calumet River on boat hulls or by floating (section 3b). The planktonic spore stage may facilitate downstream transport to Brandon Road Lock and Dam (section 3a). Habitat is suitable for *E. flexuosa* throughout much of the CAWS (section 3d), and this species has been found in rivers and tributaries where suitable water quality conditions are present (section 3d). The urban runoff entering the CAWS may provide the high nutrient and conductivity levels that this species prefers. However, this opportunistic species may require an uncolonized habitat. There is low submerged aquatic macrophyte cover in the CAWS, which is a preferred habitat for this species (section 3d). Within the current time step, *E. flexuosa* spores or fragments may drift from Calumet Harbor to Brandon Road Lock and Dam as a result of natural dispersion or attached to vessels.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *E. flexuosa*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of *E. flexuosa* through the aquatic pathway via fouled vessels.

The Nonstructural Alternative is not expected to reduce the likelihood of *E. flexuosa* passing through the aquatic pathway. The alternative does not include measures to address the passage of *E. flexuosa* by the Lake Michigan diversion and the downstream passive transport of *E. flexuosa* spores and filaments to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating	Medium	Medium	Medium	Medium

Evidence for Uncertainty Rating

T_0: Although this species is commonly found in waters that are heavily affected by human uses, it is a marine species, and the ability of hydraulic and chemical conditions in the inland portions of the CAWS to support *E. flexuosa* is uncertain. *E. flexuosa* is an opportunistic species that may grow in the CAWS where a disturbance opens up space for the species. The potential rate of spread of this species through the CAWS is uncertain.

The Nonstructural Alternative includes managing nutrient loads to waterways. The effect of nutrient management on *E. flexuosa* abundance and its natural rate of spread is uncertain. Therefore, the Nonstructural Alternative is not expected to control the natural dispersion or human-mediated transfer of *E. flexuosa* through the aquatic pathway. Overall, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. The future effects of water quality improvements on *E. flexuosa* and habitat suitability in the CAWS are uncertain.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

PATHWAY 4

INDIANA HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL ALTERNATIVE: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(passage)	Low	High	Low	High	Medium	High	Medium	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary[a]

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Medium	***Low***	Medium	***Low***	Medium	***Low***	***High***
P(passage)	Low	High	Low	High	Medium	High	Medium	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[b]	***Low(2)***	–	***Low***	–	***Low***	–

[a] The highlighted table cells indicate a rating change in the probability element.

[b] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Indiana Harbor and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative is not expected to impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

E. flexuosa is a marine attached alga with a worldwide distribution. The spores are released into the water daily and can float for 8 to 11 days (Beach et al. 1995). The species is highly invasive, has a rapid growth rate, and is tolerant to a wide range of environmental conditions (Lougheed and Stevenson 2004). The ecological success of *E. flexuosa* is, in part, attributable to the readily available pool of motile unicells that are able to rapidly colonize new areas (Hill 2001). The chance for successful settlement of these cells is greatly enhanced because gametes and zoospores of this species remain viable for 10 or more days after release due to their ability to photosynthesize (Beach et al. 1995). Adults are attached unless they become dislodged, in which case they can be transported as floating mats (John et al. 2002).

The Nonstructural Alternative is expected to impact the arrival of *E. flexuosa* from natural dispersion through aquatic pathways to the CAWS. The Nonstructural Alternative includes ANS control methods such as algaecides, dredging, water drawdown, and alum application, which may impact the invasion speed of *E. flexuosa* by reducing its existing population.

b. Human-Mediated Transport through Aquatic Pathways

E. flexuosa is documented to be transported by boat hulls (Lougheed and Stevenson 2004). There is heavy boat traffic between the Indiana Harbor and multiple ports in Lake Superior and Lake Michigan (USACE 2011a, b), including Muskegon, Michigan, where this species can be found (NBIC 2012).

Anti-fouling hull paints are a possible measure for controlling *E. flexuosa* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS because of wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity as a result of leaching.

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS from human-mediated transport through aquatic pathways. Agency monitoring and voluntary occurrence reporting in combination with education and outreach may be used to determine where to target nonstructural control measures, in particular, algaecides. The implementation of a ballast/bilge water exchange program, education and outreach, as well as laws and regulations, may reduce the human-mediated transport of *E. flexuosa* to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: *E. flexuosa* is highly fecund (Beach et al. 1995); propagule release via mitotic spores and meiotic gametes occurs on a daily basis in lower latitudes (Hill 2001). Spores and gametes of this species are photosynthetically competent upon release into the water column, and unicells remain motile for up to 11 days (Hill 2001). A 2003 study indicated *E. flexuosa* was present in Muskegon Lake and in 2 of 11 nearby inland lakes and lagoons that were surveyed (Sturtevant 2011). Overall, the results suggested that, although *E. flexuosa* may not be widespread, local abundance can be high (Lougheed and Stevenson 2004). *E. flexuosa* is an excellent pioneer species, able to colonize newly available strata year-round (Emerson and Zedler 1978). However, it is not good at competing with other successional species. In an experimental study of the recolonization of intertidal algae following disturbance, Emerson and Zedler (1978) showed that *E. flexuosa* tends to be present in low densities (as measured in percent cover) throughout the year in undisturbed zones. Following a disturbance to an area, the density of this species increases dramatically within 2–3 weeks (Emerson and Zedler 1978). However, as other algae become established, the percent cover for *E. flexuosa* declines (Emerson and Zedler 1978). This observation suggests that *E. flexuosa* may be unable to maintain dominance in the presence of later successional species such as *Ulva* spp. and other perennial algae that are present in the Great Lakes (Emerson and Zedler 1978).

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS from natural dispersion through aquatic pathways. The Nonstructural Alternative would include agency monitoring to locate areas where *E. flexuosa* is established. Additionally, outreach and education may be used to inform the public of *E. flexuosa* management efforts, and voluntary occurrence reporting may supplement agency monitoring. Data collected through agency monitoring and voluntary occurrence reporting would focus management efforts on locations where *E. flexuosa* is abundant. Managing nutrient loads to waterways may reduce habitat suitability for this species at current infestations and may reduce the ability for species establishment near CAWS. The Nonstructural Alternative may reduce the current abundance and distribution of *E. flexuosa*.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: The closest to Indiana Harbor that *E. flexuosa* has been recorded was on the beaches of Muskegon Lake in 2003 (Lougheed and Stevenson 2004). Muskegon Lake is a coastal lake on the eastern shore of, and with a hydrologic connection to, Lake Michigan (Lougheed and Stevenson 2004). Muskegon Lake is approximately 290 km (180 mi) from the pathway entrance. Water circulation in Lake Michigan is typically counterclockwise (Beletsky and Schwab 2001). Therefore, currents would transport the species north, away from the pathway entrance.

The Nonstructural Alternative includes ANS control methods such as algaecides, dredging, water drawdown, and alum application, which may control the expansion of *E. flexuosa* from its current location.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *E. flexuosa* is widespread around the world in inland and/or coastal waters (Lougheed and Stevenson 2004). The native range of the species is unknown, but *E. flexuosa* is found worldwide, and therefore the climate in southern Lake Michigan is likely to be suitable. *E. flexuosa* is primarily a marine species, but it is highly tolerant of freshwater conditions. Lougheed and Stevenson (2004) state that industrial activity resulting in increased nutrients and salinity of associated waters may have facilitated the invasion of this marine taxon. It is found at depths ranging from the intertidal zone to approximately 5 m (16.4 ft) below the surface (Beach et al. 1995). Species of this weedy genus are often the first to colonize open substrata (Beach et al. 1995). Growth of this species in outdoor ponds in India showed that *E. flexuosa* was able to sustain growth in water temperatures as high as 30°C (86°F) (Mairh et al. 1986). Favorable growth was maintained at temperatures ranging from 15.5 to 30°C (59.9 to 86°F) (Hill 2001). Optimal reproduction occurs at temperatures under 30°C (86°F), in waters with a pH of approximately 8.2 (Hill 2001). Historically, urban runoff has allowed the establishment of several eutrophic and/or marine species offshore of the Chicago area, including *Bangia atropurpurea* and *Cyclotella cryptica*.

E. flexuosa typically grows in clusters on plant roots, rocks, or wood, or as an epiphyte on other plants (Beach et al. 1995). In Muskegon Lake, it was primarily found growing on submerged aquatic macrophytes in windswept, littoral areas of eutrophic and mesotrophic lakes (Lougheed and Stevenson 2004). Submerged macrophytes are not common along the shoreline of southern Lake Michigan, but there are extensive *Cladophora* beds that may provide suitable habitat (MTRI 2012). Indiana Harbor has generally sandy beaches and riprap that are suitable for the species to colonize.

The Nonstructural Alternative includes measures such as managing nutrient loads to waterways. Such measures may reduce habitat suitability for *E. flexuosa* at its current location at Muskegon Lake.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. The Nonstructural Alternative is expected to manage nutrient loads to waterways where *E. flexuosa* is currently located. Additionally, future climate change or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for *E. flexuosa*. In particular, mean water temperature is expected to increase (Wuebbles et al. 2010). However, *E. flexuosa* is found in a wide range of water temperatures and is globally distributed (Hill 2001). Therefore, temperature is expected to remain suitable. However, changes in nutrients and conductivity related to future climate change or new environmental regulations may affect the suitability of southern Lake Michigan for this species.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Low	***Low***	***Low***	***Low***

[a] The highlighted table cells indicate a rating change in the probability element.

Evidence for Probability Rating (Considering All Life Stages)

T_0: *E. flexuosa* is a highly invasive, highly fecund species (sections 2a, 2c) that can be transferred by boats (section 2b). Indiana Harbor receives heavy cargo vessel traffic from ports in the Great Lakes, including Muskegon, Michigan, where grass kelp can be found. The species has been established in Lake Michigan since 2003, but it has yet to be identified at Indiana Harbor (section 2e). The habitat near Indiana Harbor is likely suitable for *E. flexuosa* due to the higher energy shoreline of Lake Michigan, and its rocky shoals and hard substrate. The species is opportunistic and may be able to populate disturbed areas that remove competitors such as *Cladophora* (section 2f). Historically, urban runoff has supported marine algal species in the vicinity of Indiana Harbor (section 2e). Currently, *E. flexuosa* has only been recorded along the eastern shoreline of central Lake Michigan.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *E. flexuosa*. Until additional study is completed and these issues are addressed, anti-fouling

hull paints are considered ineffective at controlling the arrival of *E. flexuosa* at the CAWS via fouled vessels.

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS from natural dispersion and human-mediated transport through aquatic pathways. The Nonstructural Alternative would also include agency monitoring to locate areas where *E. flexuosa* is established. Additionally, outreach and education may be used to inform the public of *E. flexuosa* management efforts, and voluntary occurrence reporting may supplement agency monitoring. Informed by monitoring information, management efforts may be directed at controlling *E. flexuosa* abundance. Data collected through agency monitoring and voluntary occurrence reporting may be used to target dense populations of *E. flexuosa* and implement algaecide treatments to reduce biomass and population density. Additionally, managing nutrient loads to waterways may reduce habitat suitability for this species. The Nonstructural Alternative may reduce the current abundance and distribution of *E. flexuosa*.

The Nonstructural Alternative reduces the likelihood of *E. flexuosa* arriving at the pathway by reducing the current abundance and distribution of *E. flexuosa*. However, the Nonstructural Alternative's low probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. *E. flexuosa* is highly invasive, and suitable physical habitat is present in the vicinity of Indiana Harbor.

The Nonstructural Alternative is expected to manage the spread of *E. flexuosa*, thereby reducing the likelihood of *E. flexuosa* arriving at the CAWS through aquatic pathways. Therefore, the probability of arrival is reduced to low.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Medium	Medium	Medium	***High***

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Uncertainty Rating

T_0: *E. flexuosa* is considered to be a rapid invader (section 2a), and the latest record of its presence is from 2003. Therefore, the current location of the species is uncertain (section 2e). In addition, this is a marine species, and the suitability of nutrient and conductivity levels in the vicinity of Indiana Harbor is uncertain.

The Nonstructural Alternative is expected to manage the spread and distribution of *E. flexuosa*. However, it is uncertain whether *E. flexuosa* has spread past the locations identified in 2003; therefore, the overall uncertainty is medium.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. In addition, the future effects of climate change on *E. flexuosa* and habitat suitability in Lake Michigan are uncertain.

The uncertainty revolving around the effectiveness of the Nonstructural Alternative to control the arrival of *E. flexuosa* at the CAWS is thought to increase with time. Therefore, uncertainty is high.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

E. flexuosa must move downstream to reach Brandon Road Lock and Dam. The species is highly invasive, has a rapid growth rate, and is tolerant to a wide range of environmental conditions (Lougheed and Stevenson 2004). Its spores are transported by currents, but adults are attached unless they become dislodged, in which case they can be transported as floating mats (John et al. 2002).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., current-driven passage) of *E. flexuosa* spores and filaments through the aquatic pathway; therefore, this alternative is not expected to control the natural dispersion of *E. flexuosa* through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

E. flexuosa has been documented to be transported by boat hulls (Lougheed and Stevenson 2004). Hull transport to Brandon Road Lock and Dam is possible, but most commercial vessel traffic to Indiana Harbor is via the lake, and there is little commercial vessel traffic to inland ports in the CAWS from Indiana Harbor (NBIC 2012). There is little, if any, vessel traffic in the Grand Calumet River due to its shallow depth. *E. flexuosa* could be transported in ballast water, but the discharge of ballast water originating from the Great Lakes would not likely occur within the CAWS (NBIC 2012).

Anti-fouling hull paints are a possible measure for controlling *E. flexuosa* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS because of wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative does not address the human-mediated transport of *E. flexuosa* spores and filaments through the aquatic pathway; therefore, this alternative is not expected to control the human-mediated transport of *E. flexuosa* through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *E. flexuosa* has been found in drainage channels with slow water currents (Fernandez et al. 1998), as well as in reservoirs, ponds, and fast- and slow-flowing rivers (John et al. 2002). Most flows in the CAWS were less than 0.15 m/s (0.49 ft/s); the highest was 0.27 m/s (0.89 ft/s) (LimnoTech 2010). Water flows out of Indiana Harbor into Lake Michigan. West of Indiana Harbor Canal, the easternmost sections of the Grand Calumet River also generally flow toward Lake Michigan, while other sections can flow east or west depending on location (Weiss et al. 1997). Thus, grass kelp would have to spread upstream to enter the CAWS and move to the Calumet Sag Channel. The CAWS is a heavily modified channel with little floodplain connection and few shallow marshy areas. The species is found at depths ranging from the intertidal zone to approximately 5 m (16.4 ft) below the surface (Beach et al. 1995). The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically around 5 m (16.4 ft) (LimnoTech 2010), suggesting that the depth there is suitable. Growth of the species is maintained at temperatures ranging from 15.5 to 30°C (59.9 to 86°F) (Hill 2001). The water temperature in the CAWS averages from 11.3 to 19.3°C (52.3 to 66.7°F) (MWRDGC 2010). The species has been found in turbid water (Sand-Jenson et al. 2008), and turbidity is high in the CAWS (LimnoTech 2010). *E. flexuosa* can be abundant in rivers and tributaries that have hard water and high nutrient levels (Holmes and Whitton 1977). Aguilar-Rosas and Pacheco-Ruiz (1989) showed that *Enteromorpha* species develop abundantly in zones directly affected by pollution, even as the abundance of other genera decreases. In areas affected by polluted discharge, *E. flexuosa* can be a highly successful invader (Lougheed and Stevenson 2004). Portions of the CAWS flow through limestone bedrock, and there is heavy municipal water discharge into the CAWS; these sources may provide the nutrients and carbonates required by *E. flexuosa*.

Species of this weedy genus are often the first to colonize open substrata (Beach et al. 1995). *E. flexuosa* typically grows in clusters on plant roots, rocks, or wood, or as an epiphyte on other plants (Beach et al. 1995). The banks of the CAWS are typically a mix of stone blocks, steel sheet piling, and earthen banks with vegetation, and riprap banks are common. In the Grand Calumet River, the Calumet Sag Channel, and the CSSC, there is suitable hard substrate in the form of concrete, riprap, pilings, bridges, and sheet pile (LimnoTech 2010). There are also ditches and tributaries along the Calumet Sag Channel that may provide suitable habitat.

The Nonstructural Alternative includes managing nutrient loads to waterways, which may reduce the probability of *E. flexuosa* establishing in the CAWS and thereby reducing the abundance of spores and filaments in the CAWS. However, the transport of spores and filaments through the CAWS would not be affected.

T_{10}: See T_0.

T_{25}: See T_0. The discharge of common municipal contaminants such as nutrients, metals, total dissolved solids, and sewage may decrease due to the adoption of water quality standards and effluent discharge limitations currently proposed for the CAWS (Raber 2012; Illinois Pollution Control Board 2012). These changes may reduce habitat suitability in the CAWS.

T_{50}: See T_{25}.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: *E. flexuosa* is thought to have a rapid invasion speed (section 3a) and can move from Lake Michigan to the Grand Calumet River by floating or on boat hulls (section 3b). The planktonic spore stage may facilitate downstream transport to Brandon Road Lock and Dam (section 3a). Habitat is suitable throughout much of the CAWS for *E. flexuosa* (section 3d), and this species has been found in rivers and tributaries where suitable water quality conditions are present (section 3d). The urban runoff entering the CAWS may provide the high nutrient and conductivity levels this species prefers. However, this is an opportunistic species that may require uncolonized habitat. There is low submerged aquatic macrophyte cover, a preferred habitat for this species, in the CAWS (section 3d). The lack of vessel traffic and the need for upstream movement through Indiana Harbor and the Grand Calumet River would likely slow the spread of this species to Brandon Road Lock and Dam.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *E. flexuosa*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of *E. flexuosa* through the aquatic pathway via fouled vessels.

The Nonstructural Alternative is not expected to reduce the likelihood of *E. flexuosa* passing through the aquatic pathway. The alternative does not include measures to address the passage of *E. flexuosa* by downstream passive transport of *E. flexuosa* spores and filaments to Brandon Road Lock and Dam.

Therefore, the Nonstructural Alternative's low probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0. Over time, grass kelp may be able to spread upstream through Indiana Harbor and the Grand Calumet River by wind driven currents. *E. flexuosa* is found in canals and rivers that have high nutrients and hard water, and these conditions are likely present in the CAWS (section 3d). This species can be a potentially rapid invader and, over time, may spread closer to Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to reduce the likelihood of *E. flexuosa* passing through the aquatic pathway. Therefore, the Nonstructural Alternative's medium probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Although this species is commonly found in waters that are heavily affected by human uses, it is a marine species, and the ability of hydraulic and chemical conditions in the inland portions of the CAWS to support *E. flexuosa* is uncertain. The potential rate of spread of this species through the CAWS is also uncertain. The lack of vessel traffic and the upstream movement required to pass through Indiana Harbor and the Grand Calumet River would slow passage to an uncertain degree.

The Nonstructural Alternative includes managing nutrient loads to waterways. The effect of nutrient management on *E. flexuosa* abundance and its natural rate of spread is uncertain. Therefore, the Nonstructural Alternative is not expected to control the natural dispersion or human-mediated transport of this species through the aquatic pathway. Overall, uncertainty remains high.

T_{10}: See T_0.

T_{25}: See T_0. Although the probability of *E. flexuosa* passing through the CAWS increases with time, the future effects of water quality improvements on *E. flexuosa* and habitat suitability in the CAWS are uncertain. The ability to move upstream through Indiana Harbor and the Grand Calumet River also remain uncertain. Therefore, the Nonstructural Alternative is not expected to control the natural dispersion or human-mediated transport of *E. flexuosa* through the aquatic pathway. Overall, the uncertainty remains high.

T_{50}: See T_0.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

PATHWAY 5

BURNS SMALL BOAT HARBOR (BSBH) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL ALTERNATIVE: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(passage)	Low	High	Low	High	Medium	High	Medium	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary[a]

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Medium	***Low***	Medium	***Low***	Medium	***Low***	***High***
P(passage)	Low	High	Low	High	Medium	High	Medium	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[b]	***Low(2)***	–	***Low***	–	***Low***	–

[a] The highlighted table cells indicate a rating change in the probability element.

[b] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Burns Small Boat Harbor (BSBH) and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative is not expected to impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

E. flexuosa is a marine attached alga with a worldwide distribution. The spores are released into the water daily and can float for 8–11 days (Beach et al. 1995). The species is highly invasive, has a rapid growth rate, and is tolerant to a wide range of environmental conditions (Lougheed and Stevenson 2004). The ecological success of *E. flexuosa* is in part attributable to the readily available pool of motile unicells that are able to rapidly colonize new areas (Hill 2001). The chance for successful settlement of these cells is greatly enhanced because gametes and zoospores of this species remain viable for 10 or more days due to their ability to photosynthesize (Beach et al. 1995). Adults are attached unless they become dislodged, in which case they can be transported as floating mats (John et al. 2002).

The Nonstructural Alternative is expected to impact the arrival of *E. flexuosa* from natural dispersion through aquatic pathways to the CAWS. The Nonstructural Alternative includes ANS control methods such as algaecides, dredging, water drawdown, and alum application, which may impact the invasion speed of *E. flexuosa* by reducing its existing population.

b. Human-Mediated Transport through Aquatic Pathways

E. flexuosa has been documented to be transported by boat hulls (Lougheed and Stevenson 2004). There is no commercial vessel traffic to the BSBH from Lake Michigan (USACE 2011a). However, there is heavy commercial traffic to the adjacent Burns Harbor (USACE 2011a), including traffic from Muskegon, Michigan, where this species can be found (NBIC 2012).

Anti-fouling hull paints are a possible measure for controlling *E. flexuosa* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS because wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use

of biocide-based hull paints because of their impact on biodiversity as a result of leaching.

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS from human-mediated transport through aquatic pathways. Agency monitoring and voluntary occurrence reporting in combination with education and outreach may be used to determine where to target nonstructural control measures, in particular, algaecides. The implementation of a ballast/bilge water exchange program, education and outreach, as well as laws and regulations, may reduce the human-mediated transport of *E. flexuosa* to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: *E. flexuosa* is highly fecund (Beach et al. 1995); propagule release via mitotic spores and meiotic gametes occurs on a daily basis in lower latitudes (Hill 2001). Spores and gametes of this species are photosynthetically competent upon release into the water column, and unicells remain motile for up to 11 days (Hill 2001). A 2003 study indicated *E. flexuosa* was present in Muskegon Lake and in 2 of 11 nearby inland lakes and lagoons that were surveyed (Sturtevant 2011). Overall, the results suggested that, although *E. flexuosa* may not be widespread, local abundance can be high (Lougheed and Stevenson 2004). *E. flexuosa* is an excellent pioneer species, able to colonize newly available strata year-round (Emerson and Zedler 1978). However, it is not good at competing with other successional species. In an experimental study of recolonization of intertidal algae following disturbance, Emerson and Zedler (1978) showed that *E. flexuosa* tends to be present at low densities (as measured in percent cover) throughout the year in undisturbed zones. Following disturbance to an area, the density of this species increases dramatically within 2–3 weeks (Emerson and Zedler 1978). However, as other algae become established, the percent cover for this species declines (Emerson and Zedler 1978). This observation suggests that *E. flexuosa* may be unable to maintain dominance in the presence of later successional species such as *Ulva* spp. and other perennial algae that are present in the Great Lakes (Emerson and Zedler 1978).

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS from natural dispersion and human-mediated transport through aquatic pathways. The Nonstructural Alternative would include agency monitoring to locate areas where *E. flexuosa* is established. Additionally, outreach and education may be used to inform the public of *E. flexuosa* management efforts, and voluntary occurrence reporting may supplement agency monitoring. Data collected through agency monitoring and voluntary occurrence reporting would focus management efforts on locations where *E. flexuosa* is abundant. Managing nutrient loads to waterways may reduce habitat suitability for this species at current infestations and may reduce the ability for species establishment near CAWS. The Nonstructural Alternative may reduce the current abundance and distribution *of E. flexuosa*.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Existing Physical Human/Natural Barriers*

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. *Distance from Pathway*

T_0: The closest that *E. flexuosa* has been recorded to BSBH was on the beaches of Muskegon Lake in 2003 (Lougheed and Stevenson 2004). Muskegon Lake is a coastal lake on the eastern shore of, and with a hydrologic connection to, Lake Michigan (Lougheed and Stevenson 2004). Muskegon Lake is approximately 290 km (180 mi) from the pathway entrance. Water circulation in Lake Michigan is typically counterclockwise (Beletsky and Schwab 2001). Therefore, currents would transport the species north, away from the pathway entrance.

The Nonstructural Alternative includes ANS control methods such as algaecides, dredging, water drawdown, and alum application, which may control the expansion of *E. flexuosa* from its current location.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: The species is widespread around the world in inland and/or coastal waters (Lougheed and Stevenson 2004). The native range of *E. flexuosa* is unknown, but the species is found worldwide, and therefore the climate in southern Lake Michigan is likely to be suitable. *E. flexuosa* is primarily a marine species, but it is highly tolerant of freshwater conditions. Lougheed and Stevenson (2004) state that industrial activity resulting in increased nutrients and salinity of associated waters may have facilitated the invasion of this marine taxon. It is found at depths ranging from the intertidal zone to approximately 5 m (16.4 ft) below the surface (Beach et al. 1995). Species of this weedy genus are often the first to colonize open substrata (Beach et al. 1995). Growth of this species in outdoor ponds in India showed that *E. flexuosa* was able to sustain growth in water temperatures as high as 30°C (86°F) (Mairh et al. 1986). Favorable growth was maintained at temperatures ranging from 15.5 to 30°C (59.9 to 86°F) (Hill 2001). Optimal reproduction occurs at temperatures under 30°C (86°F) in waters with a pH of approximately 8.2 (Hill 2001). Historically, urban runoff has allowed the establishment of several eutrophic and/or marine species offshore of the Chicago area, including *Bangia atropurpurea* and *Cyclotella cryptica*.

E. flexuosa typically grows in clusters on plant roots, rocks, or wood, or as an epiphyte on other plants (Beach et al. 1995). In Muskegon Lake it was primarily found growing on submerged aquatic macrophytes in windswept, littoral areas of eutrophic and mesotrophic lakes (Lougheed and Stevenson 2004). Submerged macrophytes are

not common along the shoreline of southern Lake Michigan, but there are extensive *Cladophora* beds that may provide suitable habitat (MTRI 2012). BSBH has generally sandy beaches and riprap that are suitable for the species to colonize.

The Nonstructural Alternative includes measures such as managing nutrient loads to waterways. Such measures may reduce habitat suitability for *E. flexuosa* at its current location at Muskegon Lake.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

The Nonstructural Alternative is expected to manage nutrient loads to waterways where *E. flexuosa* is currently located. Additionally, future climate change or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes Basin for *E. flexuosa*. Mean water temperature in particular is expected to increase (Wuebbles et al. 2010). However, *E. flexuosa* is found in a wide range of water temperatures and is globally distributed (Hill 2001). Therefore, temperature is expected to remain suitable. However, changes in nutrients and conductivity related to future climate change or new environmental regulations may affect the suitability of southern Lake Michigan for this species.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Low	***Low***	***Low***	***Low***

[a] The highlighted table cells indicate a rating change in the probability element.

Evidence for Probability Rating (Considering All Life Stages)

T_0: *E. flexuosa* is a highly invasive, highly fecund species (sections 2a and 2c) that can be transferred by boats (section 2b). BSBH does not receive cargo vessels, but the adjacent Burns Harbor receives heavy cargo vessel traffic from ports in the Great Lakes, including Muskegon, Michigan, where grass kelp can be found. The species has been established in Lake Michigan since 2003, but it has yet to be identified at BSBH (section 2e). The habitat near BSBH is likely suitable for *E. flexuosa* to inhabit due to the higher energy shoreline of Lake Michigan, which has rocky shoals and hard substrate. The species is opportunistic and may be able to populate disturbed areas that remove competitors such as *Cladophora* (section 2f). Historically, urban runoff has supported marine algal species in the vicinity of BSBH (section 2e). Currently, *E. flexuosa* has only been recorded along the eastern shoreline of central Lake Michigan.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *E. flexuosa*. Until additional study is completed and these issues are addressed, anti-fouling

hull paints are considered ineffective at controlling the arrival of *E. flexuosa* at the CAWS via fouled vessels.

The Nonstructural Alternative is expected to affect the arrival of *E. flexuosa* at the CAWS from natural dispersion and human-mediated transport through aquatic pathways. The Nonstructural Alternative would also include agency monitoring to locate areas where *E. flexuosa* is established. Additionally, outreach and education may be used to inform the public of *E. flexuosa* management efforts, and voluntary occurrence reporting may supplement agency monitoring. Informed by monitoring information, management efforts may be directed at controlling *E. flexuosa* abundance. Data collected through agency monitoring and voluntary occurrence reporting may be used to target dense populations of *E. flexuosa* and implement algaecide treatments to reduce biomass and population density. Additionally, managing nutrient loads to waterways may reduce habitat suitability for this species. The Nonstructural Alternative may reduce the current abundance and distribution of *E. flexuosa*.

The Nonstructural Alternative reduces the likelihood of *E. flexuosa* arriving at the pathway by reducing the current abundance and distribution of *E. flexuosa*. However, the Nonstructural Alternative's low probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. The current of the lake may transport the species away from the pathway entrance; however, transport by boat is possible. The Nonstructural Alternative is expected to manage the natural dispersion (i.e. current-driven pasage) of *E. flexuosa* through aquatic pathways to the CAWS, thereby reducing the likelihood of *E. flexuosa* arriving at the aquatic pathway. Therefore, the probability of arrival is reduced to low.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Medium	Medium	Medium	***High***

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Uncertainty Rating

T_0: *E. flexuosa* is considered to be a rapid invader (section 2a), and the latest record of its presence is from 2003. Therefore, the current location of the species is uncertain (section 2e). In addition, this is a marine species, and the suitability of nutrient and conductivity levels in the vicinity of BSBH is uncertain.

The Nonstructural Alternative is expected to manage the spread and distribution of *E. flexuosa*. However, it is uncertain whether *E. flexuosa* has spread past the locations identified in 2003; therefore, the overall uncertainty is medium.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. In addition, the future effects of climate change on *E. flexuosa* and habitat suitability in Lake Michigan are uncertain.

The uncertainty revolving around the effectiveness of the Nonstructural Alternative to control the arrival of *E. flexuosa* at the CAWS is thought to increase with time. Therefore, uncertainty is high.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

E. flexuosa must move downstream to reach Brandon Road Lock and Dam. The species is highly invasive, has a rapid growth rate, and is tolerant to a wide range of environmental conditions (Lougheed and Stevenson 2004). Its spores are transported by currents, but adults are attached unless they become dislodged, in which case they can be transported as floating mats (John et al. 2002).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., current-driven passage) of *E. flexuosa* spores and filaments through the aquatic pathway; therefore, this alternative is not expected to control the natural dispersion of *E. flexuosa* through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

E. flexuosa has been documented to be transported by boat hulls (Lougheed and Stevenson 2004). Hull transport to Brandon Road Lock and Dam is possible, but vessel traffic to BSBH is via the lake, and there is little commercial vessel traffic to inland ports in the CAWS from Indiana Harbor (NBIC 2012). There is no commercial vessel traffic in the south branch of the Little Calumet River due to its shallow depth. This species could be transported in ballast water, but the discharge of ballast water originating from the Great Lakes would not be likely to occur within the CAWS (NBIC 2012).

Anti-fouling hull paints are a possible measure for controlling *E. flexuosa* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS because of wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity as a result of leaching.

The Nonstructural Alternative does not address the human-mediated transport of *E. flexuosa* through the aquatic pathway; therefore, this alternative is not expected to control the human-mediated transport of *E. flexuosa* through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *E. flexuosa* has been found in drainage channels with slow water currents (Fernandez et al. 1998), as well as in reservoirs, ponds, and fast- and slow-flowing rivers (John et al. 2002). Most flows in the CAWS were less than 0.15 m/s (0.49 ft/s); the highest was 0.27 m/s (0.89 ft/s) (LimnoTech 2010). Water flows out of BSBH into Lake Michigan. The eastern segment of the south Branch of the Little Calumet River also generally flows toward Lake Michigan, while other sections can flow east or west depending on their location (GSWMD 2008). Thus, grass kelp would have to spread upstream to enter the CAWS and move to the Calumet Sag Channel. The CAWS is a heavily modified channel with little floodplain connection and few shallow marshy areas. The species is found at depths ranging from the intertidal zone to approximately 5 m (16.4 ft) below the surface (Beach et al. 1995). The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically around 5 m (16.4 ft) (LimnoTech 2010), suggesting that the depth there is suitable. Growth of the species is maintained at temperatures ranging from 15.5 to 30°C (59.9 to 86°F) (Hill 2001). The water temperature in the CAWS averages from 11.3 to 19.3°C (52.3 to 66.7°F) (MWRDGC 2010). The species has been found in turbid water (Sand-Jenson et al. 2008), and turbidity is high in the CAWS (LimnoTech 2010). *E. flexuosa* can be abundant in rivers and tributaries with hard water and high nutrient levels (Holmes and Whitton 1977). Aguilar Rosas and Pacheco-Ruiz (1989) showed that *Enteromorpha* species develop abundantly in zones directly affected by pollution, even as the abundance of other genera decreases. In areas affected by polluted discharge, *E. flexuosa* can be a highly successful invader (Lougheed and Stevenson 2004). Portions of the CAWS flow through limestone bedrock, and there is heavy municipal water discharge into the CAWS; these sources may provide the nutrients and carbonates required by *E. flexuosa.*

Species of this weedy genus are often the first to colonize open substrata (Beach et al. 1995). The species typically grows in clusters on plant roots, rocks, or wood, or as an epiphyte on other plants (Beach et al. 1995). The banks of the CAWS are typically a mix of stone blocks, steel sheet piling, and earthen banks with vegetation, and riprap banks are common. Large sections of the Little Calumet River have overhanging vegetation and may be suitable for the species. In the North Leg of the Little Calumet River, the Calumet Sag Channel, and the CSSC, there is suitable hard substrate in the form of concrete, riprap, pilings, bridges, and sheet pile (LimnoTech 2010). There are also ditches and tributaries along the Calumet Sag Channel that may provide suitable habitat.

The Nonstructural Alternative includes managing nutrient loads to waterways, which may affect *E. flexuosa* establishing in the CAWS and thereby reducing the abundance of spores and filaments in the CAWS. However, the transport of spores and filaments through the CAWS would not be affected.

T_{10}: See T_0.

T_{25}: See T_0. The discharge of common municipal contaminants such as nutrients, metals, total dissolved solids, and sewage may decrease due to the adoption of water quality standards and effluent discharge limitations currently proposed for the CAWS (Raber 2012; Illinois Pollution Control Board 2012). These changes may reduce habitat suitability in the CAWS.

T_{50}: See T_{25}.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: *E. flexuosa* is thought to have a rapid invasion speed (section 3a) and can move from Lake Michigan to the Little Calumet River by floating (section 3a). The planktonic spore stage may facilitate downstream transport to Brandon Road Lock and Dam (section 3a). Habitat is suitable throughout much of the CAWS for *E. flexuosa* (section 3d), and this species has been found in rivers and tributaries where suitable water quality conditions are present (section 3d). The urban runoff entering the CAWS may provide the high nutrient and conductivity levels that this species prefers. However, this opportunistic species may require uncolonized habitat. There is low submerged aquatic macrophyte cover, a preferred habitat for this species (section 3d), in the CAWS. The lack of vessel traffic and the need for upstream movement through BSBH and the south branch of the Little Calumet River would likely slow the spread of this species to Brandon Road Lock and Dam.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *E. flexuosa*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of *E. flexuosa* through the aquatic pathway via fouled vessels.

The Nonstructural Alternative is not expected to reduce the likelihood of *E. flexuosa* passing through the aquatic pathway. The alternative does not include measures to address the passage of *E. flexuosa* by the Lake Michigan diversion and the downstream passive transport of *E. flexuosa* spores and filaments to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's low probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0. Over time, grass kelp may be able to spread upstream through BSBH and the Little Calumet River by wind-driven currents. *E. flexuosa* is found in canals and rivers that have high nutrients and hard water, and these conditions are likely to be present in the CAWS (section 3d). This species is a potentially rapid invader and, over time, may spread closer to Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to reduce the likelihood of *E. flexuosa* passing through the aquatic pathway; therefore, the Nonstructural Alternative's medium probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Although this species is commonly found in waters that are heavily affected by human uses, it is a marine species, and the ability of hydraulic and chemical conditions in the inland portions of the CAWS to support *E. flexuosa* is uncertain. The potential rate of spread of this species through the CAWS is also uncertain. The lack of vessel traffic and the upstream movement required to move through BSBH and the Little Calumet River would slow passage to an uncertain degree.

The Nonstructural Alternative includes managing nutrient loads to waterways. The effect of nutrient management on *E. flexuosa* abundance and its natural rate of spread is uncertain. Overall, the Nonstructural Alternative is not expected to control the natural dispersion or human-mediated transport of *E. flexuosa* through the aquatic pathway. Therefore, the uncertainty remains high.

T_{10}: See T_0.

T_{25}: See T_0. Although the probability of *E. flexuosa* passing through the CAWS increases with time, the future effects of water quality improvements on *E. flexuosa* and habitat suitability in the CAWS are uncertain. Therefore, the uncertainty remains high.

T_{50}: See T_0.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. **P(spreads) T_0-T_{50}: MEDIUM**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

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E.2.2.1.2 Red Algae (Bangia atropurpurea)

NONSTRUCTURAL ALTERNATIVE

This alternative would potentially include a combination of the following measures that may be implemented at time step 0 (T_0, in units of years) by local, state, and federal agencies and the public. The Nonstructural Alternative would include the development of a monitoring and response program.

Nonstructural Alternative Measures for Red Algae

Option or Technology	Description
Education and Outreach	• Education of recreational waterway users • Signage, pamphlets, and brochures on how to identify ANS and control the spread of ANS; promote national campaigns (i.e., "Stop Aquatic Hitchhikers") • Managing nutrient loads to waterways (e.g., grass buffer zones, limited fertilizer use, voluntary improvements to waterway discharges, etc.)
Anti-fouling Hull Paints	• Education of vessel owners and operators to promote use of anti-fouling paints
Ballast/Bilge-water Exchange	• Ballast/Bilge-water exchange
Monitoring	• Agency monitoring • Voluntary occurrence reporting
Laws and Regulations	• Quarantine-restricted site access • Mandatory watercraft and trailer inspection and decontamination • Restrictions on nutrient loads to waterways

	ANS Controls	ANS Factsheet[a]
ANS Control Methods	Algaecides	Algaecides
	Dredging	Manual harvest and mechanical control methods
	Alteration of water quality (alum)	Alteration of water quality

[a] For more information, refer to GLMRIS Team (2012).

PATHWAY 1

WILMETTE PUMPING STATION (WPS) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Medium	High	Medium	High	Medium	High	Medium	High
P(passage)	High	High	High	High	High	High	High	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Medium	High	Medium	High	Medium	High	Medium	High
P(passage)	High	High	High	High	High	High	High	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the WPS and the Brandon Road Lock and Dam over the next 50 years. The Nonstructural Alternative does not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

b. Type of Mobility/Invasion Speed

Red algae was first recorded from Lake Erie in 1964 (Edwards and Harrold 1970). Rapid spread has been documented for red algae (Edwards and Harrold 1970; Sonzogni et al. 1983). In the Great Lakes, it spread from Lake Erie to southern Lake Michigan within a decade; in Milwaukee, it grew from a few filaments to a high-density community within 4 years (Lin and Blum 1977). Red algae was documented on the Canadian side of Lake Huron in 1980 (Jackson 1988). Red algae has a prolonged monospore release that promotes population spread (Sheath et al. 1985).

The Nonstructural Alternative is not expected to affect the arrival of red algae at the Chicago Area Waterway System (CAWS) from natural dispersion (i.e., current-driven passage) through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Ballast water and ship hulls may transport red algae (Kipp 2011; Lin and Blum 1977). There is recreational boat traffic between Lake Michigan and the WPS, but no commercial traffic (USACE 2011a,b). The WPS is not a port with cargo vessel use; however, there is recreational boat use in the Wilmette Harbor that could potentially transport this species from the Great Lakes to the WPS.

Anti-fouling hull paints are a possible measure for controlling red algae on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic (with biocide) or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g. possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching. The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS from human-mediated transport through aquatic pathways.

c. *Current Abundance and Reproductive Capacity*

T_0: Recent information is not available to assess the current abundance of the species. Red algae has a prolonged monospore (Sheath et al. 1985). Red algae produces highest biomass in spring and fall, and it persists through the summer at low biomass (Kipp 2011). It is a seasonal annual (producing several generations per year) with a 4- to 6-week generation time (Sheath and Cole 1980; Sheath et al. 1985). Based on recent data from Lake Michigan, red algae (Division Rhodophyta) is rarely found in the Lake Michigan watershed (Whitman 2012). Agency monitoring and control methods to manage red algae in the Great Lakes and other locations where it has been documented are not likely to be successful because of the prolonged monospore release, which promotes rapid population spread.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the current abundance or reproductive capacity of red algae.

T_{10}: See T_0. The distribution and abundance of red algae in the Great Lakes could decrease because of improvements in the water quality of southern Lake Michigan, and this could reduce the anthropogenic inputs into Lake Michigan preferred by this species.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

d. *Existing Physical Human/Natural Barriers*

T_0: None. This species has been found in southern Lake Michigan (Lin and Blum 1977).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: None.

T_{25}: None.

T_{50}: None.

e. *Distance from Pathway*

T_0: Red algae was documented on the Canadian side of Lake Huron in 1980 (Jackson 1988). The species has been observed in southern Lake Michigan, including offshore of Wilmette, Illinois (Lin and Blum 1977). Red algae may be present at the WPS. However, based on recent data from Lake Michigan, red algae is not frequently found in southern Lake Michigan (Whitman 2012).

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect where it is able to establish and hence its locations in relation to the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: Red algae has been found in southern Lake Michigan offshore of the Chicago area. Suitable habitat is present at the WPS in the form of a rocky shoreline, consisting of concrete and steel manmade structures (Kipp 2011). The occurrence of red algae is restricted largely to harbor areas, which provide necessary levels of halogens and trace metals from point and nonpoint sources (Lin and Blum 1977). Harbors exist all along the shoreline of Lake Michigan.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the habitat suitability of southern Lake Michigan.

T_{10}: See T_0. The habitat of Lake Michigan is expected to remain suitable for red algae during this time step.

T_{25}: See T_{10}.

T_{50}: See T_{25}. Future climate change or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for red algae. Mean temperature in particular is expected to increase (Wuebbles et al. 2010). However, red algae is found in a wide range of water temperatures (2–26°C [35.6–78°F]) (Kipp 2011; Garwood 1982) and is globally distributed across wide latitudes from boreal to tropical (Guiry and Guiry 2012).

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating	Medium	Medium	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Red algae has been found in southern Lake Michigan in the vicinity of the CAWS (section 2e), and there is suitable habitat near and within the harbor adjacent to the WPS (section 2f). However, recent surveys suggest that red algae is not frequently found in southern Lake Michigan. Even if red algae is not currently present at the WPS, red algae has spread to multiple Great Lakes within a few decades (Kipp 2011), likely by vessel traffic; there is recreational vessel traffic between the northern Great Lakes and the WPS (USACE 2011b). Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by red algae. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of red algae to the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect the arrival of red algae through aquatic pathways to the CAWS. Therefore, the Nonstructural Alternative's medium probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Red algae is tolerant of a wide range of temperatures (section 2f). Therefore appropriate habitat conditions are expected to continue to be present (sections 2f, 2c) along the shoreline of Lake Michigan even when impacts on habitat related to future climate change (section 2f) are taken into account.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Although historically, red algae has been present in southern Lake Michigan, recent surveys do not indicate the presence of this species.
The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS through aquatic pathways. Therefore, the uncertainty remains high.
T_{10}: See T_0.
T_{25}: See T_0. The future population trends of red algae are uncertain. The future rate of spread for this species is uncertain. The effects of measures to improve water quality in Lake Michigan on red algae are uncertain.
T_{50}: See T_{25}. The future effects of climate change on red algae and habitat suitability in Lake Michigan are uncertain.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Red algae may disperse by passive-current transportation. The species must move more than 80.5 km (50 mi) from the WPS downstream to the Brandon Road Lock and Dam. Rapid spread is possible (Edwards and Harrold 1970; Sonzogni et al. 1983), but the rate of spread through the CAWS by natural dispersion is uncertain. Red algae has been present in southern Lake Michigan for decades and has not been reported in the CAWS.

The Nonstructural Alternative does not address the natural dispersion (i.e., current-driven passage) of red algae spores and filaments through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of red algae as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

Ballast water and ship hulls may transport red algae (Kipp 2011; Lin and Blum 1977). There is no commercial vessel traffic in the North Shore Channel (USACE 2011a). There may be recreational boat traffic in the North Shore Channel, which could transport the species to the Brandon Road Lock and Dam or other areas of the CAWS where commercial vessels do operate. The downstream flow of the CAWS would also enable the eventual transport of this species to the Brandon Road Lock and Dam. The discharge of ballast water originating from the Great Lakes would not likely occur within the CAWS (NBIC 2012), but hull transport from the Chicago River to the Brandon Road Lock and Dam is possible. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the red algae into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Anti-fouling hull paints are a possible measure for controlling red algae on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e. chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic (with biocide) or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g. possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of red algae spores and filaments through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: None. Water depth is adequate throughout the CAWS (LimnoTech 2010). There is a sluice gate separating the WPS from Lake Michigan, which is periodically opened and closed. Water from Lake Michigan is periodically pumped into the North Shore Channel. Spores or filaments could be pumped into the North Shore Channel.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: This species was reported in southern Lake Michigan in 1968 (Lin and Blum 1977), but no records of red algae colonizing inland areas of the CAWS were found. In Lake Michigan, red algae is typically found in harbor areas, which provide necessary levels of halogens and trace metals from point and nonpoint sources (Lin and Blum 1977). Much of the water in the CAWS is municipal effluent, which could contain the nutrients and halogens that promote growth of this species (Lin and Blum 1977; Eloranta and Kwandrans 2004). In Britain, red algae was found in a navigation channel that was 32.8 km (10 mi) upstream from tidal influence in an area with high alkalinity, sulphates, and chlorides (Belcher 1956). There is heavy canopy cover and lack of hard substrate in the North Shore Channel, but further downstream in the Chicago River and the Chicago

Sanitary and Ship Canal (CSSC) there is suitable hard substrate in the form of concrete, riprap, pilings, bridges, and sheet pile (LimnoTech 2010). Turbidity in the CAWS is high, which could limit photosynthesis (LimnoTech 2010). This species is typically found in flowing water or active intertidal zones. In Lake Michigan, red algae is typically found in the littoral splash zone on exposed permanent rocky substrates (Kipp 2011). Current velocity in the CAWS is typically very low (LimnoTech 2010). However, this species has been found to colonize in slow-moving water in sheltered areas, harbors, and freshwater canals (Belcher 1956; Lin and Blum 1977; Sheath and Cole 1980; Reed 1980). Red algae is found in waters from 2 to 26.5°C (35.6 to 79.7°F) (Garwood 1982; Sheath et al. 1985), which is typical of the seasonal temperature of the CAWS (MWRD 2010).

The Nonstructural Alternative includes managing nutrient loads to waterways, which may affect red algae establishing in the CAWS and thereby reduce the abundance of spores and filaments in the CAWS. However, the transport of spores and filaments through the CAWS would not be affected.

T_{10}: See T_0.

T_{25}: See T_0. The discharge of common municipal contaminants, such as nutrients, metals, total dissolved solids, and sewage, may decrease because of the adoption of water quality standards and effluent discharge limitations currently proposed for the CAWS (Raber 2012; Illinois Pollution Control Board 2012).

T_{50}: See T_{25}.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Red algae could move from Lake Michigan into the North Shore Channel by water pumping at the WPS (section 3c). Vessel transport in the North Shore Channel is unlikely, but there is vessel traffic between the Chicago River and the Brandon Road Lock and Dam that could also transport this species. Recreational vessels such as canoes and kayaks transferred over land from Wilmette Harbor to the North Shore Channel could also transport this species through the pathway. In addition, this species could be transported downstream to the Brandon Road Lock and Dam by natural spread (section 3b).There is suitable habitat for red algae (section 3d) throughout much of the CAWS, although the North Shore Channel may not be suitable because of the heavy canopy cover and lack of hard substrate (section 3d). Red algae has been found in slow-moving inland freshwaters under the appropriate chemical conditions (section 3d). These conditions are likely to be present in the CAWS, given the high municipal inputs. Water temperature in the CAWS is suitable for red algae (section 3d).

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required.

Additional study is needed to assess the effectiveness of these paints to control fouling by red algae. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of red algae through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to control the passage for red algae through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of red algae by the diversion of Lake Michigan water or the downstream passive transport of red algae spores and filaments to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Although this species is commonly found in waters that are heavily affected by human uses, the ability of hydraulic and chemical conditions in the inland portions of the CAWS to support red algae is uncertain. The effectiveness of hull transport in spreading this species is not well known. The potential natural spread rate of red algae in the CAWS is not known. In addition, this species was reported in southern Lake Michigan in 1968, but has not been reported in inland areas of the CAWS (section 3d). It is uncertain whether this species was unable to exist in the CAWS or whether its presence was unreported due to lack of surveys.

The Nonstructural Alternative includes managing nutrient loads to waterways. The effectiveness of nutrient management on red algae abundance and its natural rate of spread is uncertain. Therefore, the Nonstructural Alternative is not expected to control the passage of red algae through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains high.

T_{10}: See T_0.

T_{25}: See T_0. The future rate of spread for this species is uncertain. Over time, red algae is more certain to spread through the CAWS, assuming appropriate conditions are present. However, future efforts to improve water quality in the CAWS may reduce the discharge of municipal effluents that this species requires. The effects of such changes on red algae are unknown. For this reason, the uncertainty remains high.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: HIGH

PATHWAY 2

CHICAGO RIVER CONTROLLING WORKS (CRCW) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Medium	High	Medium	High	Medium	High	Medium	High
P(passage)	High	High	High	High	High	High	High	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Medium	High	Medium	High	Medium	High	Medium	High
P(passage)	High	High	High	High	High	High	High	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to P(establishment) because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the CRCW and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural is Alternative does not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Red algae was first recorded from Lake Erie in 1964 (Edwards and Harrold 1970). Rapid spread has been documented for red algae (Edwards and Harrold 1970; Sonzogni et al. 1983). In the Great Lakes, it spread from Lake Erie to southern Lake Michigan within a decade; in Milwaukee, it grew from a few filaments to a high-density community within 4 years (Lin and Blum 1977). Red algae was documented on the Canadian side of Lake Huron in 1980 (Jackson 1988). Red algae has a prolonged monospore release that promotes population spread (Sheath et al. 1985).

The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS from natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Ballast water and ship hulls may transport red algae (Kipp 2011; Lin and Blum 1977). There is recreational and commercial boat traffic between the CRCW and multiple ports in Lake Michigan where red algae might be found (USACE 2011a,b). These recreational and commercial vessels could potentially transport this species from the Great Lakes to the CRCW.

Anti-fouling hull paints are a possible measure for controlling red algae on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of red algae from human-mediated transport through aquatic pathways to the CAWS.

c. Current Abundance and Reproductive Capacity

T_0: Recent information is not available to assess the current abundance of the species. Red algae has a prolonged monospore (Sheath et al. 1985). Red algae produces the highest biomass in spring and fall, and it persists through the summer at low biomass (Kipp 2011). It is a seasonal annual (producing several generations per year) with a 4- to 6-week generation time (Sheath and Cole 1980; Sheath et al. 1985). Based on recent data from Lake Michigan, red algae (Division Rhodophyta) is rarely found in the Lake Michigan watershed (Whitman 2012).

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the current abundance or reproductive capacity of red algae.

T_{10}: See T_0. The distribution and abundance of red algae in the Great Lakes could decrease because of improvements in the water quality of southern Lake Michigan, and this could reduce the anthropogenic inputs into Lake Michigan that are preferred by this species.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

d. Existing Physical Human/Natural Barriers

T_0: None. This species has been found in southern Lake Michigan (Lin and Blum 1977).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: Red algae was documented on the Canadian side of Lake Huron in 1980 (Jackson 1988). Red algae may be present at the CRCW. It has been observed in southern Lake Michigan including the Chicago area (Lin and Blum 1977). However, based on recent data from Lake Michigan, red algae is not frequently found in southern Lake Michigan (Whitman 2012).

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect where red algae is able to establish and hence its location in relation to the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Suitable habitat is present at the CRCW in the form of rocky shoreline, concrete, and steel manmade structures (Kipp 2011). The occurrence of red algae is restricted largely to harbor areas, which provide necessary levels of halogens and trace metals from point and nonpoint sources (Lin and Blum 1977). Harbors exist all along the shoreline of Lake Michigan.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the habitat suitability of southern Lake Michigan.

T_{10}: See T_0. The habitat of Lake Michigan is expected to remain suitable for red algae during this time step.
T_{25}: See T_{10}.
T_{50}: See T_{25}. Future climate change or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for red algae. Mean temperature in particular is expected to increase (Wuebbles et al. 2010). However, red algae can tolerate a wide range of temperatures 2–26°C (35.6–78°F) (Kipp 2011; Garwood 1982), and it is globally distributed across wide latitudes from boreal to tropical (Guiry and Guiry 2012).

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating	Medium	Medium	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Red algae has been found in southern Lake Michigan, in the vicinity of the CAWS (section 2e), and there is suitable habitat near and within the harbor adjacent to the CRCW (section 2f). However, recent surveys suggest red algae is not frequently found in southern Lake Michigan. Even if red algae is not currently present at the CRCW, it has spread to multiple Great Lakes within a few decades (Kipp 2011), likely by vessel traffic. Vessel traffic between the northern Great Lakes and the CRCW is high (USACE 2011a,b). However, recent surveys do not suggest red algae is found near the CRCW (section 2e).

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by red algae. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of red algae at the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's medium probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_{25}. Red algae is tolerant of a wide range of temperatures (section 2f). Red algae has been found in southern Lake Michigan in the vicinity of the CRCW (section 2e), and appropriate habitat conditions are expected to continue to be present (sections 2c, 2f) along the shoreline of Lake Michigan, even when impacts on habitat related to future climate change (section 2f) are taken into account.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Although historically red algae has been present in southern Lake Michigan, recent surveys do not indicate the presence of this species.

The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS through aquatic pathways. Therefore, the uncertainty remains high.

T_{10}: See T_0.

T_{25}: See T_0. The future population trends of red algae are uncertain. The future rate of spread for this species is uncertain. The effects of measures to improve water quality in Lake Michigan on red algae are uncertain.

T_{50}: See T_{25}. The future effects of climate change on red algae and habitat suitability in Lake Michigan are uncertain.

3. P(passage) T_0-T_{50} : HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Red algae may disperse by passive-current transportation. It is approximately 64 km (40 mi) from the CRCW to the Brandon Road Lock and Dam. Rapid spread is possible (Edwards and Harrold 1970; Sonzogni et al. 1983), but the rate of spread through the CAWS by natural dispersion is uncertain. Red algae produces the highest biomass in spring and fall, and it persists through the summer at low biomass (Kipp 2011). It is a seasonal annual (producing several generations per year [Sheath et al. 1985]). Red algae has been present in southern Lake Michigan for decades and has not been reported in the CAWS.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., current-driven passage) of red algae spores and filaments through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of red algae as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

Ballast water and ship hulls may transport red algae through the CAWS (Kipp 2011; Lin and Blum 1977), and there is recreational and commercial vessel traffic between the CRCW and the Brandon Road Lock and Dam (USACE 2011a,b). The discharge of ballast water originating from the Great Lakes would not likely occur within the CAWS (NBIC 2012), but hull transport from the CRCW to the Brandon Road Lock and Dam is possible. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the red algae into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Anti-fouling hull paints are a possible measure for controlling red algae on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of red algae spores and filaments through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: None. Water depth is adequate throughout the CAWS (LimnoTech 2010). This species has been found in the vicinity of the CRCW, and the lock is opened and closed routinely, which would allow this species to pass into the CAWS.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: This species was reported in southern Lake Michigan in 1968 (Lin and Blum 1977), but no records of red algae colonizing inland areas of the CAWS were found. However, much of CAWS water is municipal effluent, which could contain the nutrients and halogens that promote growth of this species (Lin and Blum 1977; Eloranta and Kwandrans 2004). In Lake Michigan, red algae is typically found in harbor areas, which provide necessary levels of halogens and trace metals from point and nonpoint sources (Lin and Blum 1977). In Britain, red algae was found in a navigation channel 32.8 km (10 mi) upstream from tidal influence in an area with high alkalinity, sulphates, and chlorides (Belcher 1956). In the Chicago River and the CSSC there is suitable hard substrate in the form of concrete, riprap, pilings, bridges, and sheet pile (LimnoTech 2010). Turbidity in the CAWS is high, which could limit photosynthesis (LimnoTech 2010). This species is typically found in flowing water or active intertidal zones on exposed permanent rocky substrates (Kipp 2011). Current velocity in the CAWS is typically very low (LimnoTech 2010). However, this species has been found to colonize slow-moving water in sheltered areas, harbors, and freshwater canals (Belcher 1956; Lin and Blum 1977; Sheath and Cole 1980; Reed 1980). Red algae is found in waters from 2 to 26.5°C (35.6 to 79.7°F) (Garwood 1982; Sheath et al. 1985), which is typical of the seasonal temperature of the CAWS (MWRD 2010).

The Nonstructural Alternative includes managing nutrient loads to waterways, which may affect red algae establishing in the CAWS and thereby reduce the abundance of spores and filaments in the CAWS. However, the transport of spores and filaments through the CAWS would not be affected.

T_{10}: See T_0.

T_{25}: See T_0. The discharge of common municipal contaminants, such as nutrients, metals, total dissolved solids, and sewage, may decrease because of the adoption of water quality standards and effluent discharge limitations currently proposed for the CAWS (Raber 2012; Illinois Pollution Control Board 2012).

T_{50}: See T_{25}.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Water quality in the CAWS near downtown Chicago may be suitable for red algae (section 3e). Red algae could move from the Chicago River throughout the CAWS by attaching to the hulls of recreational and commercial boats (section 3b). This species could also be transported downstream to the Brandon Road Lock and Dam by natural spread (section 3b). There is suitable habitat for red algae (section 3e) throughout much of the CAWS, including the vicinity of the Brandon Road Lock and Dam. This species has been found in slow-moving inland freshwaters under the appropriate chemical conditions (section 3e). These conditions are likely to be present in the CAWS, given the high municipal pollution inputs.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by red algae. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of red algae through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to control the passage of red algae through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of red algae by the diversion of Lake Michigan water or the downstream passive transport of red algae spores and filaments to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's

high probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Vessel traffic is known to exist between the CRCW and the Brandon Road Lock and Dam (USACE 2011a,b). This species has been found in slow-moving inland freshwaters under the appropriate chemical conditions (section 3e). However, the ability of hydraulic and chemical conditions in the inland portions of the CAWS to support red algae is not known. In addition, this species was reported in southern Lake Michigan in 1968, but has not been reported in inland areas of the CAWS (section 3d). It is uncertain whether this species was unable to exist in the CAWS or whether its presence was unreported due to lack of surveys. The effectiveness of hull transport in spreading this species is not well known. The potential natural spread rate of red algae in the CAWS is not known. For these reasons, there is a high level of uncertainty associated with the probability of passage.

The Nonstructural Alternative includes managing nutrient loads to waterways. The effectiveness of nutrient management on red algae abundance and its natural rate of spread is uncertain. Therefore, the Nonstructural Alternative is not expected to control the passage of red algae through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains high.
T_{10}: See T_0.
T_{25}: See T_0. The future rate of spread for this species is not known. Over time, red algae is more certain to spread through the CAWS, assuming appropriate conditions are present. However, future efforts to improve water quality in the CAWS may reduce the discharge of municipal effluents that this species requires. The effects of such changes on red algae are unknown. For this reason, the uncertainty remains high.
T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.
Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: HIGH

PATHWAY 3

CALUMET HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Medium	High	Medium	High	Medium	High	Medium	High
P(passage)	High	High	High	High	High	High	High	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] “–” Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Medium	High	Medium	High	Medium	High	Medium	High
P(passage)	High	High	High	High	High	High	High	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Medium	–[a]	Medium	–	Medium	–-	Medium	–

[a] “–” Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Calumet Harbor and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Red algae was first recorded from Lake Erie in 1964 (Edwards and Harrold 1970). Rapid spread has been documented for red algae (Edwards and Harrold 1970; Sonzogni et al. 1983). In the Great Lakes, it spread from Lake Erie to southern Lake Michigan within a decade, and in Milwaukee, it grew from a few filaments to a high-density community within 4 years (Lin and Blum 1977). Red algae was documented on the Canadian side of Lake Huron in 1980 (Jackson 1988). Red algae has a prolonged monospore release that promotes population spread (Sheath et al. 1985).

The Nonstructural Alternative is not expected to affect the arrival of red algae from natural dispersion through aquatic pathways to the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

Ballast water and ship hulls might transport red algae (Kipp 2011; Lin and Blum 1977). There is boat traffic between Calumet Harbor and multiple ports in Lake Michigan where red algae might be found (USACE 2011a,b; NBIC 2012). Recreational and commercial vessels could potentially transport this species from the Great Lakes to Calumet Harbor. Anti-fouling hull paints are a possible measure for controlling red algae on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e. chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic (with biocide) or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS from human-mediated transport through aquatic pathways.

c. Current Abundance and Reproductive Capacity

T_0: Recent information is not available to assess the current abundance of the species. Red algae has a prolonged monospore (Sheath et al. 1985). Red algae produces highest biomass in spring and fall, and it persists through the summer at low biomass (Kipp 2011). It is a seasonal annual (producing several generations per year) with a 4- to 6-week generation time (Sheath and Cole 1980; Sheath et al. 1985). Based on recent data from Lake Michigan, red algae (Division Rhodophyta) is rarely found in the Lake Michigan watershed (Whitman 2012).

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the current abundance or reproductive capacity of red algae.

T_{10}: See T_0. The distribution and abundance of red algae in the Great Lakes could decrease because of improvements in the water quality of southern Lake Michigan, which could reduce the anthropogenic inputs into Lake Michigan that are preferred by this species.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

d. Existing Physical Human/Natural Barriers

T_0: None. This species has been found in southern Lake Michigan (Lin and Blum 1977).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: Red algae was documented on the Canadian side of Lake Huron in 1980 (Jackson 1988). The species has been observed in southern Lake Michigan (Lin and Blum 1977). Red algae may be present at Calumet Harbor. However, based on recent data from Lake Michigan, red algae is not frequently found in southern Lake Michigan (Whitman 2012).

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect where it is able to establish and hence its location in relation to the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Red algae has been found in southern Lake Michigan (Lin and Blum 1977). Suitable habitat is present at Calumet Harbor in the form of rocky shoreline, concrete, and steel manmade structures (Kipp 2011). The occurrence of red algae is restricted largely to harbor areas, which provide necessary levels of halogens and trace metals from point and nonpoint sources (Lin and Blum 1977). Harbors exist all along the shoreline of Lake Michigan.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the habitat suitability of southern Lake Michigan.

T_{10}: See T_0. The habitat of Lake Michigan is expected to remain suitable for red algae during this time step.
T_{25}: See T_{10}.
T_{50}: See T_{25}. Future climate change or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for red algae. Mean temperature, in particular, is expected to increase (Wuebbles et al. 2010). However, red algae can tolerate a wide range of temperatures (i.e., 2–26°C [35.6–78°F]) (Kipp 2011; Garwood 1982), and it is globally distributed across wide latitudes from boreal to tropical (Guiry and Guiry 2012).

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating	Medium	Medium	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Red algae has been found in southern Lake Michigan, and there is suitable habitat adjacent to Calumet Harbor (section 2f). Recent surveys suggest red algae is not frequently found in southern Lake Michigan. However, even if red algae is not currently present at Calumet Harbor, it has spread to multiple Great Lakes within a few decades (Kipp 2011), likely by vessel traffic. Vessel traffic between the northern Great Lakes and Calumet Harbor is high. Recreational and commercial vessels using Calumet Harbor could provide a means for the species to arrive at the pathway.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by red algae. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of red algae at the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect the arrival of red algae through aquatic pathways to the CAWS. Therefore, the Nonstructural Alternative's medium probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_{25}. Red algae is tolerant of a wide range of temperatures (section 2f). Red algae has been found in southern Lake Michigan (section 2e), and appropriate habitat conditions are expected to continue to be present (sections 2f, 2c) along the shoreline of Lake Michigan, even when impacts on habitat related to future climate change are taken into account (section 2f).

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Although historically red algae has been present in southern Lake Michigan, recent surveys do not indicate the presence of this species.

The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS through aquatic pathways. Therefore, the uncertainty remains high.

T_{10}: See T_0.

T_{25}: See T_0. The future population trends of red algae are uncertain. The future rate of spread for this species is uncertain. The effects of measures to improve water quality in Lake Michigan on red algae are uncertain.

T_{50}: See T_{25}. The future effects of climate change on red algae and habitat suitability in Lake Michigan are uncertain.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Red algae may disperse by passive-current transportation. It is more than 56 km (35 mi) from Calumet Harbor to the Brandon Road Lock and Dam. Rapid spread is possible (Edwards and Harrold 1970; Sonzogni et al. 1983), but the rate of spread through the CAWS by natural dispersion is uncertain. Red algae produces the highest biomass in spring and fall, and it persists through the summer at low biomass (Kipp 2011). It is a seasonal annual (producing several generations per year) (Sheath et al. 1985).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., current-driven passage) of red algae spores and filaments through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of red algae as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

In the Great Lakes, red algae spread from Lake Erie to southern Lake Michigan within a decade (Lin and Blum 1977). Ballast water and ship hulls may transport red algae through the CAWS (Kipp 2011; Lin and Blum 1977). Vessel traffic to Calumet Harbor is typically lakewise, but there is heavy commercial vessel traffic between the Brandon Road Lock and Dam and the T.J. O'Brien Lock and Dam, which is located downstream of

Calumet Harbor (USACE 2011a,b). The discharge of ballast water originating from the Great Lakes would not likely occur within the CAWS (NBIC 2012), but hull transport to the Brandon Road Lock and Dam is possible. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the red algae into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Anti-fouling hull paints are a possible measure for controlling red algae on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic (with biocide) or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of red algae spores and filaments through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: None. Water depth is adequate throughout the CAWS (LimnoTech 2010). This species has been found in the vicinity of Calumet Harbor, and the lock is opened and closed routinely, which would allow this species to pass into the CAWS.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: This species was reported in southern Lake Michigan in 1968 (Lin and Blum 1977), but no records of red algae colonizing inland areas of the CAWS were found. However, much of CAWS water is municipal effluent, which could contain the nutrients and halogens that promote growth of this species (Lin and Blum 1977; Eloranta and Kwandrans 2004). In Lake Michigan, red algae is typically found in harbor areas, which provide necessary levels of halogens and trace metals from point and nonpoint sources (Lin and Blum 1977). In Britain, red algae was found in a navigation channel 32.8 km (10 mi) upstream from tidal influence in an area with high alkalinity, sulphates, and chlorides (Belcher 1956). In the Calumet River, the Cal-Sag Channel, and the CSSC, there is suitable hard substrate in the form of concrete, riprap, pilings, bridges, and sheet pile (LimnoTech 2010). Turbidity in the CAWS is high, which could limit photosynthesis (LimnoTech 2010). This species is typically found in flowing water or active intertidal zones on exposed permanent rocky substrates (Kipp 2011). Current velocity in the

CAWS is typically very low (LimnoTech 2010). However, this species has been found to colonize slow-moving water in sheltered areas, harbors, and freshwater canals (Belcher 1956; Lin and Blum 1977; Sheath and Cole 1980; Reed 1980). Red algae is found in waters from 2 to 26.5°C (35.6 to 79.7°F) (Sheath et al. 1985), which is typical of the seasonal temperature of the CAWS (MWRD 2010).

The Nonstructural Alternative includes managing nutrient loads to waterways, which may affect red algae establishing in the CAWS and thereby reduce the abundance of spores and filaments in the CAWS. However, the transport of spores and filaments through the CAWS would not be affected.

T_{10}: See T_0.

T_{25}: See T_0. The discharge of common municipal contaminants, such as nutrients, metals, total dissolved solids, and sewage, may decrease because of the adoption of water quality standards and effluent discharge limitations currently proposed for the CAWS (Raber 2012; Illinois Pollution Control Board 2012).

T_{50}: See T_{25}.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Red algae could move from Calumet Harbor throughout the CAWS by attaching to the hulls of recreational and commercial boats (section 3b). There is vessel traffic between the T.J. O'Brien Lock and Dam and the Brandon Road Lock and Dam that could also transport this species. In addition, this species could be transported downstream to the Brandon Road Lock and Dam by natural spread. There is suitable habitat for red algae (section 3e) throughout much of the CAWS, including the vicinity of the Brandon Road Lock and Dam. This species has been found in slow-moving inland freshwaters under the appropriate chemical conditions (section 3e). These conditions are likely to be present in the CAWS, given the limestone substrate and the high municipal pollution inputs. Water temperature in the CAWS is suitable for red algae (section 3d). However, red algae has been in southern Lake Michigan near the WPS for decades and has not been reported in the CAWS. Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by red algae. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of red algae through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to control the passage of red algae through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of red algae by the Lake

Michigan water diversion and the downstream passive transport of red algae spores and filaments to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Vessel traffic is known to exist between Calumet Harbor and the Brandon Road Lock and Dam. Although this species is commonly found in waters that are heavily affected by human uses, the ability of hydraulic and chemical conditions in the inland portions of the CAWS to support red algae is uncertain. The effectiveness of hull transport in spreading this species through the CAWS is uncertain. The potential natural spread rate of red algae in the CAWS is uncertain. In addition, this species was reported in southern Lake Michigan in 1968, but has not been reported in inland areas of the CAWS (section 3d). It is uncertain whether this species was unable to exist in the CAWS of whether its presence was unreported due to lack of surveys.

The Nonstructural Alternative includes managing nutrient loads to waterways. The effectiveness of nutrient management on red algae abundance and its natural rate of spread is uncertain. Therefore, the Nonstructural Alternative is not expected to control the passage of red algae through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains high.

T_{10}: See T_0.

T_{25}: See T_0. The future rate of spread for this species is not known. Over time, red algae is more certain to spread through the CAWS, assuming appropriate conditions are present. However, the effects of future water quality improvements on red algae and habitat suitability in the CAWS are uncertain. Therefore, uncertainty remains high.

T_{50}: See T_{25}.

4. **P(colonizes) T_0-T_{50}: MEDIUM**

   The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

   Uncertainty: MEDIUM

5. **P(spreads) T_0-T_{50}: MEDIUM**

   The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

   Uncertainty: HIGH

PATHWAY 4

INDIANA HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Medium	High	Medium	High	Medium	High	Medium	High
P(passage)	Low	High	Low	High	Medium	High	Medium	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–-	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Medium	High	Medium	High	Medium	High	Medium	High
P(passage)	Low	High	Low	High	Medium	High	Medium	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Indiana Harbor and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Red algae was first recorded from Lake Erie in 1964 (Edwards and Harrold 1970). Rapid spread has been documented for red algae (Edwards and Harrold 1970; Sonzogni et al. 1983). In the Great Lakes, it spread from Lake Erie to southern Lake Michigan within a decade, and in Milwaukee, it grew from a few filaments to a high-density community within 4 years (Lin and Blum 1977). Red algae was documented on the Canadian side of Lake Huron in 1980 (Jackson 1988). Red algae has a prolonged monospore release that promotes population spread (Sheath et al. 1985).

The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS from natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Ballast water and ship hulls may transport red algae (Kipp 2011; Lin and Blum 1977). There is heavy boat traffic between Indiana Harbor and multiple ports in Lake Superior and Lake Michigan where red algae may be found (USACE 2011a,b; NBIC 2012). Recreational and commercial traffic could potentially transport this species from the Great Lakes to Indiana Harbor. Anti-fouling hull paints are a possible measure for controlling red algae on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS from human-mediated transport through aquatic pathways.

c. Current Abundance and Reproductive Capacity

T_0: Red algae has a prolonged monospore (Sheath et al. 1985). Red algae produces the highest biomass in spring and fall, and it persists through the summer at low biomass

(Kipp 2011). It is a seasonal annual (producing several generations per year) with a 4- to 6-week generation time (Sheath and Cole 1980; Sheath et al. 1985). Based on recent data from Lake Michigan, red algae (Division Rhodophyta) is rarely found in the Lake Michigan watershed (Whitman 2012). Agency monitoring and control methods to manage red algae in the Great Lakes Basin where it has been documented are not likely to be successful because of the prolonged monospore release, which promotes rapid population growth.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the current abundance or reproductive capacity of red algae.

T_{10}: See T_0. The distribution and abundance of red algae in the Great Lakes could decrease because of improvements in the water quality of southern Lake Michigan, which could reduce the anthropogenic inputs into Lake Michigan that are preferred by this species.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

d. *Existing Physical Human/Natural Barriers*

T_0: None. This species has been found in southern Lake Michigan (Lin and Blum 1977).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. *Distance from Pathway*

T_0: Red algae was documented on the Canadian side of Lake Huron in 1980 (Jackson 1988). The species has been observed in southern Lake Michigan (Lin and Blum 1977). Red algae may be present at Indiana Harbor. However, based on recent data from Lake Michigan, red algae is not frequently found in southern Lake Michigan (Whitman 2012).

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect where it is able to establish and hence its location in relation to the CAWS.

T_{10}: See T_{10}.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

f. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: Red algae has been found in southern Lake Michigan in the vicinity of the CAWS. Suitable habitat is present at Indiana Harbor in the form of rocky shoreline, concrete, and steel manmade structures (Kipp 2011). The occurrence of red algae is restricted largely to harbor areas, which provide necessary levels of halogens and trace metals from point and nonpoint sources (Lin and Blum 1977). Harbors exist all along the shoreline of Lake Michigan.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the habitat suitability of southern Lake Michigan.

T_{10}: See T_0. The habitat of Lake Michigan is expected to remain suitable for red algae during this time step.

T_{25}: See T_{10}.

T_{50}: See T_{25}. Future climate change or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for red algae. Mean temperature, in particular, is expected to increase (Wuebbles et al. 2010). However, red algae is found in a wide range of water temperatures (2–26°C [35.6–78°F]) (Kipp 2011; Garwood 1982) and is globally distributed across a wide latitude range from boreal to tropical (Guiry and Guiry 2012)

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating	Medium	Medium	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Red algae has been found in southern Lake Michigan, and there is suitable habitat adjacent to Indiana Harbor (section 2f). However, recent surveys suggest red algae is not frequently found in southern Lake Michigan. Even if the species is not currently present at Indiana Harbor, it has spread to multiple Great Lakes within a few decades (Kipp 2011), likely by vessel traffic. Vessel traffic between the northern Great Lakes and Indiana Harbor is high and could provide a means of transport for the species to arrive at the pathway.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by red algae. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of red algae to the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's medium probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Red algae is tolerant of a wide range of temperatures (section 2f). Therefore, appropriate habitat conditions are expected to continue to be present (sections 2f, 2c) along the shoreline of Lake Michigan, even when the impacts on habitat that are related to future climate change are taken into account (section 2f).

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Although historically red algae has been present in southern Lake Michigan, recent surveys do not indicate the presence of this species.

The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS through aquatic pathways. Therefore, the uncertainty remains high.

T_{10}: See T_0.

T_{25}: See T_0. The future population trends of red algae are uncertain. The future rate of spread for this species is uncertain. The effects of measures to improve water quality in Lake Michigan on red algae are uncertain.

T_{50}: See T_{25}. The future effects of climate change on red algae and habitat suitability in Lake Michigan are uncertain.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Red algae may disperse by passive-current transportation. It is more than 56 km (35 mi) from Indiana Harbor downstream to the Brandon Road Lock and Dam. Rapid spread is possible (Edwards and Harrold 1970; Sonzogni et al. 1983), but the rate of spread through the CAWS by natural dispersion is uncertain. Red algae has been present in southern Lake Michigan for decades and has not been reported in the CAWS.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., current-driven passage) of red algae spores and filaments through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of red algae as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

In the Great Lakes, red algae spread from Lake Erie to southern Lake Michigan within a decade (Lin and Blum 1977). Ballast water and ship hulls may transport red algae through the CAWS (Kipp 2011; Lin and Blum 1977). The discharge of ballast water originating from the Great Lakes would not likely occur within the CAWS (NBIC 2012), although transport on boat hulls is possible. Vessel traffic to Indiana Harbor is lakewise, but there is vessel traffic from the Brandon Road Lock and Dam and the T.J. O'Brien Lock and Dam (USACE 2011a; NBIC 2012) that could transport this species. In addition, recreational vessel traffic, such as canoes and kayaks, could potentially transport this species to other areas of the CAWS where commercial and larger recreational vessels operate. Some natural dispersal would likely be necessary to reach the Brandon Road Lock and Dam. Anti-fouling hull paints are a possible measure for controlling red algae on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of red algae spores and filaments through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: None. Water depth is adequate throughout the CAWS (LimnoTech 2010). There is sheet pile across the Grand Calumet River between the Indiana Harbor Canal and the Calumet River that could act as a barrier during low flows.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Much of CAWS water is municipal effluent, which could contain the nutrients and halogens that promote growth of this species (Lin and Blum 1977; Eloranta and Kwandrans 2004). In Lake Michigan, red algae is typically found in harbor areas, which provide necessary levels of halogens and trace metals from point and nonpoint sources (Lin and Blum 1977). In Britain, red algae was found in a navigation channel 32.8 km (10 mi) upstream from tidal influence in an area with high alkalinity, sulphates, and chlorides (Belcher 1956). In Indiana Harbor, Grand Calumet River, the Cal-Sag Channel, and the CSSC there is suitable hard substrate in the form of concrete, riprap, pilings, bridges, and sheet pile (LimnoTech 2010). However, there are marshy reaches of the Grand Calumet River that may not be suitable for this species. Turbidity in the CAWS is high, which could limit photosynthesis (LimnoTech 2010). This species is typically found in flowing water or active intertidal zones on exposed permanent rocky substrates (Kipp 2011). Current velocity in the CAWS is typically very low (LimnoTech 2010). However, this species has been found to colonize slow-moving water in sheltered areas, harbors, and freshwater canals (Belcher 1956; Lin and Blum 1977; Sheath and Cole 1980; Reed 1980). The flow direction and water depth of the Grand Calumet River varies with effluent discharge volumes and water levels in Lake Michigan. Water flows out of the Indiana Harbor into Lake Michigan. West of the Indiana Harbor Canal, the easternmost sections of the Grand Calumet River also generally flow toward Lake Michigan, while other sections can flow east or west, depending on location (Weiss et al. 1997). Thus, red algae would have to float upstream to enter the CAWS and move to the Cal-Sag Channel. Red algae is found in waters from 2 to 26.5°C (35.6 to 79.7°F) (Garwood 1982; Sheath et al. 1985), which is typical of the seasonal temperature of the CAWS (MWRD 2010).

The Nonstructural Alternative includes managing nutrient loads to waterways, which may affect red algae establishing in the CAWS and thereby reduce the abundance of spores and filaments in the CAWS. However, the transport of spores and filaments through the CAWS would not be affected.

T_{10}: See T_0.

T_{25}: See T_0. The discharge of common municipal contaminants such as nutrients, metals, total dissolved solids, and sewage may decrease because of the adoption of water quality standards and effluent discharge limitations that are currently proposed for the CAWS (Raber 2012; Illinois Pollution Control Board 2012).

T_{50}: See T_{25}.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: There is a potential for human-mediated transport to the Brandon Road Lock and Dam via vessel traffic (section 3b). There is no vessel traffic in the Grand Calumet River, so red algae would have to disperse naturally from Calumet Harbor to the Little Calumet River. Or, it could potentially be transported by small recreational watercraft, such as canoes and kayaks, to other areas of the CAWS where commercial vessels and larger recreational vessels operate. These vessels could then transport the species to the Brandon Road Lock and Dam. Flow in Indiana Harbor and portions of the Grand Calumet River are toward Lake Michigan, which could inhibit the spread of this species from Indiana Harbor to the Little Calumet River. Once in the Little Calumet River, red algae could potentially be transported to the Brandon Road Lock and Dam by attaching to the hulls of recreational and commercial boats (section 3b). In addition, there is suitable habitat for red algae (section 3e) throughout much of the CAWS, including the vicinity of the Brandon Road Lock and Dam. Although this species is typically found in high-energy shorelines, it has been found in slow-moving inland freshwaters, under the appropriate chemical conditions (section 3e). These conditions are likely to be present in the CAWS, given the high municipal pollution inputs (section 3e). Water temperature in the CAWS is suitable for red algae (section 3d). Red algae has been present in southern Lake Michigan for decades, and it has not been reported in the CAWS. Therefore, red algae is not likely to move from Indiana Harbor to the Brandon Road Lock and Dam by natural dispersion within the current time step.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by red algae. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of red algae through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of red algae through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of red algae by downstream passive transport of red algae spores and filaments to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's low probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0. Sufficient time may elapse during this time step to allow red algae to spread through the CAWS by natural spread, boat traffic, or a combination of both. Overall, the habitat in the CAWS is expected to remain suitable for red algae. However, future efforts to improve water quality in the CAWS may reduce the discharge of municipal effluents with which this species tends to be associated.

The Nonstructural Alternative is not expected to control the passage of red algae through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's medium probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Although this species is commonly found in waters that are heavily affected by human uses, the ability of hydraulic and chemical conditions in the inland portions of the CAWS to support red algae is unknown. The direction of flow in the Indiana Harbor Canal and the Grand Calumet River is toward Lake Michigan, and it could inhibit the spread of this species to the Cal-Sag Channel. The potential natural spread rate of red algae in the CAWS is not known. In addition, red algae has been reported in southern Lake Michigan, and it is uncertain why this species has not been reported in the CAWS.

The Nonstructural Alternative includes managing nutrient loads to waterways. The effectiveness of nutrient management on red algae abundance and its natural rate of spread is uncertain. Therefore, the Nonstructural Alternative is not expected to control the passage of red algae through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains high.

T_{10}: See T_0.

T_{25}: See T_0. The future rate of spread for this species is not known. Over time, red algae is more certain to spread through the CAWS, assuming appropriate conditions are present. However, future efforts to improve water quality in the CAWS may reduce the discharge of municipal effluents that this species requires. The effects of such changes on red algae are unknown.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: HIGH

PATHWAY 5

BURNS SMALL BOAT HARBOR (BSBH) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Medium	High	Medium	High	Medium	High	Medium	High
P(passage)	Low	High	Low	High	Medium	High	Medium	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Medium	High	Medium	High	Medium	High	Medium	High
P(passage)	Low	High	Low	High	Medium	High	Medium	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the BSBH and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Red algae was first recorded from Lake Erie in 1964 (Edwards and Harrold 1970). Rapid spread has been documented for red algae (Edwards and Harrold 1970, Sonzogni et al. 1983). In the Great Lakes, it spread from Lake Erie to southern Lake Michigan within a decade; in Milwaukee, it grew from a few filaments to a high-density community within 4 years (Lin and Blum 1977). Red algae was documented on the Canadian side of Lake Huron in 1980 (Jackson 1988). Red algae has a prolonged monospore release that promotes population spread (Sheath et al. 1985).

The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS from natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Ballast water and ship hulls may transport red algae (Kipp 2011; Lin and Blum 1977). There is recreational, but not commercial, vessel traffic from the Great Lakes to the BSBH. There is commercial vessel traffic to Burns Harbor, which is adjacent to the BSBH (USACE 2011a,b), that could potentially transport this species from the Great Lakes to BSBH.

Anti-fouling hull paints are a possible measure for controlling red algae on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS from human-mediated transport through aquatic pathways.

c. Current Abundance and Reproductive Capacity

T_0: Recent information is not available to assess the current abundance of the species. Red algae has a prolonged monospore (Sheath et al. 1985). Red algae produces the highest biomass in the spring and fall, and it persists through the summer at low biomass (Kipp 2011). It is a seasonal annual (producing several generations per year) with a 4- to 6-week generation time (Sheath and Cole 1980; Sheath et al. 1985). Based on recent data from Lake Michigan, red algae (Division Rhodophyta) is rarely found in the Lake Michigan watershed (Whitman 2012).

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the current abundance or reproductive capacity of red algae.

T_{10}: See T_0. The distribution and abundance of red algae in the Great Lakes could decrease because of improvements in the water quality of southern Lake Michigan, which could reduce the anthropogenic inputs into Lake Michigan that are preferred by this species.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

d. Existing Physical Human/Natural Barriers

T_0: None. This species has been found in southern Lake Michigan (Lin and Blum 1977).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: Red algae was documented on the Canadian side of Lake Huron in 1980 (Jackson 1988). Red algae has been observed in southern Lake Michigan (Lin and Blum 1977). However, based on recent data from Lake Michigan, red algae is not frequently found in southern Lake Michigan (Whitman 2012).

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect where red algae is able to establish and hence its location in relation to the CAWS.

T_{10}: See T_0. The species may be present at the BSBH. Alternatively, its range could contract, which would increase its distance from the pathway.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Suitable habitat is present at the BSBH in the form of rocky shoreline and concrete and steel manmade structures (Kipp 2011). The occurrence of red algae is restricted largely to harbor areas, which provide necessary levels of halogens and trace metals from point and nonpoint sources (Lin and Blum 1977). Harbors exist all along the shoreline of Lake Michigan.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the habitat suitability of southern Lake Michigan.

T_{10}: See T_0. The habitat of Lake Michigan is expected to remain suitable for red algae during this time step.
T_{25}: See T_0. Future climate change or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for red algae. The species can tolerate a wide range of temperatures.
T_{50}: See T_{25}.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating	Medium	Medium	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Red algae has been found in southern Lake Michigan, and there is suitable habitat adjacent to the BSBH (section 2f). However, recent surveys suggest red algae is not frequently found in southern Lake Michigan. No recent surveys of red algae are available. However, even if it is not currently present at the BSBH, the species has spread to multiple Great Lakes within a few decades (Kipp 2011), likely by vessel traffic. There is vessel traffic between the northern Great Lakes, the BSBH, and the adjacent Burns Harbor. Recreational vessels using the BSBH could provide a means for the species to arrive at the pathway. In addition, commercial vessels using the nearby Burns Harbor could also transport the species to the pathway.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by red algae. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of red algae at the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's medium probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0. Red algae is tolerant of a wide range of temperatures (section 2f). The species has been found in southern Lake Michigan in the vicinity of Indiana Harbor (section 2e), and appropriate habitat conditions are expected to continue to be present (sections 2c, 2f) along the shoreline of Lake Michigan, even when impacts on habitat related to future climate change are taken into account (section 2f).

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Although historically, red algae has been present in southern Lake Michigan, recent surveys do not indicate the presence of this species.

The Nonstructural Alternative is not expected to affect the arrival of red algae at the CAWS through aquatic pathways. Therefore, the uncertainty remains high.

T_{10}: See T_0.

T_{25}: See T_0. The future population trends of red algae are uncertain. The future rate of spread for this species is uncertain. The effects of measures to improve water quality in Lake Michigan on red algae are uncertain.

T_{50}: See T_{25}. The future effects of climate change on red algae and habitat suitability in Lake Michigan are uncertain.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Red algae may disperse by passive-current transportation. It is more than 64 km (40 mi) from the BSBH to the Brandon Road Lock and Dam. Rapid spread is possible (Edwards and Harrold 1970; Sonzogni et al. 1983), but the rate of spread through the CAWS by natural dispersion is unknown. Red algae has been present in southern Lake Michigan for decades, and it has not been reported in the CAWS.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., current-driven passage) of red algae spores and filaments through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of red algae as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

Ballast water and ship hulls may transport red algae through the CAWS (Kipp 2011; Lin and Blum 1977). Vessel traffic to the BSBH and the adjacent Burns Harbor is lakewise. Recreational vessel traffic (e.g., canoes and kayaks) could potentially transport this species to other areas of the CAWS where commercial and larger recreational vessels operate. There is vessel traffic between the Brandon Road Lock and Dam and the T.J. O'Brien Lock and Dam (USACE 2011a,b; NBIC 2012). The discharge of ballast water originating from the Great Lakes would not likely occur within the CAWS (NBIC 2012), but hull transport to the Brandon Road Lock and Dam is possible. In addition, some natural downstream dispersal would likely be necessary to reach the Brandon Road Lock and Dam. Anti-fouling hull paints are a possible measure for controlling red algae on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic (with biocide) or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of red algae spores and filaments through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: None. Water depth is adequate for red algae throughout the CAWS (Kipp 2011; LimnoTech 2010).This species has been found in the vicinity of the BSBH. The Lockport Lock and Dam may act as a temporary barrier to natural dispersion, but not to hull-mediated transport.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See $T_{0.}$

T_{25}: See $T_{0.}$

T_{50}: See $T_{0.}$

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: Much of CAWS water is municipal effluent, which could contain the nutrients and halogens that promote growth of this species (Lin and Blum 1977; Eloranta and Kwandrans 2004). In Lake Michigan, red algae is typically found in harbor areas, which provide the necessary levels of halogens and trace metals from point and nonpoint sources (Lin and Blum 1977). In Britain, red algae was found in a navigation channel 32.8 km (10 mi) upstream from tidal influence in an area with high alkalinity, sulphates, and chlorides (Belcher 1956). Large sections of the Little Calumet River have overhanging vegetation and may not be suitable for the species. In the north branch of the Little Calumet River, the Cal-Sag Channel, and the CSSC, there is suitable hard substrate in the form of concrete, riprap, pilings, bridges, and sheet pile (LimnoTech 2010). Turbidity in the CAWS is high, which could limit photosynthesis (LimnoTech 2010). This species is typically found in flowing water or in active intertidal zones on exposed permanent rocky substrates (Kipp 2011). Current velocity in the CAWS is typically very low (LimnoTech 2010). However, this species has been found to colonize slow-moving water in sheltered areas, harbors, and freshwater canals

(Belcher 1956; Lin and Blum 1977; Sheath and Cole 1980; Reed 1980). Water flows out of the BSBH into Lake Michigan. The eastern segment of the south branch of the Little Calumet River also generally flows toward Lake Michigan, depending on the location and water level in Lake Michigan (GSWMD 2008). Thus, the red algae would have to move upstream to enter the CAWS and move to the Cal-Sag Channel.

The Nonstructural Alternative includes managing nutrient loads to waterways, which may affect red algae establishing in the CAWS and thereby reduce the abundance of spores and filaments in the CAWS. However, the transport of spores and filaments through the CAWS would not be affected.

T_{10}: See T_0.

T_{25}: See T_0. Future climate change may alter the physical, chemical, and climatological suitability of the CAWS for red algae. Temperature, in particular, may increase. Red algae has a wide temperature tolerance (Kipp 2011). Efforts to improve water quality in the CAWS will continue under the U.S. Environmental Protection Agency (EPA) mandates.

T_{50}: See T_{25}.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: There is no vessel traffic in the south branch of the Little Calumet River (section 3b); therefore, red algae would have to spread naturally through the south branch of the Little Calumet River to the Cal-Sag Channel. If red algae reaches the Cal-Sag Channel, it could be transported to the Brandon Road Lock and Dam by attaching to the hulls of recreational and commercial boats (section 3b). In addition, there is suitable habitat for the species (section 3e) throughout much of the CAWS, including in the vicinity of the Brandon Road Lock and Dam. This species has been found in slow-moving inland freshwaters under the appropriate chemical conditions (section 3e). These conditions are likely to be present in the CAWS, given the high municipal pollution inputs. Red algae has been in southern Lake Michigan near the WPS for decades, and it has not been reported in the CAWS.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by red algae. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of red algae through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of red algae through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of red algae by the diversion of Lake

Michigan water and the downstream passive transport of red algae spores and filaments to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's low probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0. There is a potential for human-mediated transport to the Brandon Road Lock and Dam via vessel traffic (section 3b). Red algae can spread quickly over hundreds of miles via boat traffic (section 3b). Sufficient time may elapse during this time step to allow red algae to spread through the CAWS by natural spread, boats, or a combination of both.

The Nonstructural Alternative is not expected to control the passage of red algae through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's medium probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Vessel traffic is known to exist in the CAWS. There may be low potential for transport in ballast water. The effectiveness of hull transport in spreading this species is not certain (section 3b). Although this species is commonly found in waters that are heavily affected by human uses, the ability of hydraulic and chemical conditions in the inland portions of the CAWS to support red algae is unknown. The direction of flow in the south branch of the Little Calumet River could inhibit the spread of this species from Lake Michigan to the Cal-Sag Channel. The potential natural spread rate of the species in the CAWS is not known. In addition, red algae has been reported in southern Lake Michigan, and it is uncertain why this species has not been reported in the CAWS.

The Nonstructural Alternative includes managing nutrient loads to waterways. The effectiveness of nutrient management on red algae abundance and its natural rate of spread is uncertain. Therefore, the Nonstructural Alternative is not expected to control the passage of red algae through the aquatic pathway by natural dispersion or human-mediated transport. Overall, uncertainty remains high.

T_{10}: See T_0.

T_{25}: See T_0. The future rate of spread for this species is uncertain. Over time, red algae is more certain to spread through the CAWS, assuming appropriate conditions are present. However, future efforts to improve water quality in the CAWS may reduce the discharge of municipal effluents that this species requires. The effects on red algae of such changes are unknown.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: HIGH

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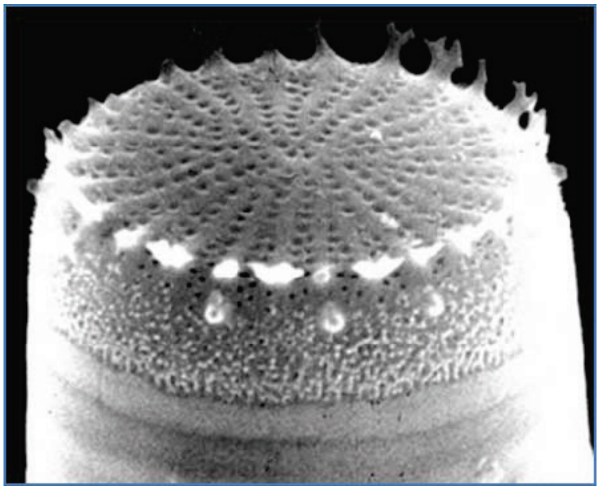
E.2.2.1.3 Diatom (*Stephanodiscus binderanus*)

NONSTRUCTURAL ALTERNATIVE

This alternative would potentially include the implementation of a combination of the following measures that can be implemented at time step 0 (T_0, in units of years) by local, state, and federal agencies and the public. The Nonstructural Alternative would include the development of a monitoring and response program.



Nonstructural Alternative Measures for *Stephanodiscus binderanus*

<table>
<tr><th>Option or Technology</th><th colspan="2">Description</th></tr>
<tr><td>Education & Outreach</td><td colspan="2">• Signage, pamphlets, brochures on how to identify aquatic nuisance species (ANS) and control the spread of ANS; promote national campaigns (i.e., “Stop Aquatic Hitchhikers”)
• Education of recreational waterway users</td></tr>
<tr><td>Anti-Fouling Hull Paints</td><td colspan="2">• Education of vessel owners and operators to promote use of antifouling paints</td></tr>
<tr><td>Ballast/Bilge-water Exchange</td><td colspan="2">• Ballast/bilge-water exchange</td></tr>
<tr><td>Monitoring</td><td colspan="2">• Agency monitoring
• Voluntary occurrence reporting</td></tr>
<tr><td>Laws & Regulations</td><td colspan="2">• U.S. Fish and Wildlife Service Lacey Act listing
• Mandatory watercraft inspection and decontamination</td></tr>
<tr><th></th><th>ANS Controls</th><th>ANS Factsheet[a]</th></tr>
<tr><td rowspan="2">ANS Control Methods</td><td>Algaecides</td><td>Algaecides</td></tr>
<tr><td>Alteration of Water Quality (Alum)</td><td>Alteration of Water Quality</td></tr>
</table>

[a] For more information refer to GLMRIS Team (2012).

PATHWAY 1

WILMETTE PUMPING STATION (WPS) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	High	High	High	High	High	High	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	High	High	High	High	High	High	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Wilmette Pumping Station (WPS) and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

c. Type of Mobility/Invasion Speed

S. binderanus is a planktonic diatom that moves passively in flowing water. *S. binderanus* was first recorded in Lake Michigan in 1938 and appeared in Lake Ontario in the late 1940s to early 1950s (Kipp 2011). It may have been in Lake Erie before the 1930s. It also now occurs in Lake Huron as well as in the Cuyahoga River, suggesting relatively rapid spread (Kipp 2011).

The Nonstructural Alternative is not expected to affect the arrival of *S. binderanus* from natural dispersion (i.e., current-driven passage) through aquatic pathways to the Chicago Area Waterway System (CAWS).

b. Human-Mediated Transport through Aquatic Pathways

S. binderanus is native to the Baltic Sea, so it was very likely introduced into the Great Lakes by ballast water discharge (Kipp 2011). Diatoms are commonly transported in ballast water over long distances (Klein et al. 2010). There is no commercial vessel traffic from the Great Lakes to the WPS, but there is recreational boat traffic (USACE 2011a,b). WPS is not a port with cargo vessel use; however, there is recreational boat use in the Wilmette Harbor that could potentially transport this species from the Great Lakes to the WPS.

Anti-fouling hull paints are a possible measure for controlling *S. binderanus* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of *S. binderanus* at the CAWS from human-mediated transport through aquatic pathways.

c. Current Abundance and Reproductive Capacity

T_0: In the Great Lakes, *S. binderanus* has a high reproductive capacity and may form dense near-shore blooms in more eutrophic inshore waters, with little invasion of offshore waters. While *S. binderanus* is common in the Great Lakes, it has fluctuated in abundance; its population has declined as nutrient inputs into the Great Lakes declined (Kipp 2011) and possibly from grazing by *Dreissena spp*. (Barbiero et al. 2006). In southern Lake Michigan specifically, it has dramatically declined since the 1960s as Lake Michigan became oligotrophic (Makarewicz and Baybutt 1981; Barbiero et al. 2006; Kipp 2011). This species was not found in 1998 surveys in Lake Michigan but was found in low abundance in 1999 (Barbiero and Tuchman 2001, 2002). Monitoring and control methods to completely eradicate *S. binderanus* in the Great Lakes and other locations where it has been documented are not likely to be successful because of the species' small size, high reproductive capacity, and large-scale dispersion in the Great Lakes.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the current abundance or reproductive capacity of *S. binderanus*.

T_{10}: See T_0. Future abundance cannot be predicted with any accuracy; however, reproductive capacity is predicted to remain the same, which can be very high during certain times of the year and with certain nutrient conditions.

T_{25}: See T_{10}. Further reductions in nutrient levels in Lake Michigan may continue to reduce the abundance of this species in southern Lake Michigan.

T_{50}: See T_{25}. Changes in water temperature and rainfall related to future climate change (Wuebbles et al. 2010) could affect the productivity of this species (see section 2f).

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: No data on the current distribution of *S. binderanus* in the Great Lakes are available (Kipp 2011), but this species historically does occur in Lake Michigan offshore of Chicago (Makarewicz and Baybutt 1981).

The Nonstructural Alternative is not expected to limit the movement of *S. binderanus* outside of its current distribution.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *S. binderanus* has been found in southern Lake Michigan offshore of the Chicago area (Kipp 2011), suggesting that the climate and habitat are suitable. It is most abundant in near-shore areas but is also common in pelagic habitat in Lake Michigan (Stoermer and Yang 1969). However, *S. binderanus* prefers eutrophic waters, and the decline of this species in Lake Michigan mirrored the decline in nutrient levels in Lake Michigan (Makarewicz and Baybutt 1981). *S. binderanus* also sometimes specifically occurs at river outlets into lakes (Kipp 2011). Resting cells are found in sediment (Kipp 2011).

The Nonstructural Alternative is not expected to reduce the habitat suitability for *S. binderanus* in southern Lake Michigan. As part of the Nonstructural Alternative, restrictions on nutrient loads to waterways may affect habitat suitability for this species.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Diatoms are sensitive to climatological conditions. Future climate change and/or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for *S. binderanus*. Future climate change is projected to increase water temperature in the Great Lakes (Wuebbles et al. 2010), and this could increase the productivity of *S. binderanus*. However, future climate change could also affect other variables that determine phytoplankton productivity, such as nutrients and water circulation, and the effects of these changes on *S. binderanus* are uncertain.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Conditions in southern Lake Michigan are not generally ideal because of the low nutrient levels (section 2f), but municipal discharge may create localized conditions that are favorable for this species. Although surveys suggest it is not abundant, *S. binderanus* is considered to be established in Lake Michigan and has been found offshore of the Chicago area (section 2e). Recreational vessels operating in the Great Lakes and using Wilmette Harbor could provide a means for the species to arrive at the WPS pathway.

Before antifouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *S. binderanus*. Until additional study is completed and these issues are addressed, antifouling hull paints are considered ineffective at controlling the arrival of *S. binderanus* at the CAWS due to fouled vessels.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways. These reductions may reduce the productivity of this species but they are not expected to affect the arrival of *S. binderanus* through aquatic pathways at the CAWS. Therefore, the Nonstructural Alternative's high probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Southern Lake Michigan may remain suitable for *S. binderanus,* although abundance may continue to decrease.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: *S. binderanus* is considered to be established in Lake Michigan and was documented offshore of the Chicago area (section 2e).

The Nonstructural Alternative is not expected to affect the arrival of *S. binderanus* at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.

T_{10}: See T_0.

T_{25}: See T_0. *S. binderanus* is documented to have declined significantly in Lake Michigan, and this species is not consistently found in phytoplankton surveys (section 2c). Future improvements in water quality in southern Lake Michigan may continue to reduce the abundance of *S. binderanus* near the WPS. However, the species is not expected to be eliminated.

T_{50}: See T_{25}. Diatoms are sensitive to climatological and water quality conditions, which are a source of uncertainty for this species. The effects of future climate change and new environmental regulations on *S. binderanus* populations are uncertain (section 2f) but may alter the distribution and annual occurrence.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

S. binderanus is a planktonic diatom that can spread rapidly by downstream flow or human-mediated mechanisms. From the WPS, *S. binderanus* must move more than 64 km (40 mi) downstream to reach the Brandon Road Lock and Dam. The downstream flow of water would facilitate the transport of this species downstream of the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., current-driven passage) of *S. binderanus* through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of *S. binderanus* as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

S. binderanus can be carried in ballast water (Kipp 2011), although the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). In addition, a sluice gate at the WPS controls the entry of vessel traffic from Lake Michigan into the North Shore Channel. Water from Lake Michigan is periodically pumped into the North Shore Channel, which could transport *S. binderanus* into the CAWS. There is no commercial vessel traffic in the North Shore Channel. Therefore, some natural downstream movement would likely be required to reach the Brandon Road Lock and Dam. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport *S. binderanus* into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River. The Nonstructural Alternative would not address the passage of *S. binderanus* by the Lake Michigan diversion through the CAWS.

Anti-fouling hull paints are a possible measure for controlling *S. binderanus* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the human-mediated transport of *S. binderanus* through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: None. Surface water is present year-round, and water depth is adequate throughout the CAWS (LimnoTech 2010). There is a sluice gate separating the CAWS from Lake Michigan that is periodically opened and closed. Water from Lake Michigan is periodically pumped into the North Shore Channel, which could transport *S. binderanus* into the CAWS.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *S. binderanus* is typically reported in lakes, but it is established in the Cuyahoga River (Kipp 2011) and in European lowland rivers and their tributaries (Hindák et al. 2006). *S. binderanus* sometimes occurs in lakes near river outlets (Kipp 2011). Resting cells are found in sediment (Kipp 2011). *S. binderanus* prefers eutrophic waters with high phosphate and a nitrogen-to-phosphate ratio of 7 (Kipp 2011). The CAWS has high nutrient levels because of municipal discharge (LimnoTech 2010).

The Nonstructural Alternative includes managing nutrient loads to waterways, which may affect *S. binderanus* entering and establishing in the CAWS, thereby reducing the abundance and potential passage of *S. binderanus* through the CAWS to Brandon Road Lock and Dam.

T_{10}: See T_0.

T_{25}: See T_0. *S. binderanus* is sensitive to nutrient levels. The discharge of nutrients may decrease because of the adoption of water quality standards and effluent discharge limitations currently proposed for the CAWS (Illinois Pollution Control Board 2012). However, the potential impact from these future water quality changes is uncertain.

T_{50}: See T_{25}.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: *S. binderanus* is typically a lake species, but it has been reported in rivers and water quality may be suitable in the CAWS (section 3d). The high nutrients in the CAWS may promote the productivity of this species. This species could drift through the WPS as a result of the Lake Michigan diversion or be transported on recreational vessels (e.g., canoes, kayaks) transferred over land from Wilmette Harbor to the North Shore Channel and flow or be carried downstream to the Brandon Road Lock and Dam. However, although *S. binderanus* has been in Lake Michigan since 1938, there are no records of it in the CAWS or downstream of the Brandon Road Lock and Dam. The lack of records may be due to the unsuitability of the habitat in the CAWS or a lack of phytoplankton surveys being conducted in the Illinois Waterway.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *S. binderanus*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of *S. binderanus* through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to control the passage of *S. binderanus* through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of *S. binderanus* by the Lake Michigan diversion or the downstream passive transport of *S. binderanus* to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: The hydraulic suitability and light conditions (e.g., turbidity) in the CAWS for *S. binderanus* are uncertain, although this species has been documented in rivers. Suitable habitat potentially exists for *S. binderanus*, and this species is considered to have time to transit to the Brandon Road Lock and Dam during this time step. Although it has been in Lake Michigan for decades, there are no records of *S. binderanus* in the CAWS or downstream of the Brandon Road Lock and Dam. It is uncertain why this species has not been detected.

The Nonstructural Alternative includes managing nutrient loads to waterways. The effectiveness of nutrient management on *S. binderanus* abundance and its natural rate of spread are uncertain. Therefore, the Nonstructural Alternative is not expected to control the passage of *S. binderanus* through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains high.

T_{10}: See T_0.
T_{25}: See T_0. Future efforts to improve water quality in the CAWS may reduce the concentrations of nutrients and halogens that this species tends to be associated with (section 3d). These changes in water quality may reduce the habitat suitability of the CAWS for *S. binderanus*.
T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

PATHWAY 2

CHICAGO RIVER CONTROLLING WORKS (CRCW) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	High	High	High	High	High	High	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	High	High	High	High	High	High	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Chicago River Controlling Works (CRCW) and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not affect the presence of the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

S. binderanus is a planktonic diatom that moves passively in flowing water. S. binderanus was first recorded in Lake Michigan in 1938 and appeared in Lake Ontario in the late 1940s to early 1950s (Kipp 2011). It may have been in Lake Erie before the 1930s. It also now occurs in Lake Huron as well as in the Cuyahoga River, suggesting relatively rapid spread (Kipp 2011).

The Nonstructural Alternative is not expected to affect the arrival of *S. binderanus* from natural dispersion (i.e., current-driven passage) through aquatic pathways at the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

S. binderanus is native to the Baltic Sea, so it was very likely introduced into the Great Lakes by ballast water discharge (Kipp 2011). Diatoms are commonly transported in ballast water over long distances (Klein et al. 2010). There is commercial and recreational vessel traffic from the Great Lakes to the CRCW (USACE 2011a,b) that could potentially transport this species from the Great Lakes to the CRCW.

Anti-fouling hull paints are a possible measure for controlling *S. binderanus* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the human-mediated transport of *S. binderanus* through aquatic pathways to the CAWS.

c. Current Abundance and Reproductive Capacity

T_0: In the Great Lakes, *S. binderanus* has a high reproductive capacity and may form dense near-shore blooms in more eutrophic inshore waters, with little invasion of

offshore waters. While *S. binderanus* is common in the Great Lakes, it has fluctuated in abundance; its population has declined as nutrient inputs into the Great Lakes declined (Kipp 2011) and possibly from grazing by *Dreissena spp*.
(Barbiero et al. 2006). In southern Lake Michigan specifically, it has dramatically declined since the 1960s as Lake Michigan became oligotrophic (Makarewicz and Baybutt 1981; Barbiero et al. 2006; Kipp 2011). This species was not found in 1998 surveys in Lake Michigan but was found in low abundance in 1999 (Barbiero and Tuchman 2001, 2002). Monitoring and control methods to completely eradicate *S. binderanus* in the Great Lakes and other locations where it has been documented are not likely to be successful because of the species' small size and high reproductive capacity.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the current abundance or reproductive capacity of *S. binderanus*.

T_{10}: See T_0. Future abundance cannot be predicted with any accuracy; however, reproductive capacity is predicted to remain the same, which can be very high during certain times of the year and with certain nutrient conditions.

T_{25}: See T_{10}. Further reductions in nutrient levels in Lake Michigan may continue to reduce the abundance of this species in southern Lake Michigan.

T_{50}: See T_{25}. Changes in water temperature and rainfall related to future climate change (Wuebbles et al. 2010) could affect the productivity of this species (see section 2f).

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: No data on the current distribution of *S. binderanus* in the Great Lakes are available (Kipp 2011), but this species historically does occur in Lake Michigan offshore of Chicago (Makarewicz and Baybutt 1981).

The Nonstructural Alternative is not expected to limit the movement of *S. binderanus* outside of its current distribution.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *S. binderanus* was been found in southern Lake Michigan offshore of the Chicago area (Kipp 2011), suggesting that climate and habitat are suitable. It is most abundant in near-shore areas but also common in pelagic habitat in Lake Michigan (Stoermer and Yang 1969). However, *S. binderanus* prefers eutrophic waters, and the decline of this species in Lake Michigan mirrored the decline in nutrient levels in Lake Michigan (Makarewicz and Baybutt 1981). *S. binderanus* also sometimes specifically occurs at river outlets into lakes (Kipp 2011). Resting cells are found in sediment (Kipp 2011).

The Nonstructural Alternative is not expected to reduce the habitat suitability for *S. binderanus* in southern Lake Michigan. As part of the Nonstructural Alternative, restrictions on nutrient loads to waterways may affect habitat suitability for this species.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Diatoms are sensitive to climatological conditions. Future climate change and new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for *S. binderanus*. Climate change is projected to increase water temperature in the Great Lakes (Wuebbles et al. 2010), and this condition could increase the productivity of *S. binderanus*. However, future climate change could also affect other variables that determine phytoplankton productivity, such as nutrients and water circulation, and the effects of these changes on *S. binderanus* are uncertain.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Conditions in southern Lake Michigan are not generally ideal because of the low nutrient levels (section 2f), but municipal discharge may create localized conditions that are favorable for this species. Although surveys suggest it is not abundant, *S. binderanus* is considered to be established in Lake Michigan and has been found offshore of the Chicago area (section 2e). Recreational and commercial vessels using the CRCW could provide a means for the species to arrive at the CRCW pathway.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *S. binderanus*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of *S. binderanus* at the CAWS due to fouled vessels.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways. These reductions may reduce the productivity of this species but they are not expected to affect the arrival of *S. binderanus* through aquatic pathways at the CAWS. Therefore, the Nonstructural Alternative's high probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Southern Lake Michigan may remain suitable for *S. binderanus*, although abundance may continue to decrease.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: *S. binderanus* is considered to be established in Lake Michigan and was documented offshore of the Chicago area (section 2e).

The Nonstructural Alternative is not expected to affect the arrival of *S. binderanus* through aquatic pathways at the CAWS. Therefore, the uncertainty remains low.

T_{10}: See T_0.

T_{25}: See T_0. *S. binderanus* is documented to have declined significantly in Lake Michigan, and this species is not consistently found in phytoplankton surveys (section 2c). Future improvements in water quality in southern Lake Michigan may continue to reduce the abundance of *S. binderanus* near the CRCW. However, the species is not expected to be eliminated.

T_{50}: See T_{25}. Diatoms are sensitive to climatological and water quality conditions, which are a source of uncertainty for this species. The effects of future climate change and new environmental regulations on *S. binderanus* populations are uncertain (section 2f), but they may alter the distribution and annual occurrence.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

S. binderanus is a planktonic diatom that can spread rapidly by downstream flow or human-mediated mechanisms. From the CRCW, *S. binderanus* must move more than 64 km (40 mi) downstream to reach the Brandon Road Lock and Dam. The downstream flow of water would facilitate the transport of this species downstream of the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., current-driven passage) of *S. binderanus* through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of *S. binderanus* as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

S. binderanus can be carried in ballast water (Kipp 2012), and there is some commercial and recreational vessel traffic between the CRCW and the Brandon Road Lock and Dam (USACE 2011a; NBIC 2012). However, the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the *S. binderanus* into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Anti-fouling hull paints are a possible measure for controlling *S. binderanus* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of *S. binderanus* through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: None. Surface water is present year-round, and water depth is adequate throughout the CAWS (LimnoTech 2010).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *S. binderanus* is typically reported in lakes, but it is established in the Cuyahoga River (Kipp 2011) and in European lowland rivers and their tributaries (Hindák et al. 2006). *S. binderanus* sometimes occurs in lakes near river outlets (Kipp 2011). Resting cells are found in sediment (Kipp 2011). *S. binderanus* prefers eutrophic waters with high phosphate and a nitrogen-to-phosphate ratio of 7 (Kipp 2011). The CAWS has high nutrient levels because of municipal discharge (LimnoTech 2010).

The Nonstructural Alternative includes managing nutrient loads to waterways, which may affect *S. binderanus* entering and establishing in the CAWS, thereby reducing the abundance and potential passage of *S. binderanus* through the CAWS to Brandon Road Lock and Dam.

T_{10}: See T_0.

T_{25}: See T_0. *S. binderanus* is sensitive to nutrient levels. The discharge of nutrients may decrease due to the adoption of water quality standards and effluent discharge limitations currently proposed for the CAWS (Illinois Pollution Control Board 2012). However, the potential impact of these future water quality changes is uncertain.

T_{50}: See T_{25}.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: *S. binderanus* is typically a lake species, but it has been reported in rivers, and water quality may be suitable in the CAWS (section 3d). The high nutrients in the CAWS may promote the productivity of this species. This species could be transported through the CRCW and flow downstream to the Brandon Road Lock and Dam. However, although it has been in Lake Michigan since 1938, there are no records of *S. binderanus* in the CAWS or downstream of the Brandon Road Lock and Dam. The lack of records may be due to the unsuitability of the habitat in the CAWS or to a lack of phytoplankton surveys conducted in the Illinois Waterway.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *S. binderanus*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of *S. binderanus* through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of *S. binderanus* through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of *S. binderanus* by the Lake Michigan diversion or the downstream passive transport of *S. binderanus* to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Although this species has been documented in rivers (section 3d), the suitability of hydraulic, chemical, and light conditions (e.g., turbidity) in the CAWS for *S. binderanus* is uncertain. Suitable habitat potentially exists for *S. binderanus*, and this species is considered to have time to transit to the Brandon Road Lock and Dam during this time step. Although *S. binderanus* has been in Lake Michigan for decades, there are no records of it in the CAWS or downstream of the Brandon Road Lock and Dam. It is uncertain why this species has not been detected.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *S. binderanus*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at reducing the uncertainty related to passage of *S. binderanus* due to fouled vessels.

The Nonstructural Alternative includes managing nutrient loads to waterways. The effectiveness of nutrient management on *S. binderanus* abundance and its natural rate of spread are uncertain. Therefore, the Nonstructural Alternative is not expected to control the passage of *S. binderanus* through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the uncertainty remains high.

T_{10}: See T_0.
T_{25}: See T_0. Future efforts to improve water quality in the CAWS may reduce the concentrations of nutrients and halogens that this species tends to be associated with (section 3d). These changes in water quality may reduce the habitat suitability of the CAWS for *S. binderanus*.
T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

PATHWAY 3

CALUMET HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Measures

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	High	High	High	High	High	High	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	High	High	High	High	High	High	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Calumet Harbor and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not affect the presence of the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

S. binderanus is a planktonic diatom that moves passively by flowing water. *S. binderanus* was first recorded in Lake Michigan in 1938 and appeared in Lake Ontario in the late 1940s to early 1950s (Kipp 2011). It may have been in Lake Erie before the 1930s. It also now occurs in Lake Huron as well as the Cuyahoga River, suggesting relatively rapid spread (Kipp 2011).

The Nonstructural Alternative is not expected to affect the arrival of *S. binderanus* from natural dispersion (i.e., current-driven passage) through aquatic pathways at the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

S. binderanus is native to the Baltic Sea, so it was very likely introduced into the Great Lakes by ballast water discharge (Kipp 2011). Diatoms are commonly transported in ballast water over long distances (Klein et al. 2010). There is commercial and recreational vessel traffic from the Great Lakes to Calumet Harbor (USACE 2011a,b) that could potentially transport this species from the Great Lakes to Calumet Harbor.

Anti-fouling hull paints are a possible measure for controlling *S. binderanus* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of *S. binderanus* from human-mediated transport through aquatic pathways at the CAWS.

c. Current Abundance and Reproductive Capacity

T_0: In the Great Lakes, *S. binderanus* has a high reproductive capacity and may form dense near-shore blooms in more eutrophic inshore waters, with little invasion of offshore waters. While *S. binderanus* is common in the Great Lakes, it has fluctuated in abundance; its population has declined as nutrient inputs into the Great Lakes declined (Kipp 2011) and possibly from grazing by *Dreissena spp*. (Barbiero et al. 2006). In southern Lake Michigan specifically, it has dramatically declined since the 1960s as Lake Michigan became oligotrophic (Makarewicz and Baybutt 1981; Barbiero et al. 2006; Kipp 2011). This species was not found in 1998 surveys in Lake Michigan but was found in low abundance in 1999 (Barbiero and Tuchman 2001, 2002). Monitoring and control methods to completely eradicate *S. binderanus* in the Great Lakes and other locations where it has been documented are not likely to be successful because of the species' small size and high reproductive capacity.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the current abundance or reproductive capacity of *S. binderanus*.

T_{10}: See T_0. Future abundance cannot be predicted with any accuracy; however, reproductive capacity is predicted to remain the same, which can be very high during certain times of the year and with certain nutrient conditions.

T_{25}: See T_{10}. Further reductions in nutrient levels in Lake Michigan may continue to reduce the abundance of this species in southern Lake Michigan.

T_{50}: See T_{25}. Changes in water temperature and rainfall related to future climate change (Wuebbles et al. 2010) could affect the productivity of this species (see section 2f).

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: No data on the current distribution of *S. binderanus* in the Great Lakes (Kipp 2011) are available, but this species historically does occur in Lake Michigan offshore of Chicago (Makarewicz and Baybutt 1981).

The Nonstructural Alternative is not expected to limit the movement of *S. binderanus* outside of its current distribution.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *S. binderanus* has been found in southern Lake Michigan offshore of the Chicago area (Kipp 2011), suggesting that the climate and habitat are suitable. It is most abundant in near-shore areas but also is common in pelagic habitat in Lake Michigan (Stoermer and Yang 1969). However, *S. binderanus* prefers eutrophic waters, and the decline of this species in Lake Michigan mirrored the decline in nutrient levels in

Lake Michigan (Makarewicz and Baybutt 1981). *S. binderanus* also sometimes specifically occurs at river outlets into lakes (Kipp 2011). Resting cells are found in sediment (Kipp 2011).

The Nonstructural Alternative is not expected to reduce the habitat suitability for *S. binderanus* in southern Lake Michigan. As part of the Nonstructural Alternative, restrictions on nutrient loads to waterways may affect habitat suitability for this species.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_{25}. Diatoms are sensitive to climatological conditions. Future climate change and new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for *S. binderanus*. Future climate change is projected to increase water temperature in the Great Lakes (Wuebbles et al. 2010), which could increase the productivity of *S. binderanus*. However, climate change could also affect other variables that determine phytoplankton productivity, such as nutrients and water circulation, and the effects of these changes on *S. binderanus* are uncertain.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Conditions in southern Lake Michigan are not generally ideal because of the low nutrient levels (section 2f), but municipal discharge may create localized conditions that are favorable for this species. Although surveys suggest it is not abundant, *S. binderanus* is considered to be established in Lake Michigan and has been found offshore of the Chicago area (section 2e).

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *S. binderanus*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of *S. binderanus* at the CAWS due to fouled vessels.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways. These reductions may reduce the productivity of this species but they are not expected to affect the arrival of *S. binderanus* through aquatic pathways at the CAWS. Therefore, the Nonstructural Alternative's high probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Southern Lake Michigan may remain suitable for *S. binderanus*, although abundance may continue to decrease.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: *S. binderanus* is considered to be established in Lake Michigan and was documented offshore of the Chicago area (section 2e).

The Nonstructural Alternative is not expected to affect the arrival of *S. binderanus* through aquatic pathways at the CAWS. Therefore, the uncertainty remains low.

T_{10}: See T_0.

T_{25}: See T_0. *S. binderanus* is documented to have declined significantly in Lake Michigan, and this species is not consistently found in phytoplankton surveys (section 2c). Future improvements in water quality in southern Lake Michigan may continue to reduce the abundance of *S. binderanus* near Calumet Harbor. However, the species is not expected to be eliminated.

T_{50}: See T_{25}. Diatoms are sensitive to climatological and water quality conditions, which are a source of uncertainty for this species. The effects of future climate change on *S. binderanus* populations are uncertain (section 2f) but may alter the distribution and annual occurrence.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

S. binderanus is a planktonic diatom that can spread rapidly by downstream flow or human-mediated mechanisms. From Calumet Harbor, *S. binderanus* must move approximately 64 km (40 mi) downstream to reach the Brandon Road Lock and Dam. The downstream flow of water would facilitate the transport of this species downstream of the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., current-driven passage) of *S. binderanus* through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of *S. binderanus* as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Although there is little commercial river traffic to Calumet Harbor (NBIC 2012), there is heavy commercial vessel traffic between the Brandon Road Lock and Dam and the

T.J. O'Brien Lock and Dam, which is approximately 8 km (5 mi) south of Calumet Harbor (USACE 2011a; NBIC 2012). Recreational vessel traffic also occurs between Calumet Harbor and Brandon Road Lock and Dam. *S. binderanus* can be carried in ballast water (Kipp 2011), although the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the *S. binderanus* into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Anti-fouling hull paints are a possible measure for controlling *S. binderanus* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of S. binderanus through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: None. Surface water is present year-round, and water depth is adequate throughout the CAWS (LimnoTech 2010).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *S. binderanus* is typically reported in lakes, but it is established in the Cuyahoga River (Kipp 2011) and in European lowland rivers and their tributaries (Hindák et al. 2006). *S. binderanus* sometimes occurs in lakes near river outlets (Kipp 2011). Resting cells are found in sediment (Kipp 2011). *S. binderanus* prefers eutrophic waters with high phosphate and a nitrogen-to-phosphate ratio of 7 (Kipp 2011). The CAWS has high nutrient levels because of municipal discharge (LimnoTech 2010).

The Nonstructural Alternative includes managing nutrient loads to waterways, which may affect *S. binderanus* entering and establishing in the CAWS, thereby reducing the abundance and potential passage of *S. binderanus* through the CAWS to Brandon Road Lock and Dam.

T_{10}: See T_0.

T_{25}: See T_0. *S. binderanus* is sensitive to nutrient levels. The discharge of nutrients may decrease due to the adoption of water quality standards and effluent discharge limitations currently proposed for the CAWS (Illinois Pollution Control Board 2012). However, the potential impact of these future water quality changes is uncertain.
T_{50}: See T_{25}.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: *S. binderanus* is typically a lake species, but it has been reported in rivers, and water quality may be suitable in the CAWS (section 3d). The high nutrient levels in the CAWS may promote the productivity of this species. This species could be transported through Calumet Harbor and downstream to the Brandon Road Lock and Dam by floating or potentially by recreational and commercial vessel transport (sections 3a, 3b). However, although it has been in Lake Michigan since 1938, there are no records of *S. binderanus* in the CAWS or downstream of the Brandon Road Lock and Dam. The lack of records may be due to the unsuitability of the habitat in the CAWS or to a lack of phytoplankton surveys conducted in the Illinois Waterway.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *S. binderanus*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of *S. binderanus* through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of *S. binderanus* through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of *S. binderanus* by the Lake Michigan diversion or the downstream passive transport of *S. binderanus* to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Although this species has been documented in rivers (section 3d), the suitability of hydraulic, chemical, and light conditions (e.g., turbidity) in the CAWS for *S. binderanus* is uncertain. Suitable habitat potentially exists for *S. binderanus*, and this species is considered to have time to transit to the Brandon Road Lock and Dam during this time step. Although it has been in Lake Michigan for decades, there are no records of *S. binderanus* in the CAWS or downstream of the Brandon Road Lock and Dam. It is uncertain why this species has not been detected.

The Nonstructural Alternative includes managing nutrient loads to waterways. The effectiveness of nutrient management on *S. binderanus* abundance and its natural rate of spread are uncertain. Therefore, the Nonstructural Alternative is not expected to control the passage of *S. binderanus* through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains high.

T_{10}: See T_0.

T_{25}: See T_0. Future efforts to improve water quality in the CAWS may reduce the concentrations of nutrients and halogens that this species tends to be associated with (section 3d). These changes in water quality may reduce the habitat suitability of the CAWS for *S. binderanus*.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

PATHWAY 4

INDIANA HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Measures

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	High	Low	High	Low	High	Medium	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	High	Low	High	Low	High	Medium	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Indiana Harbor and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative is not expected to affect the presence of the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

S. binderanus is a planktonic diatom that moves passively by flowing water. *S. binderanus* was first recorded in Lake Michigan in 1938 and appeared in Lake Ontario in the late 1940s to early 1950s (Kipp 2011). It may have been in Lake Erie since before the 1930s. It also now occurs in Lake Huron as well as in the Cuyahoga River, suggesting relatively rapid spread (Kipp 2011).

The Nonstructural Alternative is not expected to affect the arrival of *S. binderanus* from natural dispersion (i.e., current-driven passage) through aquatic pathways at the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

S. binderanus is native to the Baltic Sea, so it was very likely introduced into the Great Lakes by ballast water discharge (Kipp 2011). Diatoms are commonly transported in ballast water over long distances (Klein et al. 2010). There is heavy commercial vessel traffic from the Great Lakes to Indiana Harbor (USACE 2011a) that could potentially transport this species from the Great Lakes to Indiana Harbor.

Anti-fouling hull paints are a possible measure for controlling *S. binderanus* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of *S. binderanus* from human-mediated transport through aquatic pathways at the CAWS.

c. Current Abundance and Reproductive Capacity

T_0: In the Laurentian Great Lakes, *S. binderanus* has a high reproductive capacity and may form dense near-shore blooms in more eutrophic inshore waters, with little invasion of offshore waters. While *S. binderanus* is common in the Great Lakes, it has fluctuated in abundance; its population has declined as nutrient inputs into the Great Lakes declined (Kipp 2011) and possibly from *Dreissena spp*. (Barbiero et al. 2006). In southern Lake Michigan specifically, it has dramatically declined since the 1960s as Lake Michigan became oligotrophic (Makarewicz and Baybutt 1981; Barbiero et al. 2006; Kipp 2011). This species was not found in 1998 surveys in Lake Michigan but was found in low abundance in 1999 (Barbiero and Tuchman 2001, 2002). Monitoring and control methods to completely eradicate *S. binderanus* in the Great Lakes and other locations where it has been documented are not likely to be successful because of the species' small size and high reproductive capacity.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the current abundance or reproductive capacity of *S. binderanus*.

T_{10}: See T_0. Future abundance cannot be predicted with any accuracy; however, reproductive capacity is predicted to remain the same but can be very high during certain times of the year and with certain nutrient conditions.

T_{25}: See T_{10}. Further reductions in nutrient levels in Lake Michigan may continue to reduce the abundance of this species in southern Lake Michigan.

T_{50}: See T_{25}. Changes in water temperature and rainfall related to future climate change (Wuebbles et al. 2010) could affect the productivity of this species (see section 2f).

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: No data on the current distribution of *S. binderanus* in the Great Lakes (Kipp 2011) are available, but this species historically does occur in Lake Michigan offshore of Chicago (Makarewicz and Baybutt 1981).

The Nonstructural Alternative is not expected to limit the movement *of S. binderanus* outside of its current distribution.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *S. binderanus* has been found in southern Lake Michigan offshore of the Chicago area (Kipp 2011), suggesting that the climate and habitat are suitable. It is most abundant in near-shore areas but is also common in pelagic habitat in Lake Michigan

(Stoermer and Yang 1969). However, *S. binderanus* prefers eutrophic waters, and the decline in this species in Lake Michigan mirrored the decline in nutrient levels in Lake Michigan (Makarewicz and Baybutt 1981). *S. binderanus* also sometimes specifically occurs at river outlets into lakes (Kipp 2011). Resting cells are found in sediment (Kipp 2011).

The Nonstructural Alternative is not expected to reduce the habitat suitability for *S. binderanus* in southern Lake Michigan. As part of the Nonstructural Alternative, restrictions on nutrient loads to waterways could affect habitat suitability for this species.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_{25}. Diatoms are sensitive to climatological conditions. Future climate change and new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for *S. binderanus.* Future climate change is projected to increase water temperature in the Great Lakes (Wuebbles et al. 2010), which could increase the productivity of *S. binderanus*. However, future climate change could also affect other variables that determine phytoplankton productivity, such as nutrients and water circulation, and the effects of these changes on *S. binderanus* are uncertain.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Conditions in southern Lake Michigan are not generally ideal because of the low nutrient levels (section 2f), but municipal discharge may create localized conditions that are favorable for this species. Although surveys suggest it is not abundant, *S. binderanus* is considered to be established in Lake Michigan and has been found offshore of the Chicago area (section 2e). Recreational and commercial vessels using Indiana Harbor could provide a means for the species to arrive at the pathway.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *S. binderanus*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of *S. binderanus* at the CAWS due to fouled vessels.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways. These reductions may reduce the productivity of this species but they are not expected to affect the arrival of *S. binderanus* through aquatic pathways at the CAWS. Therefore,

the Nonstructural Alternative's high probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0. Southern Lake Michigan may remain suitable for *S. binderanus*, although abundance may continue to decrease.
T_{25}: See T_{10}.
T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: *S. binderanus* is considered to be established in Lake Michigan and was documented offshore of the Chicago area (section 2e).

The Nonstructural Alternative is not expected to affect the arrival of *S. binderanus* at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.
T_{10}: See T_0.
T_{25}: See T_0. *S. binderanus* is documented to have declined significantly in Lake Michigan, and this species is not consistently found in phytoplankton surveys (section 2c). Future improvements in water quality in southern Lake Michigan may continue to reduce the abundance of *S. binderanus* near Indiana Harbor. However, the species is not expected to be eliminated.
T_{50}: See T_{25}. Diatoms are sensitive to climatological and water quality conditions, which are a source of uncertainty for this species. The effects of future climate change and new environmental regulations on *S. binderanus* populations are uncertain (section 2f) but may alter the distribution and annual occurrence.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

S. binderanus is a planktonic diatom that can spread rapidly by downstream flow or human-mediated mechanisms. From Indiana Harbor, *S. binderanus* must move approximately 64 km (40 mi) downstream to reach the Brandon Road Lock and Dam. The downstream flow of water would facilitate the transport of this species downstream of the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., current-driven passage) of *S. binderanus* through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of *S. binderanus* as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Vessel traffic to Indiana Harbor is primarily lake-wide (USACE 2011a). *S. binderanus* can be carried in ballast water (Kipp 2012), although the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). There is no vessel traffic in the Grand Calumet River east of Indiana Harbor. However, recreational vessel traffic (e.g., canoe, kayak) could potentially transport this species to other areas of the CAWS where commercial and larger recreational vessels operate. In addition, some natural downstream dispersal would likely be necessary to reach the Brandon Road Lock and Dam.

Anti-fouling hull paints are a possible measure for controlling *S. binderanus* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of S. binderanus through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: None. Surface water is present year-round, and water depth is adequate throughout the CAWS (LimnoTech 2010). There is sheet pile across the Grand Calumet River between the Indiana Harbor Canal and the Calumet River that could act as a temporary barrier, especially under low flows.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *S. binderanus* is typically reported in lakes, but it is established in the Cuyahoga River (Kipp 2011) and in European lowland rivers and their tributaries (Hindák et al. 2006). *S. binderanus* sometimes occurs in lakes near river outlets

(Kipp 2011). Resting cells are found in sediment (Kipp 2011). *S. binderanus* prefers eutrophic waters with high phosphate and a nitrogen-to-phosphate ratio of 7 (Kipp 2011). The CAWS has high nutrient levels due to municipal discharge (LimnoTech 2010). Water flows out of Indiana Harbor into Lake Michigan. West of the Indiana Harbor Canal, the easternmost sections of the Grand Calumet River also generally flow toward Lake Michigan, while other sections can flow east or west depending on location (Weiss et al. 1997). Thus, *S. binderanus* would have to move upstream to enter the CAWS and move to the Calumet Sag Channel.

The Nonstructural Alternative includes managing nutrient loads to waterways, which may affect *S. binderanus* entering and establishing in the CAWS, thereby reducing the abundance and potential passage of *S. binderanus* through the CAWS to Brandon Road Lock and Dam.

T_{10}: See T_0.

T_{25}: See T_0. *S. binderanus* is sensitive to nutrient levels. The discharge of nutrients may decrease because of the adoption of water quality standards and effluent discharge limitations currently proposed for the CAWS (Illinois Pollution Control Board 2012). However, the potential impact of these future water quality changes is uncertain.

T_{50}: See T_{25}.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating	Low	Low	Low	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: *S. binderanus* is typically a lake species, but it has been reported in rivers, and water quality may be suitable in the CAWS (section 3d). Because of the lack of vessel traffic (section 3b), natural spread through the Grand Calumet would likely be required for *S. binderanus* to reach the Little Calumet River and the Calumet Sag Channel. The species may also be transported by small recreational watercraft (e.g., canoe, kayak) to other areas of the CAWS where commercial vessels and larger recreational vessels operate. These vessels could then transport the species to Brandon Road Lock and Dam. Water flow in Indiana Harbor and portions of the Grand Calumet River is toward Lake Michigan. *S. binderanus* organisms are phytoplankton and are not likely to move upstream through these waters (sections 3a, 3b). However, although it has been in Lake Michigan since 1938, there are no records of *S. binderanus* in the CAWS or downstream of the Brandon Road Lock and Dam. The lack of records may be due to the unsuitability of the habitat in the CAWS or a lack of phytoplankton surveys conducted in the Illinois Waterway.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *S. binderanus*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of *S. binderanus* through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to control the passage of *S. binderanus* through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of *S. binderanus* by downstream passive transport to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's low probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Over time, this species may be able to move upstream (by wind or by aquatic life) through Indiana Harbor and the Grand Calumet River to navigable sections of the CAWS that flow toward the Mississippi River Basin (MRB).

The Nonstructural Alternative is not expected to control the passage of *S. binderanus* through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's medium probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Although this species has been documented in rivers (section 3d), the suitability of hydraulic, chemical, and light conditions (e.g., turbidity) in the CAWS for *S. binderanus* is uncertain. Although the potential for passage exists, it is uncertain why this species has not been recorded in the Illinois River despite being in southern Lake Michigan for decades. The lakeward flow of Indiana Harbor and the Grand Calumet River could decrease or inhibit spread through the pathway (section 3d).

The Nonstructural Alternative includes managing nutrient loads to waterways and hull fouling paints. The effectiveness of nutrient management on *S. binderanus* abundance and its natural rate of spread are uncertain. Hull fouling paints are not identified as an effective measure to control passage. Therefore, the Nonstructural Alternative is not expected to control the passage of *S. binderanus* through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains high.

T_{10}: See T_0.

T_{25}: See T_0. Future efforts to improve water quality in the CAWS may reduce the concentrations of nutrients and halogens that this species tends to be associated with (section 3d). These changes in water quality may reduce the habitat suitability of the CAWS for *S. binderanus*. Flow conditions in Indiana Harbor and the Grand Calumet River are expected to remain unfavorable to passage. However, this species is more certain to pass through the CAWS in 25 years compared to the previous time step.

The Nonstructural Alternative is not expected to control the passage of *S. binderanus* through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains high.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

PATHWAY 5

BURNS SMALL BOAT HARBOR (BSBH) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	High	Low	High	Low	High	Medium	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	High	Low	High	Low	High	Medium	High
P(colonizes)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Burns Small Boat Harbor (BSBH) and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not affect the presence of the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

S. binderanus is a planktonic diatom that moves passively in flowing water.
S. binderanus was first recorded in Lake Michigan in 1938 and appeared in Lake Ontario in the late 1940s to early 1950s (Kipp 2011). It may have been in Lake Erie since before the 1930s. It also now occurs in Lake Huron as well as in the Cuyahoga River, suggesting relatively rapid spread (Kipp 2011).

The Nonstructural Alternative is not expected to affect the arrival of *S. binderanus* from natural dispersion (i.e., current-driven passage) through aquatic pathways at the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

S. binderanus is native to the Baltic Sea, so it was very likely introduced into the Great Lakes by ballast water discharge (Kipp 2011). Diatoms are commonly transported in ballast water over long distances (Klein et al. 2010). There is recreational but no commercial vessel traffic from the Great Lakes to the BSBH (USACE 2011a). However, heavy commercial traffic to Burns Harbor, which is adjacent to the BSBH, could potentially transport this species from the Great Lakes to the BSBH.

Anti-fouling hull paints are a possible measure for controlling *S. binderanus* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of *S. binderanus* from human-mediated transport through aquatic pathways at the CAWS.

c. Current Abundance and Reproductive Capacity

T_0: In the Great Lakes, *S. binderanus* has a high reproductive capacity and may form dense near-shore blooms in more eutrophic inshore waters, with little invasion of offshore waters. While *S. binderanus* is common in the Great Lakes, it has fluctuated in abundance; its population has declined as nutrient inputs into the Great Lakes declined (Kipp 2011) and possibly from grazing by *Dreissena spp*. (Barbiero et al. 2006). In southern Lake Michigan specifically, it has dramatically declined since the 1960s as Lake Michigan became oligotrophic (Makarewicz and Baybutt 1981; Barbiero et al. 2006; Kipp 2011). This species was not found in 1998 surveys in Lake Michigan but was found in low abundance in 1999 (Barbiero and Tuchman 2001, 2002). Monitoring and control methods to completely eradicate *S. binderanus* in the Great Lakes and other locations where it has been documented are not likely to be successful because of the species' small size and high reproductive capacity.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways, which may affect the current abundance or reproductive capacity of *S. binderanus*.

T_{10}: See T_0. Future abundance cannot be predicted with any accuracy; however, reproductive capacity is predicted to remain the same, which can be very high during certain times of the year and with certain nutrient conditions.

T_{25}: See T_{10}. Further reductions in nutrient levels in Lake Michigan may continue to reduce the abundance of this species in southern Lake Michigan.

T_{50}: See T_{25}. Changes in water temperature and rainfall related to future climate change (Wuebbles et al., 2010) could affect the productivity of this species (see section 2f).

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: No data on the current distribution of *S. binderanus* in the Great Lakes (Kipp 2011) are available, but this species historically does occur in Lake Michigan offshore of Chicago (Makarewicz and Baybutt 1981).

The Nonstructural Alternative is not expected to limit the movement of *S. binderanus* outside of its current distribution.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: *S. binderanus* has been found in southern Lake Michigan offshore of the Chicago area (Kipp 2011), suggesting that the climate and habitat are suitable. It is most abundant in near-shore areas but also common in pelagic habitat in Lake Michigan (Stoermer and Yang 1969). However, *S. binderanus* prefers eutrophic waters, and the decline of this species in Lake Michigan mirrored the decline in nutrient levels in Lake Michigan (Makarewicz and Baybutt 1981). *S. binderanus* also sometimes occurs specifically at river outlets into lakes (Kipp 2011). Resting cells are found in sediment (Kipp 2011).

The Nonstructural Alternative is not expected to reduce the habitat suitability for *S. binderanus* in southern Lake Michigan. As part of the Nonstructural Alternative, restrictions on nutrient loads to waterways may affect habitat suitability for this species.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_{25}. Diatoms are sensitive to climatological conditions. Future climate change and/or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for *S. binderanus*. Future climate change is projected to increase water temperature in the Great Lakes (Wuebbles et al. 2010), and this condition could increase the productivity of *S. binderanus*. However, climate change could also affect other variables that determine phytoplankton productivity, such as nutrients and water circulation, and the effects of these changes on *S. binderanus* are uncertain.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Conditions in southern Lake Michigan are not generally ideal because of the low nutrient levels (section 2f), but municipal discharge may create localized conditions that are favorable for this species. Although surveys suggest it is not abundant, *S. binderanus* is considered to be established in Lake Michigan and has been found offshore of the Chicago area (section 2e). Recreational vessels using the BSBH could provide a means for the species to arrive at the pathway. In addition, commercial vessels using the nearby Burns Harbor could also transport the species to the pathway.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *S. binderanus*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of *S. binderanus* at the CAWS due to fouled vessels.

The Nonstructural Alternative includes restrictions on nutrient loads to waterways. These reductions may reduce the productivity of this species but they are not expected to affect the arrival of *S. binderanus* at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Southern Lake Michigan may remain suitable for *S. binderanus*, although abundance may continue to decrease.
T_{25}: See T_{10}.
T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: *S. binderanus* is considered to be established in Lake Michigan and was documented offshore of the Chicago area (section 2e).

The Nonstructural Alternative is not expected to affect the arrival of *S. binderanus* through aquatic pathways at the CAWS. Therefore, the uncertainty remains low.
T_{10}: See T_0.
T_{25}: See T_0. *S. binderanus* is documented to have declined significantly in Lake Michigan, and this species is not consistently found in phytoplankton surveys (section 2c). Future improvements in water quality in southern Lake Michigan may continue to reduce the abundance of *S. binderanus* near the BSBH. However, the species is not expected to be eliminated.
T_{50}: See T_{25}. Diatoms are sensitive to climatological and water quality conditions, which are a source of uncertainty for this species. The effects of future climate change and new environmental regulations on *S. binderanus* populations are uncertain (section 2f) but may alter the distribution and annual occurrence.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

S. binderanus is a planktonic diatom that can spread rapidly by downstream flow or human-mediated mechanisms. From the BSBH, *S. binderanus* must move more than 64 km (40 mi) downstream to reach the Brandon Road Lock and Dam. The downstream flow of water would facilitate the transport of this species downstream of the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., current-driven passage) of *S. binderanus* through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of *S. binderanus* as it passes through the aquatic pathway.

b. *Human-Mediated Transport through Aquatic Pathways*

Vessel traffic to the BSBH is primarily lake-wide (USACE 2011a,b). *S. binderanus* can be carried in ballast water (Kipp 2012), although the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). Recreational vessel traffic (e.g., canoe, kayak) could potentially transport this species to other areas of the CAWS where commercial and larger recreational vessels operate. In addition, some natural downstream dispersal would likely be necessary to reach the Brandon Road Lock and Dam.

Anti-fouling hull paints are a possible measure for controlling *S. binderanus* on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of *S. binderanus* through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: None. Surface water is present year-round, and water depth is adequate throughout the CAWS (LimnoTech 2010).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: *S. binderanus* is typically reported in lakes, but it is established in the Cuyahoga River (Kipp 2011) and in European lowland rivers and their tributaries (Hindák et al. 2006). *S. binderanus* sometimes occurs in lakes near river outlets (Kipp 2011). Resting cells are found in sediment (Kipp 2011). *S. binderanus* prefers eutrophic waters, with high phosphate and a nitrogen-to-phosphate ratio of 7 (Kipp 2011). The CAWS has high nutrient levels because of municipal discharge (LimnoTech 2010). Water flows out of the BSBH into Lake Michigan. The eastern segment of the south branch of the Little Calumet River also generally flows toward Lake Michigan, depending on location and water level in Lake Michigan (GSWMD 2008). To enter and pass through the BSBH, this species would have to move upstream through Burns Ditch and portions of the south branch of the Little Calumet River, where flow direction is toward Lake Michigan.

The Nonstructural Alternative includes managing nutrient loads to waterways, which may affect *S. binderanus* entering and establishing in the CAWS, thereby reducing the abundance and potential passage of the species through the CAWS to Brandon Road Lock and Dam.

T_{10}: See T_0.

T_{25}: See T_0. *S. binderanus* is sensitive to nutrients levels. The discharge of nutrients may decrease due to the adoption of water quality standards and effluent discharge limitations currently proposed for the CAWS (Illinois Pollution Control Board 2012). However, the potential impact of these future water quality changes is uncertain.

T_{50}: See T_{25}.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating	Low	Low	Low	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: *S. binderanus* is typically a lake species, but it has been reported in rivers, and water quality may be suitable in the CAWS (section 3d). The high nutrients in the CAWS may promote the productivity of this species. Because of the lack of vessel traffic (section 3b), natural spread through the south branch of the Little Calumet River would likely be required for *S. binderanus* to move from Lake Michigan to the Calumet Sag Channel. Water flow in the BSBH and portions of the Little Calumet River is toward Lake Michigan. The species may also be transported by small recreational watercraft (e.g., canoe, kayak) to other areas of the CAWS where commercial vessels and larger recreational vessels operate. These vessels could then transport the species to Brandon Road Lock and Dam. *S. binderanus* are phytoplankton and are not likely to move upstream through the BSBH and the south branch of the Little Calumet River (sections 3a, 3b). Although it has been in Lake Michigan since 1938, there are no records of *S. binderanus* in the CAWS or downstream of the Brandon Road Lock and Dam. The lack of records may be due to the unsuitability of the habitat in the CAWS or to a lack of phytoplankton surveys conducted in the Illinois Waterway.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by *S. binderanus*. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of *S. binderanus* through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to control the passage of *S. binderanus* through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of *S. binderanus* by downstream passive transport to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's low probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Over time this species may be able to move upstream (by wind or by aquatic life) through the BSBH and the Little Calumet River to navigable sections of the CAWS that flow toward the MRB.

The Nonstructural Alternative is not expected to control the passage of *S. binderanus* through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's medium probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Uncertainty Rating

T_0: Although this species has been documented in rivers (section 3d), the suitability of hydraulic, chemical, and light conditions (e.g., turbidity) in the CAWS for *S. binderanus* is uncertain. Suitable habitat potentially exists for *S. binderanus*, and this species is considered to have time to transit to the Brandon Road Lock and Dam during this time step. It is uncertain why there are no records of this species in the Illinois Waterway. Although the potential for passage exists, it is uncertain why this species has not been recorded in the Illinois River despite being in southern Lake Michigan for decades. The lakeward flow of the BSBH and south branch of the Little Calumet River could decrease or inhibit spread through the pathway (section 3d).

The Nonstructural Alternative includes managing nutrient loads to waterways and hull fouling paints. The effectiveness of nutrient management on *S. binderanus* abundance and its natural rate of spread and the effectiveness of hull fouling paints on human-mediated transport are uncertain. Therefore, the Nonstructural Alternative is not expected to control the passage of *S. binderanus* through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains high.

T_{10}: See T_0.

T_{25}: See T_0. Future efforts to improve water quality in the CAWS may reduce the concentrations of nutrients and halogens that this species tends to be associated with (section 3d). These changes in water quality may reduce the habitat suitability of the CAWS for *S. binderanus*. Flow conditions in the BSBH and the south branch of the Little Calumet River are expected to remain unfavorable to passage. However, this species is more certain to pass through the CAWS in 25 years compared to the previous time step.

The Nonstructural Alternative is not expected to control the passage of *S. binderanus* through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains high.
T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: MEDIUM

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E.2.2.2 Plant

E.2.2.2.1 Reed Sweetgrass (*Glyceria maxima*)

NONSTRUCTURAL ALTERNATIVE

This alternative would potentially include a combination of the following measures that may be implemented at time step 0 (T_0, in units of years) by local, state, and federal agencies and the public. The Nonstructural Alternative would include the development of a monitoring and response program.

Nonstructural Alternative Measures for Reed Sweetgrass

Option or Technology	Description	
Education and Outreach	• Education of recreational waterway users • Signage, pamphlets, brochures on how to identify ANS and control the spread of ANS; promote national campaigns (i.e., "Stop Aquatic Hitchhikers")	
Antifouling Hull Paints	• Education of vessel owners and operators to promote use of antifouling paints	
Ballast/Bilge-Water Exchange	• Ballast/bilge-water exchange	
Monitoring	• Agency monitoring • Voluntary occurrence reporting	
Laws and Regulations	• Quarantine, restricted site access • Prohibition of sale, cultivation, transport, release/planting • Plant nursery restrictions • Local, state, and USDA federal noxious weed listing • Mandatory watercraft and trailer inspection and decontamination	
	ANS Controls	**ANS Factsheet[a]**
ANS Control Methods	Aquatic Herbicides	Aquatic Herbicides
	Cutting	
	Burning	
	Mechanical Harvest	Manual Harvest and Mechanical Control Methods
	Soil Removal	
	Manual Harvest	

[a] For more information, refer to GLMRIS Team (2012).

PATHWAY 1

WILMETTE PUMPING STATION (WPS) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Antifouling Hull Paints, Ballast/Bilge-Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Low	Low	Low	Medium	Medium
P(passage)	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary[a]

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Low	Low	Low	***Low***	***Low***
P(passage)	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[b]	Low	–	Low	–	***Low***	–

[a] The highlighted table cells indicate a rating change in the probability element .

[b] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the WPS and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. **P(arrival) T_0-T_{50}: LOW**

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

d. Type of Mobility/Invasion Speed

Reed sweetgrass has a potentially rapid invasion speed (NatureServe 2010). The species colonizes new areas by growing roots and rhizomes or by dispersing floating fragments and seeds (DPIWE 2002). A single rootstock may cover 25 m^2 (269 ft^2) in 3 years (NatureServe 2010). This species is considered an aggressive invasive species (Washington State Noxious Weed Control Board 2012). Lambert (1947) states that, "in reed swamp, dispersal of grains probably takes place mainly by water transport. In still water, both naked and enclosed grains may be held almost indefinitely at surface by surface tension; in disturbed water, naked caryopses sink almost immediately, while enclosed grains may remain floating at surface for several hours." Seeds may be spread on water, in mud on machinery, or on livestock, and to a lesser extent by wind (DPIWE 2002). The majority of the seeds are able to germinate immediately, while others remain dormant for several years (DPIWE 2002). Reed sweetgrass was found in Racine and Milwaukee counties in Wisconsin in the 1970s, and the southernmost record of it is from Illinois Beach State Park in 2006 (Howard 2012).

The Nonstructural Alternative is expected to affect the invasion speed of reed sweetgrass to the Chicago Area Waterway System (CAWS) by natural dispersion through aquatic pathways. The Nonstructural Alternative includes aquatic nuisance species (ANS) control methods, such as aquatic herbicides, cutting, burning, mechanical and/or manual harvesting, and soil removal, that may affect the invasion speed of reed sweetgrass by reducing existing populations.

b. Human-Mediated Transport through Aquatic Pathways

Reed sweetgrass spreads by seeds, roots, or rhizome fragments that may be transported short distances by boats (DPIWE 2002). There is recreational boat use in Wilmette Harbor but no commercial vessel traffic. Evidence for ballast-water transport was not found in the literature. The WPS is not a port with cargo vessel use; however, there is recreational boat use in Wilmette Harbor that could potentially transport this species from the Great Lakes to the WPS.

Antifouling hull paints are a possible measure for controlling reed sweetgrass on vessels. However, these paints are considered only temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include the type of antifouling hull paint (toxic (with biocide) or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require antifouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS by human-mediated transport through aquatic pathways. Agency monitoring and voluntary occurrence reporting in combination with education and outreach may be used to determine where to target nonstructural control measures, in particular, aquatic herbicides. The implementation of a ballast/bilge-water exchange program, education and outreach, promotion of the use of antifouling hull paints, and laws and regulations may reduce the human-mediated transport of reed sweetgrass to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: The first North American record of reed sweetgrass came from the far west end of Lake Ontario, in the mid-1940s, and it subsequently spread to other areas of Ontario (Howard 2012). It is now established in several counties in Wisconsin. Reed sweetgrass produces vast numbers of dark brown seeds throughout summer and autumn (DPIWE 2002). It forms a sprawling mat of rhizomes or underground stems (DPIWE 2002). These rhizomes produce vast numbers of shoots to quickly expand the plant's size (DPIWE 2002). The massive root system can extend 0.9 m (3 ft) down, and the rhizomes can make up about half of the plant's total biomass (Noxious Weeds 2012). Reed sweetgrass typically goes dormant in the winter with seeds germinating the following spring, but some seeds remain dormant in the soil for many years (NBII and ISSG 2008). It is thought that North American reed sweetgrass plants are reproducing mostly by vegetative means and that most seeds are not viable (Washington State Noxious Weed Control Board 2012). Rapid early spring growth gives reed sweetgrass a competitive advantage over other wetland plants (Noxious Weeds 2012). Reed sweetgrass is not widespread in Lake Michigan (Howard 2012).

The Nonstructural Alternative includes ANS control methods, such as aquatic herbicides, cutting, burning, mechanical and/or manual harvesting, and soil removal, that are expected to affect the current abundance and propagule pressure of the species. The Nonstructural Alternative would also include agency monitoring to locate areas where reed sweetgrass is established. In addition, outreach and education may be used to inform the public of reed sweetgrass management efforts, and voluntary occurrence reporting may supplement agency monitoring. Data collected through agency monitoring and voluntary occurrence reporting would focus management efforts on locations where reed sweetgrass is abundant.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: None.

T_{25}: None.

T_{50}: None.

e. Distance from Pathway

T_0: The closest established population is in Oak Creek (a tributary of Lake Michigan) in Milwaukee County, Wisconsin (Howard 2012). The population has been established since 1979. In 2006, an isolated established population was discovered growing out of a manhole cover at the Illinois Beach State Park just north of Waukegan, Illinois. This population was treated with herbicide, and monitoring would continue (Howard 2012).

The Nonstructural Alternative includes measures that may contain the species, thereby affecting its arrival at the CAWS through aquatic pathways.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Reed sweetgrass is a large aquatic grass found in temperate areas (Howard 2012), so the climate range in the southern Great lakes is suitable. The species prefers nutrient-rich soil (NBII and ISSG 2008). It can be found on the banks of slow-moving rivers, streams, and lakes (NBII and ISSG 2008; Washington State Noxious Weed Control Board 2012) and requires full sun, tolerating only light shade (NBII and ISSG 2008; Loo et al. 2009). The species grows well in shallow water up to 1.5 m (4.9 ft) deep; in deeper water, the plant forms floating mats that remain partially attached to the banks of streams or ponds (Loo et al. 2009). High water levels limit the distribution of reed sweetgrass (Wei and Chow-Fraser 2006). The species is found in soils with relatively high concentrations of iron, phosphorus, and nitrogen (Wei and Chow-Fraser 2006). There are no emergent wetlands near the WPS (unpublished data from USACE), and shorelines in Lake Michigan near the WPS and in Wilmette Harbor generally have sandy, riprap, or manmade vertical walls. This species may be able to form populations along the Lake Michigan shoreline above the wave-washed elevations.

The Nonstructural Alternative is not expected to affect the availability of suitable habitat for reed sweetgrass within southern Lake Michigan.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating[a]	Low	Low	Low	***Low***

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Probability Rating (Considering All Life Stages)

T_0: Reed sweetgrass was found within 40 km (25 mi) of the WPS pathway, but the population was eradicated and is not known to currently exist (section 2e). Since 2006, the closest known population has been monitored and treated with herbicide to control dispersal (section 2e). The plant is dispersed by seeds, roots, or rhizome fragments (section 2a). Reed sweetgrass could float into Wilmette Harbor from Lake Michigan, but populations are not located along the shoreline of Lake Michigan so there is no likely mechanism for doing so. Vessel-mediated transport from Milwaukee (where the species is present) to the WPS is unlikely because reed sweetgrass populations are inland and may not encounter vessel traffic. This species may be able to form populations along the Lake Michigan shoreline above the wave-washed elevations. This species was found growing out of a manhole cover (section 2e), so it may establish in urban landscapes. If another population appears along the shoreline of southern Lake Michigan, the species may be able to spread closer to the pathway entrance over time. However, only one colony has been detected near the WPS since the 1970s. Eradication efforts may also keep the species from spreading to the WPS.

Before antifouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by reed sweetgrass. Until additional study is completed and these issues are addressed, antifouling hull paints are considered ineffective at controlling the arrival of reed sweetgrass at the CAWS due to fouled vessels.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS through aquatic pathways. Agency monitoring could be conducted to determine the current range of existing populations and identify the establishment of new populations followed by rapid implementation of ANS control methods, such as application of aquatic herbicides and manual and/or mechanical harvesting, to manage the species. Once the species is managed, education and outreach could control its future spread by recreational boaters and other recreational waterway users. Laws and regulations could control the cultivation of this species and subsequent spread by the nursery industry. Voluntary occurrence reports and continued agency monitoring would evaluate the effectiveness of implemented ANS control methods and identify surviving populations requiring further management.

The Nonstructural Alternative reduces the likelihood of reed sweetgrass arriving at the pathway by reducing the current abundance and distribution of reed sweetgrass. However,

the Nonstructural Alternative's low probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0. The continued implementation of nonstructural measures is expected to reduce the likelihood of reed sweetgrass arriving at the aquatic pathway; therefore, the probability of arrival is reduced to low.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating[a]	Low	Low	Low	***Low***

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Uncertainty Rating

T_0: Reed sweetgrass is found on the banks of slow-moving waters; Lake Michigan is a high-energy shoreline and there is no emergent wetland habitat documented in the vicinity of the WPS. Human-mediated transport of the species is poorly documented but is highly unlikely (section 2b). There is also little potential for movement into Wilmette Harbor from Lake Michigan because of the unsuitability of the shoreline of Lake Michigan. The species can have a rapid invasion rate, although it has not been found in the Great Lakes. Eradication efforts at Illinois Beach State Park seem to have slowed spread of the species.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS through aquatic pathways. Therefore, the uncertainty is low.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0. Implementation of the Nonstructural Alternative by local, state, and federal agencies is expected to slow the arrival of reed sweetgrass at the CAWS through aquatic pathways; therefore, uncertainty is low.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Reed sweetgrass has a potentially rapid invasion speed once it encounters a new habitat (NatureServe 2010). The species colonizes new areas by growing roots and rhizomes or by dispersing floating fragments and seeds (DPIWE 2002). A single rootstock may cover 25 m^2 (269 ft^2) in 3 years (NatureServe 2010). Reed sweetgrass is considered an aggressive invasive species (Washington State Noxious Weed Control Board 2012). Lambert (1947) states that, "in reed swamp, dispersal of grains probably takes place mainly by water transport." Seeds may be spread on water, in mud on machinery, or on livestock, and to a lesser extent by wind (DPIWE 2002). The majority of the seeds are able to germinate immediately, while others remain dormant for several years (DPIWE 2002).

The Nonstructural Alternative may manage rooted populations of reed sweetgrass; however, the natural dispersion (i.e., current-driven passage) of floating plant fragments and seeds would not be addressed. Therefore, the Nonstructural Alternative is not expected to control the natural dispersion of reed sweetgrass as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Reed sweetgrass spreads by seeds, roots, or rhizome fragments that may be transported by boats for short distances. There is no commercial vessel traffic to WPS (USACE 2011a), and the WPS controls recreational vessel movement from Lake Michigan to the North Shore Chanel. However, there is recreational vessel traffic in the North Shore Channel that could transport the species to the Brandon Road Lock and Dam or other areas of the CAWS where commercial vessels operate. The downstream flow of the CAWS would also enable the eventual transport of this species to the Brandon Road Lock and Dam. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport reed sweetgrass seeds and floating plant fragments into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Antifouling hull paints are a possible measure for controlling reed sweetgrass on vessels. However, these paints are considered only temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include the type of antifouling hull paint (toxic (with biocide) or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require antifouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative may manage the human-mediated transport of reed sweetgrass through the aquatic pathway by vessel-mediated transport and other forms of human-mediated transport; however, the human-mediated transport of plant fragments and seeds of reed sweetgrass by the Lake Michigan water diversion would not be addressed. Therefore, the Nonstructural Alternative is not expected to control the human-mediated transport of reed sweetgrass through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: The sluice gate at the WPS is a barrier that could retard natural dispersion into the CAWS. However, water is pumped from Lake Michigan into the North Shore Channel, which could transport seeds into the North Shore Channel. The Lockport Lock and Dam and the Brandon Road Lock and Dam could act as barriers because the shoreline at these locations is heavily modified. Reed sweetgrass grows well in shallow water up to 1.5 m (4.9 ft) deep and in deeper water forms floating mats that remain partially attached to the banks of streams or ponds (Loo et al. 2009). High water levels limit the distribution of the species. The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically about 5 m (16.4 ft) (LimnoTech 2010).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Reed sweetgrass prefers nutrient-rich soil (NBII and ISSG 2008) and is found on the banks of slow-moving rivers, streams, and lakes (NBII and ISSG 2008; Loo et al. 2009). Most flows in the CAWS were less than 0.15 m/s (0.49 ft/s); the highest was 0.27 m/s (0.89 ft/s) (LimnoTech 2010). The CAWS is a heavily modified channel with little floodplain connection and few shallow marshy areas.

Sediment chemical data from the CAWS show the presence of a wide range of chemicals throughout the system, including pesticides, polychlorinated biphenyls (PCBs), and heavy metals. In Scotland it was dense in an area that received sewage (West 1910). Reed sweetgrass was positively related to human population growth (Wei and Chow-Fraser 2006). The grass is phosphorus limited, so it would spread only into areas with adequate phosphorus levels (Haslam 1978). The CAWS has high nutrient inputs (LimnoTech 2010).

The North Shore Channel has in-stream aquatic habitat; however, the banks are mostly shaded, a habitat the reed sweetgrass avoids. Reed sweetgrass requires full sun and can tolerate only light shade (NBII and ISSG 2008; Loo et al. 2009). Occurrence is less likely under woody, riparian vegetation, especially dense vegetation (Loo et al. 2009). The flow and depth of the North Shore Channel are suitable for the species, so patches of suitable habitat may be present (LimnoTech 2010). Virtually all (more than 90%) of the Chicago River and the Lower North Branch of the Chicago River has vertical walls with sand, silt, or sludge sediment. Much of the Chicago Sanitary and Ship Canal (CSSC) has vertical limestone or manmade walls with silt, sand, cobble, or bedrock substrate. These habitats would not be suitable for this species. The species was identified in a lowland limestone stream in Ireland (Haslam 1978). Cobble or boulder is also common in the riparian zone of the CSSC. There is little canopy cover (LimnoTech 2010). Suitable habitat in the CAWS may be intermittently present along some shallow shoreline areas and in debris accumulated near bridge abutments (LimnoTech 2010).

The Nonstructural Alternative is not expected to affect the availability of suitable habitat for reed sweetgrass within the CAWS.

T_{10}: See T_0.

T_{25}: See T_0. Upgrading wastewater treatment plants and the closing of two power plants should improve future water quality (Illinois Pollution Control Board 2012). Reed sweetgrass appears to benefit from some eutrophication; therefore, the suitability of water quality in the CAWS for reed sweetgrass may change. The availability of suitable substrate is not expected to increase.

T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating	Low	Medium	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Reed sweetgrass could move into the CAWS as water is pumped from Lake Michigan into the North Shore Channel (section 3c). Although suitable habitat may be present in the North Shore Channel, most of the CAWS, especially the Chicago River and the CSSC, is too deep and lacks suitable sediments and riparian habitat for this species. The species has a rapid invasion speed; however, the CAWS is heavily utilized by vessels and rooting of the reed sweetgrass may be disrupted by canal maintenance and barge wakes (section 3a).

Before antifouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by reed sweetgrass. Until additional study is completed and these issues are addressed, antifouling hull paints are considered ineffective at controlling the passage of reed sweetgrass through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to reduce the likelihood of reed sweetgrass passing through the aquatic pathway. Therefore, the Nonstructural Alternative's low probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Despite the generally unfavorable habitat conditions, sufficient time may have passed during this time step for the reed sweetgrass to invade and spread (via growing roots and rhizomes, floating fragments and seeds, and vessel transport) to suitable habitats where available through the CAWS.

The Nonstructural Alternative is not expected to reduce the likelihood of reed sweetgrass passing through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address passage by the Lake Michigan water diversion or the downstream passive transport of plant fragments and seeds of reed sweetgrass to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's medium probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating	Medium	Medium	Medium	Medium

Evidence for Uncertainty Rating

T_0: Vessel use and upkeep of the CAWS should remain the same over time. There is little information on long-distance transport of the species via vessel traffic. The availability of suitable habitat in the CAWS is not documented. This species has been documented at Illinois Beach State Park.

The Nonstructural Alternative is not expected to affect the passage of reed sweetgrass through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the uncertainty remains medium.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 2

CHICAGO RIVER CONTROLLING WORKS (CRCW) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Antifouling Hull Paints, Ballast/Bilge-Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Low	Low	Low	Medium	Medium
P(passage)	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary[a]

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Low	Low	Low	***Low***	***Low***
P(passage)	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[b]	Low	–	Low	–	***Low***	–

[a] The highlighted table cells indicate a rating change in the probability element.

[b] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the CRCW and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Reed sweetgrass has a potentially rapid invasion speed (NatureServe 2010). The species colonizes new areas by growing roots and rhizomes and by dispersing floating fragments and seeds (DPIWE 2002). A single rootstock may cover 25 m^2 (269 ft^2) in 3 years (NatureServe 2010). This species is considered an aggressive invasive species (Washington State Noxious Weed Control Board 2012). Lambert (1947) states that, “in reed swamp, dispersal of grains probably takes place mainly by water transport. In still water, both naked and enclosed grains may be held almost indefinitely at surface by surface tension; in disturbed water, naked caryopses sink almost immediately, while enclosed grains may remain floating at surface for several hours.” Seeds may be spread on water, in mud on machinery, on livestock, and to a lesser extent by wind (DPIWE 2002). The majority of the seeds are able to germinate immediately, but others remain dormant for several years (DPIWE 2002). Reed sweetgrass was found in Racine and Milwaukee counties in Wisconsin in the 1970s, and the southernmost record is from Illinois Beach State Park in 2006 (Howard 2012).

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass to the CAWS by natural dispersion through aquatic pathways. The Nonstructural Alternative includes ANS control methods, such as aquatic herbicides, cutting, burning, mechanical and/or manual harvesting, and soil removal, which may affect the invasion speed of reed sweetgrass by reducing existing populations.

b. Human-Mediated Transport through Aquatic Pathways

Reed sweetgrass spreads by seeds, roots, or rhizome fragments that may be transported by boats for short distances (DPIWE 2002). There is commercial and recreational vessel traffic to the CRCW from Lake Michigan (USACE 2011a, b) that could potentially transport this species from the Great Lakes to the CRCW. Evidence for ballast-water transport was not found in the literature.

Antifouling hull paints are a possible measure for controlling reed sweetgrass on vessels. However, these paints are considered only temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include the type of antifouling hull paint (toxic—with biocide—or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require antifouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS by human-mediated transport through aquatic pathways. Agency monitoring and voluntary occurrence reporting in combination with education and outreach may be used to determine where to target nonstructural control measures, in particular, aquatic herbicides. The implementation of a ballast/bilge-water exchange program, education and outreach, promotion of the use of antifouling hull paints, and laws and regulations may reduce the human-mediated transport of reed sweetgrass to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: Reed sweetgrass produces vast numbers of dark brown seeds throughout summer and autumn (DPIWE 2002). It forms a sprawling mat of rhizomes or underground stems (DPIWE 2002). These rhizomes produce vast numbers of shoots to quickly expand the plant's size (DPIWE 2002). The massive root system can extend 0.9 m (3 ft) down, and the rhizomes can make up about half of the plant's total biomass (Noxious Weeds 2012). Reed sweetgrass typically goes dormant in the winter, with seeds germinating the following spring, but some seeds remain dormant in the soil for many years (NBII and ISSG 2008). It is thought that North American reed sweetgrass plants reproduce mostly by vegetative means and that most seeds are not viable (Washington State Noxious Weed Control Board 2012). Rapid early spring growth gives reed sweetgrass a competitive advantage over other wetland plants (Noxious Weeds 2012). The species is not widespread in Lake Michigan (Howard 2012).

The Nonstructural Alternative includes ANS control methods, such as aquatic herbicides, cutting, burning, mechanical and/or manual harvesting, and soil removal, that is expected to affect the current abundance and propagule pressure of the species. The Nonstructural Alternative would also include agency monitoring to locate areas where reed sweetgrass is established. In addition, outreach and education may be used to inform the public of reed sweetgrass management efforts, and voluntary occurrence reporting may supplement agency monitoring. Data collected through agency monitoring and voluntary occurrence reporting would focus management efforts on locations where reed sweetgrass is abundant.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: The closest established reed sweetgrass population is in Oak Creek (a tributary of Lake Michigan) in Milwaukee County, Wisconsin (Howard 2012). The population has been considered established since 1979. In 2006, an isolated established population was discovered growing out of a manhole cover at the Illinois Beach State Park, just north of Waukegan, Illinois (Howard 2012). This population was treated with herbicide, and monitoring would continue (Howard 2012).

The Nonstructural Alternative includes measures that may contain the species, thereby affecting its arrival at the CAWS through aquatic pathways.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The reed sweetgrass is a large aquatic grass found in temperate areas (Howard 2012), so the climate range in the southern Great lakes is suitable. The species prefers nutrient-rich soil (NBII and ISSG 2008); it is found on the banks of slow-moving rivers, streams, and lakes (NBII and ISSG 2008; Washington State Noxious Weed Control Board 2012) and requires full sun, only tolerating light shade (NBII and ISSG 2008; Loo et al. 2009). The species grows well in shallow water up to 1.5 m (4.9 ft) deep (Loo et al. 2009). In deeper water, the plant forms floating mats that remain partially attached to the banks of the stream or pond (Loo et al. 2009). High water levels limit the distribution of reed sweetgrass (Wei and Chow-Fraser 2006). The species is found in soils with relatively high concentrations of iron, phosphorus, and nitrogen (Wei and Chow Fraser 2006). Shorelines in Lake Michigan near the CRCW generally have sandy, riprap, or manmade vertical walls, although there are some emergent wetlands offshore of downtown Chicago. This species may be able to form populations along the Lake Michigan shoreline above the wave-washed elevations.

The Nonstructural Alternative is not expected to affect the availability of suitable habitat for reed sweetgrass within southern Lake Michigan.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating[a]	Low	Low	Low	***Low***

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Probability Rating (Considering All Life Stages)

T_0: Reed sweetgrass was found within 72 km (45 mi) of the CRCW pathway, but the population was eradicated and is not known to currently exist (section 2e). Since 2006, the closest known population has been monitored and treated with herbicide to control dispersal (section 2e). The plant is dispersed by seeds, roots, or rhizome fragments (section 2a). The reed sweetgrass could float into the CRCW from Lake Michigan, but populations are not located along the shoreline of Lake Michigan, so there is no likely mechanism for doing so. Vessel-mediated transport from Milwaukee (where the species is present) to the CRCW is unlikely because existing reed sweetgrass populations are inland and may not receive vessel traffic. This species may be able to form populations along the Lake Michigan shoreline above the wave-washed elevations. Reed sweetgrass was found growing out of a manhole cover (section 2e), so it may establish in urban landscapes. If another population appears along the shoreline of southern Lake Michigan, the species may be able to spread closer to the pathway entrance over time. However, only one colony has been detected near the CRCW since the 1970s. Eradication efforts may also keep the species from spreading to the CRCW.

Before antifouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by reed sweetgrass. Until additional study is completed and these issues are addressed, antifouling hull paints are considered ineffective at controlling the arrival of reed sweetgrass at the CAWS due to fouled vessels.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS through aquatic pathways. Agency monitoring could be conducted to determine the current range of existing populations and identify the establishment of new populations followed by rapid implementation of ANS control methods, such as application of aquatic herbicides and manual and/or mechanical harvesting, to manage the species. Once the species is managed, education and outreach could control its future spread by recreational boaters and other recreational waterway users. Laws and regulations could control the cultivation of this species and subsequent spread by the nursery industry. Voluntary occurrence reports and continued agency monitoring would evaluate the effectiveness of implemented ANS control methods and identify surviving populations requiring further management.

The Nonstructural Alternative reduces the likelihood of reed sweetgrass arriving at the pathway by reducing the current abundance and distribution of reed sweetgrass. However, the Nonstructural Alternative's low probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. The continued implementation of nonstructural measures is expected to reduce the likelihood of reed sweetgrass arriving at the aquatic pathway; therefore, the probability of arrival is reduced to low.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating[a]	Low	Low	Low	***Low***

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Uncertainty Rating

T_0: Reed sweetgrass is found on the banks of slow-moving waters; Lake Michigan is a high-energy shoreline, and there is no emergent wetland habitat documented in the vicinity of the CRCW. There is little potential for transport into the CRCW from Lake Michigan. Human-mediated transport of the species is poorly documented, but is highly unlikely (section 2b). The species can have a rapid invasion rate, although this has not been evidenced in the Great Lakes. Eradication efforts at Illinois Beach State Park seem to have slowed the species spread.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS through aquatic pathways. Therefore, uncertainty is low.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Implementation of the Nonstructural Alternative by local, state, and federal agencies is expected to slow the arrival of reed sweetgrass at the CAWS through aquatic pathways; therefore, uncertainty is low.

3. P(passage) T_0-T_{50} : LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Reed sweetgrass has a potentially rapid invasion speed once it encounters a new habitat (NatureServe 2010). The species colonizes new areas by growing roots and rhizomes and by dispersing floating fragments and seeds (DPIWE 2002). A single rootstock may cover 25 m^2 (269 ft^2) in 3 years (NatureServe 2010). The species is considered an aggressive invasive species (Washington State Noxious Weed Control Board 2012). Lambert (1947) states that, “in reed swamp, dispersal of grains probably takes place mainly by water transport.” Seeds may be spread on water, in mud on machinery, or on livestock, and to a lesser extent by wind (DPIWE 2002). The majority of the seeds are able to germinate immediately, but others remain dormant for several years (DPIWE 2002).

The Nonstructural Alternative may manage rooted populations of reed sweetgrass; however, the natural dispersion (i.e., current-driven passage) of floating plant fragments and seeds would not be addressed. Therefore, the Nonstructural Alternative is not expected to control the natural dispersion of reed sweetgrass as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Reed sweetgrass spreads by seeds, roots, or rhizome fragments, which may be transported by boats for short distances. There is some commercial and recreational vessel traffic between the CRCW and the Brandon Road Lock and Dam (USACE 2011a), which could transport the species to the Brandon Road Lock and Dam or other areas of the CAWS. The downstream flow of the CAWS would also enable the eventual transport of this species to the Brandon Road Lock and Dam. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport reed sweetgrass seeds and floating plant fragments into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Antifouling hull paints are a possible measure for controlling reed sweetgrass on vessels. However, these paints are considered only temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include the type of antifouling hull paint (toxic—with biocide—or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require antifouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative may manage the human-mediated transport of reed sweetgrass through the aquatic pathway by vessel-mediated transport and other forms of human-mediated transport; however, the human-mediated transport of plant fragments and seeds of reed sweetgrass by the Lake Michigan water diversion would not be addressed. Therefore, the Nonstructural Alternative is not expected to control the human-mediated transport of reed sweetgrass through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: The Lockport Lock and Dam and the Brandon Road Lock and Dam could act as barriers because the shoreline at these locations is heavily modified. Reed sweetgrass grows well in shallow water up to 1.5 m (4.9 ft) deep, and in deeper water it forms floating mats that remain partially attached to the banks of stream or ponds (Loo et al. 2009). High water levels limit the distribution (Wei and Chow-Fraser 2006). The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically about 5 m (16.4 ft) (LimnoTech 2010). The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Reed sweetgrass prefers nutrient-rich soil (NBII and ISSG 2008) and is found on the banks of slow-moving rivers, streams, and lakes (NBII and ISSG 2008; Loo et al. 2009). Most flows in the CAWS were less than 0.15 m/s (0.49 ft/s); the highest was 0.27 m/s (0.89 ft/s) (LimnoTech 2010). The CAWS is a heavily modified channel with little floodplain connection and few shallow marshy areas.

Sediment chemical data from the CAWS show the presence of a wide range of chemicals throughout the system, including pesticides, PCBs, and heavy metals. In Scotland, reed sweetgrass was dense in an area that received sewage (West 1910). Reed sweetgrass was positively related to human population growth (Wei and Chow Fraser 2006). The grass is phosphorus limited, so it would spread only into areas with adequate phosphorus levels (Haslam 1978). The CAWS has high nutrient inputs (LimnoTech 2010).

Reed sweetgrass requires full sun and can tolerate only light shade (NBII and ISSG 2008; Loo et al. 2009). Occurrence is less likely under woody, riparian vegetation, especially dense vegetation (Loo et al. 2009). Virtually all (more than 90%) of the Chicago River and the Lower North Branch of the Chicago River has vertical walls with sand, silt, or sludge sediment. Toxic organic and inorganic pollutants are also present in the Chicago River (Gallagher et al. 2009). In the CSSC, in-stream habitat varies by location but is generally limited. Much of the CSSC has vertical limestone or manmade walls with bedrock, cobble, or silty sediment. These habitats would not be suitable for this species. The species was identified in a lowland limestone stream in Ireland (Haslam 1978). Cobble or boulder is also common in the riparian zone of the CSSC. There is little canopy cover (LimnoTech 2010). Suitable habitat in the CAWS may be intermittently present along some shallow shoreline areas and in debris accumulated near bridge abutments (LimnoTech 2010).

The Nonstructural Alternative is not expected to affect the availability of suitable habitat for reed sweetgrass within the CAWS.

T_{10}: See T_0.

T_{25}: See T_0. Upgrading wastewater treatment plants and closing two power plants should improve future water quality (Illinois Pollution Control Board 2012). Reed sweetgrass appears to benefit from some eutrophication; therefore, the suitability of water quality in the CAWS for reed sweetgrass may change. The availability of suitable substrate is not expected to increase.

T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating	Low	Medium	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Reed sweetgrass could move into the CAWS through the CRCW (section 3c). Most of the CAWS, especially the Chicago River and CSSC, is too deep and lacks suitable sediments and riparian habitat for this species. The species has a rapid invasion speed; however, the CAWS is heavily utilized by vessels, and rooting by the reed sweetgrass may be disrupted by canal maintenance and barge wakes (section 3a). The species may be able to pass through the CAWS while attached to a vessel (section 3b), but this is unlikely, given the distance from the CRCW to the Brandon Road Lock and Dam.

Before antifouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by reed sweetgrass. Until additional study is completed and these issues are addressed, antifouling hull paints are considered ineffective at controlling the passage of reed sweetgrass through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to reduce the likelihood of reed sweetgrass passing through the aquatic pathway. Therefore, the Nonstructural Alternative's low probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Despite the generally unfavorable habitat conditions, there may be sufficient time in this time step for the reed sweetgrass to invade and spread (via growing roots and rhizomes, floating fragments and seeds, and transport by vessels) to suitable habitats, where available, through the CAWS.

The Nonstructural Alternative is not expected to reduce the likelihood of reed sweetgrass passing through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of reed sweetgrass by the Lake Michigan water diversion and the downstream passive transport of plant fragments and seeds of reed sweetgrass to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's medium probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating	Medium	Medium	Medium	Medium

Evidence for Uncertainty Rating

T_0: Vessel use and upkeep of the CAWS should remain the same over time. There is little information on long-distance transport of the species via vessel traffic. The availability of suitable habitat in the CAWS is not documented. This species has been documented at Illinois Beach State Park.

The Nonstructural Alternative is not expected to affect the passage of reed sweetgrass through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. Although this species may spread through the CAWS over time, improvements in future water quality in the CAWS could affect the reed sweetgrass in ways that are uncertain (section 3d).

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 3

CALUMET HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Antifouling Hull Paints, Ballast/Bilge-Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Low	Low	Low	Medium	Medium
P(passage)	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary[a]

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Low	Low	Low	***Low***	***Low***
P(passage)	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[b]	Low	–	Low	–	***Low***	–

[a] The highlighted table cell indicates a rating change in the probability element.

[b] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Calumet Harbor and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The reed sweetgrass has a potentially rapid invasion speed (NatureServe 2010). The species colonizes new areas by growing roots and rhizomes and by dispersing floating fragments and seeds (DPIWE 2002). A single rootstock may cover 25 m^2 (269 ft^2) in 3 years (NatureServe 2010). Reed sweetgrass is considered an aggressive invasive species (Washington State Noxious Weed Control Board 2012). Lambert (1947) states that "in reed swamp, dispersal of grains probably takes place mainly by water transport. In still water, both naked and enclosed grains may be held almost indefinitely at surface by surface tension; in disturbed water, naked caryopses sink almost immediately, while enclosed grains may remain floating at surface for several hours." Seeds may be spread on water, in mud on machinery, on livestock, and to a lesser extent by wind (DPIWE 2002). The majority of the seeds are able to germinate immediately, but others remain dormant for several years (DPIWE 2002). Reed sweetgrass was found in the 1970s in Racine and Milwaukee counties in Wisconsin, and since that time the southernmost record is from Illinois Beach State Park in 2006 (Howard 2012).

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass to the CAWS by natural dispersion through aquatic pathways. The Nonstructural Alternative includes ANS control methods, such as aquatic herbicides, cutting, burning, mechanical and/or manual harvesting, and soil removal, which may affect the invasion speed of reed sweetgrass by reducing existing populations.

b. Human-Mediated Transport through Aquatic Pathways

Reed sweetgrass spreads by seeds, roots, or rhizome fragments, which may be transported short distances by boats (DPIWE 2002). There is heavy commercial and recreational vessel traffic to Calumet Harbor from Lake Michigan (USACE 2011a,b) that could potentially transport this species from the Great Lakes to Calumet Harbor. However, evidence for ballast-water transport was not found in the literature.

Antifouling hull paints are a possible measure for controlling reed sweetgrass on vessels. However, these paints are considered only temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include the type of antifouling hull paint (toxic—with biocide—or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require antifouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS by human-mediated transport through aquatic pathways. Agency monitoring and voluntary occurrence reporting in combination with education and outreach may be used to determine where to target nonstructural control measures, in particular, aquatic herbicides. The implementation of a ballast/bilge-water exchange program, education and outreach, promotion of the use of antifouling hull paints, and laws and regulations may reduce the human-mediated transport of reed sweetgrass to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: The first North American occurrence of reed sweetgrass was recorded in the mid-1940s in the far west end of Lake Ontario, and it subsequently spread to other areas of Ontario (Howard 2012). It is currently established in several counties in Wisconsin. Reed sweetgrass produces vast numbers of dark brown seeds throughout summer and autumn (DPIWE 2002). It forms a sprawling mat of rhizomes or underground stems (DPIWE 2002). These rhizomes produce vast numbers of shoots to quickly expand the plant's size (DPIWE 2002). The massive root system can extend 0.9 m (3 ft) down, and the rhizomes can make up about half of the plant's total biomass (Noxious Weeds 2012). Reed sweetgrass typically goes dormant in the winter, with seeds germinating the following spring; some seeds remain dormant in the soil for many years (NBII and ISSG 2008). It is thought that North American reed sweetgrass plants reproduce mostly by vegetative means and that most seeds are not viable (Washington State Noxious Weed Control Board 2012). Rapid early spring growth gives reed sweetgrass a competitive advantage over other wetland plants (Noxious Weeds 2012). Reed sweetgrass is not widespread in Lake Michigan (Howard 2012).

The Nonstructural Alternative includes ANS control methods, such as aquatic herbicides, cutting, burning, mechanical and/or manual harvesting, and soil removal, that is expected to affect the current abundance and propagule pressure of the species. The Nonstructural Alternative would also include agency monitoring to locate areas where reed sweetgrass is established. In addition, outreach and education may be used to inform the public of reed sweetgrass management efforts, and voluntary occurrence reporting may supplement agency monitoring. Data collected through agency monitoring and voluntary occurrence reporting would focus management efforts on locations where reed sweetgrass is abundant.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: The closest established population is in Oak Creek (a tributary of Lake Michigan) in Milwaukee County, Wisconsin (Howard 2012). The population has been considered established since 1979. In 2006, an isolated established population was discovered growing out of a manhole cover at the Illinois Beach State Park just north of Waukegan, Illinois. This population was treated with herbicide, and monitoring would continue (Howard 2012).

The Nonstructural Alternative includes measures that may contain the species, thereby affecting its arrival at the CAWS through aquatic pathways.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The reed sweetgrass is a large aquatic grass found in temperate areas (Howard 2012), so the climate range in the southern Great lakes is suitable. The species prefers nutrient-rich soil (NBII and ISSG 2008); it is found on the banks of slow-moving rivers, streams, and lakes (NBII and ISSG 2008; Washington State Noxious Weed Control Board 2012) and requires full sun, only tolerating light shade (NBII and ISSG 2008; Loo et al. 2009). The species grows well in shallow water up to 1.5 m (4.9 ft) deep (Loo et al. 2009); in deeper water, reed sweetgrass forms floating mats that remain partially attached to the banks of streams or ponds (Loo et al. 2009). High water levels limit the distribution of reed sweetgrass (Wei and Chow-Fraser 2006). The species is found in soils with relatively high concentrations of iron, phosphorus, and nitrogen (Wei and Chow-Fraser 2006). There are no emergent wetlands near Calumet Harbor (unpublished data from USACE), and shorelines in Lake Michigan near Calumet Harbor generally have sandy, riprap, or manmade vertical walls.

The Nonstructural Alternative is not expected to affect the availability of suitable habitat for reed sweetgrass within southern Lake Michigan.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating[a]	Low	Low	Low	***Low***

[a] Risk assessment in bold italics differs from corresponding No New Federal Action rating.

Evidence for Probability Rating (Considering All Life Stages)

T_0: Reed sweetgrass was found within 80 km (50 mi) of the Calumet Harbor pathway, but the population was eradicated and is not known to currently exist (section 2e). Since 2006, the closest known population has been monitored and treated with herbicide to control dispersal (section 2e). The plant is dispersed by seeds, roots, or rhizome fragments (section 2a). The reed sweetgrass could float into Calumet Harbor from Lake Michigan, but populations are not located along the shoreline of Lake Michigan, so there is not likely a mechanism for this. Vessel-mediated transport from Milwaukee (where the species is present) to Calumet Harbor is unlikely, because existing reed sweetgrass populations are inland and may not receive vessel traffic. This species may be able to form populations along the Lake Michigan shoreline above the wave-washed elevations. Reed sweetgrass was found growing out of a manhole cover (section 2e), so it may establish in urban landscapes. If another population appears along the shoreline of southern Lake Michigan, the species may be able to spread closer to the pathway entrance over time. However, only one colony has been detected near Calumet Harbor since the 1970s. Eradication efforts may also keep the species from spreading to Calumet Harbor.

Before antifouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by reed sweetgrass. Until additional study is completed and these issues are addressed, antifouling hull paints are considered ineffective at controlling the arrival of reed sweetgrass at the CAWS due to fouled vessels.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS through aquatic pathways. Agency monitoring could be conducted to determine the current range of existing populations and identify the establishment of new populations followed by rapid implementation of ANS control methods, such as application of aquatic herbicides and manual and/or mechanical harvesting, to manage the species. Once the species is managed, education and outreach could control its future spread by recreational boaters as well as other recreational waterway users. Laws and regulations could control the cultivation of this species and subsequent spread by the nursery industry. Voluntary occurrence reports and continued agency monitoring would evaluate the effectiveness of implemented ANS control methods and identify surviving populations requiring further management.

The Nonstructural Alternative reduces the likelihood of reed sweetgrass arriving at the pathway by reducing the current abundance and distribution of reed sweetgrass. However,

the Nonstructural Alternative's low probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0. The continued implementation of nonstructural measures is expected to reduce the likelihood of reed sweetgrass arriving at the aquatic pathway; therefore, the probability of arrival is reduced to low.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating[a]	Low	Low	Low	***Low***

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Uncertainty Rating

T_0: Reed sweetgrass is found on the banks of slow-moving waters; Lake Michigan is a high-energy shoreline and there is no emergent wetland habitat documented in the vicinity of Calumet Harbor. There is little potential for movement into Calumet Harbor from Lake Michigan because of the unsuitability of the shoreline of Lake Michigan. Human-mediated transport of the species is poorly documented but is also highly unlikely (section 2b). The species can have a rapid invasion rate, but this has not been evidenced in the Great Lakes. Eradication efforts at Illinois Beach State Park seem to have slowed the species spread.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS through aquatic pathways. Therefore, the uncertainty is low.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0. Implementation of the Nonstructural Alternative by local, state, and federal agencies is expected to slow the arrival of reed sweetgrass at the CAWS through aquatic pathways; therefore, uncertainty is low.

3. P(passage) T_0-T_{50}: LOW-HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Reed sweetgrass has a potentially rapid invasion speed once it encounters a new habitat (NatureServe 2010). The species colonizes new areas by growing roots and rhizomes and by dispersing fragments and seeds (DPIWE 2002). A single rootstock may cover 25 m^2 (260 ft^2) in 3 years (NatureServe 2010). The species is considered an aggressive invasive species (Washington State Noxious Weed Control Board 2012). Lambert (1947) states that "in reed swamp, dispersal of grains probably takes place mainly by water transport." Seeds may be spread on water, in mud on machinery, on livestock, and to a lesser extent by wind (DPIWE 2002). The majority of the seeds are able to germinate immediately, but others remain dormant for several years (DPIWE 2002).

The Nonstructural Alternative may manage rooted populations of reed sweetgrass; however, the natural dispersion (i.e., current-driven passage) of floating plant fragments and seeds would not be addressed. Therefore, the Nonstructural Alternative is not expected to control the natural dispersion of reed sweetgrass as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Reed sweetgrass spreads by seeds, roots, or rhizome fragments that may be transported by boats for short distances (DPIWE 2002). Although there is little commercial river traffic to Calumet Harbor (NBIC 2012), there is heavy commercial vessel traffic between the Brandon Road Lock and Dam and the T.J. O'Brien Lock and Dam, which is approximately 8 km (5 mi) south of Calumet Harbor (USACE 2011a; NBIC 2012). Recreational vessel traffic also occurs between the Calumet Harbor and the Brandon Road Lock and Dam. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport reed sweetgrass seeds and floating plant fragments into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Antifouling hull paints are a possible measure for controlling reed sweetgrass on vessels. However, these paints are considered only temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include the type of antifouling hull paint (toxic—with biocide—or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require antifouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching. The Nonstructural Alternative may manage the human-mediated transport of reed sweetgrass through the aquatic pathway by vessel-mediated transport and other forms of human-mediated transport; however, the human-mediated transport of plant fragments and seeds of reed sweetgrass by the Lake Michigan water diversion would not be addressed. Therefore, the Nonstructural Alternative is not expected to control the human-mediated transport of reed sweetgrass through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: The T.J. O'Brien Lock and Dam, the Lockport Lock and Dam, and the Brandon Road Lock and Dam could act as barriers because the shoreline is heavily modified in these locations. Reed sweetgrass grows well in shallow water up to 1.5 m (4.9 ft) deep; in deeper water, the plant forms floating mats that remain partially attached to the banks of streams or ponds (Loo et al. 2009). High water levels limit its distribution (Wei and Chow-Fraser 2006). The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically about 5 m (16.4 ft) (LimnoTech 2010).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The reed sweetgrass prefers nutrient-rich soil (NBII and ISSG 2008); the species is found on the banks of slow-moving rivers, streams, and lakes (NBII and ISSG 2008; Washington State Noxious Weed Control Board 2012). Most flows in the CAWS were less than 0.15 m/s (0.49 ft/s); the highest flow was 0.27 m/s (0.89 ft/s) (LimnoTech 2010). The CAWS is a heavily modified channel with little floodplain connection and few shallow marshy areas.

Sediment chemical data from the CAWS show the presence of a wide range of chemicals throughout the system, including pesticides, PCBs, and heavy metals. In Scotland, it was dense in an area that received sewage (West 1910). Reed sweetgrass was positively related to human population growth (Wei and Chow-Fraser 2006). The grass is phosphorus limited, so it would spread only into areas with adequate phosphorus levels (Haslam 1978). The CAWS has high nutrients inputs (LimnoTech 2010).

In the Calumet River there is in-stream habitat for aquatic life in the form of boulders, logs, brush debris jams, overhanging terrestrial vegetation, and aquatic vegetation in some reaches. Urban, industrial, and commercial riparian land use is also present. Reed sweetgrass requires full sun and can tolerate only light shade (NBII and ISSG 2008; Loo et al. 2009). Occurrence is less likely under woody, riparian vegetation, especially dense vegetation (Loo et al. 2009). Sediments in the Little Calumet River are primarily inorganic silt, but areas of sand and gravel are also present (LimnoTech 2010). Inorganic silt sediments predominate in the Cal-Sag Channel as well. Bedrock sediments are also present (LimnoTech 2010). In the CSSC, in-stream habitat varies by location, but it is generally limited and vertical bank walls are common along the shoreline. Sediments in the CSSC vary but primarily consist of silt, sludge, bedrock, and sand, with scattered cobble (LimnoTech 2010). These habitats would not be suitable for this species. Suitable habitat in the CAWS may be present intermittently along some shallow shoreline areas and in debris accumulated near bridge abutments (LimnoTech 2010).

The Nonstructural Alternative is not expected to affect the availability of suitable habitat for reed sweetgrass within the CAWS.

T_{10}: See T_0.

T_{25}: See T_0. Upgrading wastewater treatment plants and the closing of two power plants should improve future water quality (Illinois Pollution Control Board 2012). Reed sweetgrass appears to benefit from some eutrophication; therefore, the suitability of water quality in the CAWS for reed sweetgrass may change. The availability of suitable substrate is not expected to increase.

T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating	Low	Medium	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Reed sweetgrass could move into the CAWS through Calumet Harbor (section 3c). Most of the CAWS, especially the CSSC, is too deep and lacks suitable sediments and riparian habitat for this species. The species has a potentially rapid invasion speed; however, the CAWS is heavily utilized by vessels and rooting by the reed sweetgrass may be disrupted by canal maintenance and barge wakes (section 3a). The species may be able to pass through the CAWS while attached to a vessel (section 3b), but this is unlikely given the distance from Calumet Harbor to the Brandon Road Lock and Dam.

Before antifouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by reed sweetgrass. Until additional study is completed and these issues are addressed, antifouling hull paints are considered ineffective at controlling the passage of reed sweetgrass through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to reduce the likelihood of reed sweetgrass passing through the aquatic pathway. Therefore, the Nonstructural Alternative’s low probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Despite the generally unfavorable habitat conditions, there may be sufficient time in this time step for the reed sweetgrass to establish and spread (via growing roots and rhizomes, floating fragments and seeds, and attachment to vessels) to suitable habitats, where available, through the CAWS.

The Nonstructural Alternative is not expected to reduce the likelihood of reed sweetgrass passing through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address passage by the Lake Michigan water diversion and the downstream passive transport of plant fragments and seeds of reed sweetgrass to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative’s medium probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating	Medium	Medium	Medium	Medium

Evidence for Uncertainty Rating

T_0: Vessel use and upkeep of the CAWS should remain the same over time. There is little information on long-distance transport of the species via vessel traffic. The availability of suitable habitat in the CAWS is not documented. This species has been documented at Illinois Beach State Park.

The Nonstructural Alternative is not expected to affect the passage of reed sweetgrass through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. Although this species may spread through the CAWS over time, improvements in future water quality in the CAWS could affect the reed sweetgrass in ways that are uncertain (section 3d).

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 4

INDIANA HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Antifouling Hull Paints, Ballast/Bilge-Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Low	Low	Low	Medium	Medium
P(passage)	Low	Medium	Low	Medium	Medium	High	Medium	High
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary[a]

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Low	Low	Low	***Low***	***Low***
P(passage)	Low	Medium	Low	Medium	Medium	High	Medium	High
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[b]	Low	–	Low	–	***Low***	–

[a] The highlighted table cells indicate a rating change in the probability element.

[b] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Indiana Harbor and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Reed sweetgrass has a potentially rapid invasion speed (NatureServe 2010). The species colonizes new areas by growing roots and rhizomes and by dispersing floating fragments and seeds (DPIWE 2002). A single rootstock may cover 25 m^2 (269 ft^2) in 3 years (NatureServe 2010). This species is considered an aggressive invasive species (Washington State Noxious Weed Control Board 2012). Lambert (1947) states that "in reed swamp, dispersal of grains probably takes place mainly by water transport. In still water, both naked and enclosed grains may be held almost indefinitely at surface by surface tension; in disturbed water, naked caryopses sink almost immediately, while enclosed grains may remain floating at surface for several hours." Seeds may be spread on water, in mud on machinery, on livestock, and to a lesser extent by wind (DPIWE 2002). The majority of the seeds are able to germinate immediately, but others remain dormant for several years (DPIWE 2002). Reed sweetgrass was found in the 1970s in Racine and Milwaukee counties in Wisconsin, and since that time the southernmost recorded instance is from Illinois Beach State Park in 2006 (Howard 2012).

The Nonstructural Alternative is expected to affect the arival of reed sweetgrass to the CAWS by natural dispersion through aquatic pathways. The Nonstructural Alternative includes ANS control methods, such as aquatic herbicides, cutting, burning, mechanical and/or manual harvesting, and soil removal, which may affect the invasion speed of reed sweetgrass by reducing existing populations.

b. Human-Mediated Transport through Aquatic Pathways

Reed sweetgrass spreads by seeds, roots, or rhizome fragments, which may be transported for short distances by boats (DPIWE 2002). There is heavy commercial vessel traffic to Indiana Harbor from Lake Michigan (USACE 2011a) that could potentially transport this species from the Great Lakes to Indiana Harbor. Evidence for ballast-water transport was not found in the literature.

Antifouling hull paints are a possible measure for controlling reed sweetgrass on vessels. However, these paints are considered only temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include the type of antifouling hull paint (toxic—with biocide—or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require antifouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS by human-mediated transport through aquatic pathways. Agency monitoring and voluntary occurrence reporting in combination with education and outreach may be used to determine where to target nonstructural control measures, in particular, aquatic herbicides. The implementation of a ballast/bilge-water exchange program, education and outreach, promotion of the use of antifouling hull paints, and laws and regulations may reduce the human-mediated transport of reed sweetgrass to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: The first recorded occurrence of reed sweetgrass in North America came from the far west end of Lake Ontario in the mid-1940s, and it subsequently spread to other areas of Ontario (Howard 2012). It is currently established in several counties in Wisconsin. Reed sweetgrass produces vast numbers of dark brown seeds throughout summer and autumn (DPIWE 2002). It forms a sprawling mat of rhizomes or underground stems (DPIWE 2002). These rhizomes produce vast numbers of shoots to quickly expand the plant's size (DPIWE 2002). The massive root system can extend 0.9 m (3 ft) down, and the rhizomes can make up about half of the plant's total biomass (Noxious Weeds 2012). Reed sweetgrass typically goes dormant in the winter, with seeds germinating the following spring, but some seeds remain dormant in the soil for many years (NBII and ISSG 2008). It is thought that North American reed sweetgrass plants reproduce mostly by vegetative means and that most seeds are not viable (Washington State Noxious Weed Control Board 2012). Rapid early spring growth gives reed sweetgrass a competitive advantage over other wetland plants (Noxious Weeds 2012). Reed sweetgrass is not widespread in Lake Michigan (Howard 2012).

The Nonstructural Alternative includes ANS control methods, such as aquatic herbicides, cutting, burning, mechanical and/or manual harvesting, and soil removal, that is expected to affect the current abundance and propagule pressure of the species. The Nonstructural Alternative would also include agency monitoring to locate areas where reed sweetgrass is established. In addition, outreach and education may be used to inform the public of reed sweetgrass management efforts, and voluntary occurrence reporting may supplement agency monitoring. Data collected through agency monitoring and voluntary occurrence reporting would focus management efforts on locations where reed sweetgrass is abundant.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: The closest established population is in Oak Creek (a tributary of Lake Michigan) in Milwaukee County, Wisconsin (Howard 2012). The population has been considered established since 1979. In 2006, an isolated established population was discovered growing out of a manhole cover at the Illinois Beach State Park, just north of Waukegan, Illinois (Howard 2012). This population was treated with herbicide, and monitoring would continue (Howard 2012).

The Nonstructural Alternative includes measures that may contain reed sweetgrass, thereby affecting its arrival at the CAWS through aquatic pathways.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The reed sweetgrass is a large aquatic grass found in temperate areas (Howard 2012), so the climate range in the southern Great Lakes is suitable. The species prefers nutrient-rich soil (NBII and ISSG 2008). It is found on the banks of slow-moving rivers, streams, and lakes (NBII and ISSG 2008; Washington State Noxious Weeds Control Board 2012) and requires full sun, tolerating only light shade (NBII and ISSG 2008; Loo et al. 2009). The species grows well in shallow water up to 1.5 m (4.9 ft) deep (Loo et al. 2009). In deeper water, reed sweetgrass forms floating mats that remain partially attached to the banks of streams or ponds (Loo et al. 2009). High water levels limit the distribution of the species (Wei and Chow-Fraser 2006). The species is found in soils with relatively high concentrations of iron, phosphorus, and nitrogen (Wei and Chow-Fraser 2006). There are only small scattered emergent wetlands near Indiana Harbor (unpublished data from USACE), and shorelines in Lake Michigan near Indiana Harbor generally have sandy, riprap, or manmade vertical walls. This species may be able to form populations along the Lake Michigan shoreline above the wave-washed elevations.

The Nonstructural Alternative is not expected to affect the availability of suitable habitat for reed sweetgrass within southern Lake Michigan.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating[a]	Low	Low	Low	***Low***

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Probability Rating (Considering All Life Stages)

T_0: The reed sweetgrass was found within 80.5 km (50 mi) of the Indiana Harbor pathway, but this population was eradicated and is not known to currently exist (section 2e). Since 2006, the closest known population has been monitored and treated with herbicide to control dispersal (section 2e). The plant is dispersed by seeds, roots, or rhizome fragments (section 2a). Reed sweetgrass could float into Indiana Harbor from Lake Michigan, but populations are not located along the shoreline of Lake Michigan so there is no likely mechanism for this. Vessel-mediated transport from Milwaukee (where the species is present) and Indiana Harbor is unlikely because existing reed sweetgrass populations are inland and may not receive vessel traffic. The habitat near Indiana Harbor is not likely to be suitable for the plant to establish, because of the sandy, higher energy shoreline of Lake Michigan and the lack of wetland habitat (section 2f). However, this species was found growing out of a manhole cover (section 2e), so it may establish in urban landscapes. If another population appears along the shoreline of southern Lake Michigan, the species may be able to spread closer to the pathway entrance over time. Eradication efforts may also keep the species from spreading to Indiana Harbor.

Before antifouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by reed sweetgrass. Until additional study is completed and these issues are addressed, antifouling hull paints are considered ineffective at controlling the arrival of reed sweetgrass at the CAWS due to fouled vessels.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS through aquatic pathways. Agency monitoring could be conducted to determine the current range of existing populations and identify the establishment of new populations followed by rapid implementation of ANS control methods, such as application of aquatic herbicides and manual and/or mechanical harvesting, to manage the species. Once the species is managed, education and outreach could control future spread of this species by recreational boaters and other recreational waterway users. Laws and regulations could control the cultivation of this species and subsequent spread by the nursery industry. Voluntary occurrence reports and continued agency monitoring would evaluate the effectiveness of implemented ANS control methods and identify surviving populations requiring further management.

The Nonstructural Alternative reduces the likelihood of reed sweetgrass arriving at the pathway by reducing the current abundance and distribution of reed sweetgrass. However,

the Nonstructural Alternative's low probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. The continued implementation of nonstructural measures is expected to reduce the likelihood of reed sweetgrass arriving at the aquatic pathway; therefore, the probability of arrival is reduced to low.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating[a]	Low	Low	Low	***Low***

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Uncertainty Rating

T_0: Reed sweetgrass is found on the banks of slow-moving waters; Lake Michigan is a high-energy shoreline and there is no emergent wetland habitat documented in the vicinity of Indiana Harbor. Human-mediated transport of the species is poorly documented, but is highly unlikely (section 2b). There is also little potential for movement into Indiana Harbor from Lake Michigan because of the unsuitability of the shoreline of Lake Michigan. The species can have a rapid invasion rate, but this has not been evidenced in the Great Lakes.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS through aquatic pathways. Therefore, the uncertainty is low.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Implementation of the Nonstructural Alternative by local, state, and federal agencies is expected to slow the arrival of this species at the CAWS through aquatic pathways; therefore, the uncertainty is low.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Reed sweetgrass has a potentially rapid invasion speed once it encounters a new habitat (NatureServe 2010). The species colonizes new areas by growing roots and rhizomes and by dispersing floating fragments and seeds (DPIWE 2002). A single rootstock may cover 25 m^2 (269 ft^2) in 3 years (NatureServe 2010). Reed sweetgrass is considered an aggressive invasive species (Washington State Noxious Weed Control Board 2012).

Lambert (1947) states that “in reed swamp, dispersal of grains probably takes place mainly by water transport.” Seeds may be spread on water, in mud on machinery, on livestock, and to a lesser extent by wind (DPIWE 2002). The majority of the seeds are able to germinate immediately, but others remain dormant for several years (DPIWE 2002).

The Nonstructural Alternative may manage rooted populations of reed sweetgrass; however, the natural dispersion (i.e., current-driven passage) of floating plant fragments and seeds would not be addressed. Therefore, the Nonstructural Alternative is not expected to control the natural dispersion of reed sweetgrass as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Reed sweetgrass spreads by seeds, roots, or rhizome fragments, which may be transported by boats. Most commercial vessel traffic to Indiana Harbor is lakewise (NBIC 2012). There is little, if any, vessel traffic in the Grand Calumet River because of its shallow depth. However, recreational vessel traffic (e.g., canoe, kayak) could potentially transport this species to other areas of the CAWS where commercial and recreational vessels operate. There is vessel traffic between the Cal-Sag Channel and the Brandon Road Lock and Dam. The downstream flow of the CAWS would also enable the eventual transport of this species to the Brandon Road Lock and Dam.

Antifouling hull paints are a possible measure for controlling reed sweetgrass on vessels. However, these paints are considered only temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include the type of antifouling hull paint (toxic—with biocide—or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require antifouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative may manage the human-mediated transport of reed sweetgrass through the aquatic pathway by vessel-mediated transport and other forms of human-mediated transport; however, the human-mediated transport of plant fragments and seeds of reed sweetgrass by downstream dispersion would not be addressed. Therefore, the Nonstructural Alternative is not expected to control the human-mediated transport of reed sweetgrass through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: Just to the west of its junction with the Indiana Harbor Canal, the Grand Calumet channel is blocked by sheet pile. However, reed sweetgrass could go around the sheetpile during flood conditions. The species grows well in shallow water up to 1.5 m (4.9 ft) deep; in deeper water, it forms floating mats that remain partially attached to the banks of streams or ponds (Loo et al. 2009). High water levels limit its distribution

(Wei and Chow-Fraser 2006). The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically about 5 m (16.4 ft) (LimnoTech 2010). The Lockport Lock and Dam and the Brandon Road Lock and Dam could act as barriers because the shoreline is heavily modified in these locations.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: Reed sweetgrass prefers nutrient-rich soil (NBII and ISSG 2008); it is found on the banks of slow-moving rivers, streams, and lakes (NBII and ISSG 2008; Washington State Noxious Weed Control Board 2012). Most flows in the CAWS were less than 0.15 m/s (0.49 ft/s); the highest was 0.27 m/s (0.89 ft/s) (LimnoTech 2010). Water flows out of Indiana Harbor into Lake Michigan. West of the Indiana Harbor Canal, the easternmost sections of the Grand Calumet River also generally flow toward Lake Michigan, although other sections can flow east or west depending on location (Weiss et al. 1997). Thus, reed sweetgrass would have to spread upstream to enter the CAWS and move to the Cal-Sag Channel.

The CAWS is a heavily modified channel with little floodplain connection and few shallow marshy areas. Sediment chemical data from the CAWS show the presence of a wide range of chemicals throughout the system, including pesticides, PCBs, and heavy metals. In Scotland, reed sweetgrass was dense in an area that received sewage (West 1910). The species was positively related to human population growth (Wei and Chow-Fraser 2006). The grass is phosphorus limited, so it would spread only into areas with adequate phosphorus levels (Haslam 1978), and the CAWS has high nutrient inputs (LimnoTech 2010).

Conditions at Indiana Harbor are highly industrialized. In the east branch of the Grand Calumet River, biological integrity is poor and sediment toxicity is high (Gallagher et al. 2011). Sediments primarily consist of cobble, bedrock, or concrete, but silt, sludge, and plant debris are also present (Gallagher et al. 2011). Water can flow east or west depending on the water level in Lake Michigan. The Cal-Sag Channel and the Little Calumet River also contain areas with potentially toxic sediment contaminant levels (Gallagher et al. 2011). Sediments in the Little Calumet River are primarily inorganic silt, but areas of sand and gravel are also present (LimnoTech 2010). Inorganic silt sediments predominate in the Cal-Sag Channel as well. Bedrock sediments are also present (LimnoTech 2010). In the CSSC, in-stream habitat varies by location but is generally limited, and vertical bank walls are common along the shoreline. Sediments in the CSSC vary but primarily consist of silt, sludge, bedrock, and sand, with scattered cobble (LimnoTech 2010). These habitats would not be suitable for this species. Reed sweetgrass requires full sun and can tolerate only light shade (NBII and ISSG 2008; Loo et al. 2009). Occurrence is less likely under woody, riparian vegetation, especially dense vegetation (Loo et al. 2009). Suitable habitat in the CAWS may be intermittently present along some shallow shoreline areas and in debris accumulated near bridge abutments (LimnoTech 2010).

The Nonstructural Alternative is not expected to affect the availability of suitable habitat for reed sweetgrass within the CAWS.

T_{10}: See T_0.

T_{25}: See T_0. Upgrading wastewater treatment plants and closing two power plants should improve future water quality (Illinois Pollution Control Board 2012). Reed sweetgrass appears to benefit from some eutrophication; therefore, the suitability of water quality in the CAWS for reed sweetgrass may change. The availability of suitable substrate is not expected to increase.

T_{50}: See T_{25}.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Most of the CAWS, especially the CSSC, is too deep and lacks suitable sediments and riparian habitat for the species to establish. The species can have a rapid invasion speed; however, the CAWS is heavily utilized by vessels and population formation may be disrupted by canal maintenance and barge wakes (section 3a). The lack of vessel traffic and the lakeward flow in the Grand Calumet River may slow the initial spread of reed sweetgrass toward the Brandon Road Lock and Dam (sections 3c, 3d).

Before antifouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by reed sweetgrass. Until additional study is completed and these issues are addressed, antifouling hull paints are considered ineffective at controlling the passage of reed sweetgrass through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to reduce the likelihood of reed sweetgrass passing through the aquatic pathway. Therefore, the Nonstructural Alternative’s low probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0. Despite the generally unfavorable habitat conditions, there may be sufficient time in this time step for the reed sweetgrass to invade and spread (via growing roots and rhizomes, floating fragments and seeds, and vessel transport) to suitable habitats, where available, through the CAWS.

The Nonstructural Alternative is not expected to reduce the likelihood of reed sweetgrass passing through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of reed

sweetgrass by downstream passive transport of plant fragments and seeds to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's medium probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.
T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	High	High
Nonstructural Alternative Rating	Medium	Medium	High	High

Evidence for Uncertainty Rating

T_0: This species has been documented at Illinois Beach State Park. Vessel use and upkeep of the CAWS should remain the same over time. There is little information on long-distance transport of the species via vessel traffic. The lack of vessel traffic and the upstream movement required to move through Indiana Harbor and the Grand Calumet River would slow passage to an uncertain degree. The availability of suitable habitat in the CAWS is not documented.

The Nonstructural Alternative is not expected to affect the passage of reed sweetgrass through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the uncertainty remains medium.
T_{10}: See T_0.
T_{25}: See T_0. Although this species may spread through the CAWS over time, its ability to move upstream through Indiana Harbor and the Grand Calumet River remains uncertain. Improvements in future water quality in the CAWS could affect the reed sweetgrass in ways that are uncertain (section 3d).

The Nonstructural Alternative is not expected to affect the passage of reed sweetgrass through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the uncertainty remains high.
T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 5

BURNS SMALL BOAT HARBOR (BSBH) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Antifouling Hull Paints, Ballast/Bilge-Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Low	Low	Low	Medium	Medium
P(passage)	Low	Medium	Low	Medium	Medium	High	Medium	High
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary[a]

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Low	Low	Low	***Low***	***Low***
P(passage)	Low	Medium	Low	Medium	Medium	High	Medium	High
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[b]	Low	–	Low	–	***Low***	–

[a] The highlighted table cells indicate a rating change in the probability element.

[b] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the BSBH and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Reed sweetgrass has a potentially rapid invasion speed (NatureServe 2010). The species colonizes new areas by growing roots and rhizomes and by dispersing floating fragments and seeds (DPIWE 2002). A single rootstock may cover 25 m^2 (260 ft^2) in 3 years (NatureServe 2010). This species is considered an aggressive invasive species (Washington State Noxious Weed Control Board 2012). Lambert (1947) states that "in reed swamp, dispersal of grains probably takes place mainly by water transport. In still water, both naked and enclosed grains may be held almost indefinitely at surface by surface tension; in disturbed water, naked caryopses sink almost immediately, while enclosed grains may remain floating at surface for several hours." Seeds may be spread on water, in mud on machinery, on livestock, and to a lesser extent by wind (DPIWE 2002). The majority of the seeds are able to germinate immediately, but others remain dormant for several years (DPIWE 2002). Reed sweetgrass was found in the 1970s in Racine and Milwaukee counties in Wisconsin, and since that time the southernmost recorded occurrence is from Illinois Beach State Park in 2006 (Howard 2012).

The Nonstructural Alternative is expected to affect the invasion speed of reed sweetgrass to the Chicago Area Waterway System (CAWS) by natural dispersion through aquatic pathways. The Nonstructural Alternative includes ANS control methods, such as aquatic herbicides, cutting, burning, mechanical and/or manual harvesting, and soil removal, which may affect the invasion speed of reed sweetgrass by reducing existing populations.

b. Human-Mediated Transport through Aquatic Pathways

Reed sweetgrass spreads by seeds, roots, or rhizome fragments, which may be transported for short distances by boats (DIPWE 2002). There is recreational, but not commercial, vessel traffic to the BSBH from Lake Michigan (USACE 2011a,b). However, there is heavy lakewise commercial traffic to the adjacent Burns Harbor that could potentially transport this species from the Great Lakes to the BSBH. Evidence for ballast-water transport was not found in the literature.

Antifouling hull paints are a possible measure for controlling reed sweetgrass on vessels. However, these paints are considered only temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include the type of antifouling hull paint (toxic—with biocide—or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require antifouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS by human-mediated transport through aquatic pathways. Agency monitoring and voluntary occurrence reporting in combination with education and outreach may be used to determine where to target nonstructural control measures, in particular, aquatic herbicides. The implementation of a ballast/bilge-water exchange program, education and outreach, promotion of the use of antifouling hull paints, and laws and regulations may reduce the probability of human-mediated transport of reed sweetgrass to the CAWS pathway.

c. *Current Abundance and Reproductive Capacity*

T_0: The first recorded occurrence of reed sweetgrass in North America was in the far west end of Lake Ontario, in the mid-1940s; it subsequently spread to other areas of Ontario (Howard 2012). The species is currently established in several counties in Wisconsin. Reed sweetgrass produces vast numbers of dark brown seeds throughout summer and autumn (DPIWE 2002). It forms a sprawling mat of rhizomes or underground stems (DPIWE 2002). These rhizomes produce vast numbers of shoots to quickly expand the plant's size (DPIWE 2002). The massive root system can extend 0.9 m (3 ft) down, and the rhizomes can make up about half of the plant's total biomass (Noxious Weeds 2012). Reed sweetgrass typically goes dormant in the winter, with seeds germinating the following spring; some seeds remain dormant in the soil for many years (NBII and ISSG 2008). It is thought that North American reed sweetgrass plants reproduce mostly by vegetative means and that most seeds are not viable (Washington State Noxious Weed Control Board 2012). Rapid early spring growth gives reed sweetgrass a competitive advantage over other wetland plants (Noxious Weeds 2012). Reed sweetgrass is not widespread in Lake Michigan (Howard 2012).

The Nonstructural Alternative includes ANS control methods, such as aquatic herbicides, cutting, burning, mechanical and/or manual harvesting, and soil removal, that is expected to affect the current abundance and propagule pressure of the species. The Nonstructural Alternative would also include agency monitoring to locate areas where reed sweetgrass is established. In addition, outreach and education may be used to inform the public of reed sweetgrass management efforts, and voluntary occurrence reporting may supplement agency monitoring. Data collected through agency monitoring and voluntary occurrence reporting would focus management efforts on locations where reed sweetgrass is abundant.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: The closest established population is in Oak Creek (a tributary of Lake Michigan) in Milwaukee County, Wisconsin (Howard 2012). The population has been considered established since 1979. In 2006, an isolated established population was discovered growing out of a manhole cover at the Illinois Beach State Park, just north of Waukegan, Illinois (Howard 2012). This population was treated with herbicide, and monitoring would continue (Howard 2012).

The Nonstructural Alternative includes measures that may contain the species, thereby affecting its arrival at the CAWS through aquatic pathways.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The reed sweetgrass is a large aquatic grass found in temperate areas (Howard 2012), so the climate range in the southern Great lakes is suitable. The species prefers nutrient-rich soil (NBII and ISSG 2008); it is found on the banks of slow-moving rivers, streams, and lakes (NBII and ISSG 2008; Washington State Noxious Weed Control Board 2012) and requires full sun, tolerating only light shade (NBII and ISSG 2008; Loo et al. 2009). The species grows well in shallow water up to 1.5 m (4.9 ft) deep (Loo et al. 2009); in deeper water, the plant forms floating mats that remain partially attached to the banks of streams or ponds (Loo et al. 2009). High water levels limit the distribution of reed sweetgrass (Wei and Chow-Fraser 2006). The species is found in soils with relatively high concentrations of iron, phosphorus, and nitrogen (Wei and Chow-Fraser 2006). There are emergent wetlands inland of Lake Michigan near the BSBH (unpublished data from USACE), but shorelines in Lake Michigan near the BSBH generally have sandy, riprap, or manmade vertical walls.

The Nonstructural Alternative is not expected to affect the availability of suitable habitat for reed sweetgrass within southern Lake Michigan.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating[a]	Low	Low	Low	***Low***

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Probability Rating (Considering All Life Stages)

T_0: Reed sweetgrass was found within 80 km (50 mi) of the BSBH pathway, but the population was eradicated and is not known to currently exist (section 2e). Since 2006, the closest known population has been monitored and treated with herbicide to control dispersal (section 2e). The plant is dispersed by seeds, roots, or rhizome fragments (section 2a). The reed sweetgrass could float into the BSBH from Lake Michigan, but populations are not located along the shoreline of Lake Michigan, so there is not likely a mechanism for this. Vessel-mediated transport from Milwaukee (where the species is present) and the BSBH is unlikely because existing reed sweetgrass populations are inland and may not encounter vessel traffic. The habitat near the BSBH is not likely suitable for the plant to establish because of the sandy, higher energy shoreline of Lake Michigan and the lack of wetland habitat (section 2f). However, this species was found growing out of a manhole cover (section 2e), so it may establish in urban landscapes. If another population appears along the shoreline of southern Lake Michigan, the species may be able to spread closer to the pathway entrance over time. However, only one colony has been detected near the BSBH since the 1970s. Eradication efforts may also keep the species from spreading to the BSBH.

Before antifouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by reed sweetgrass. Until additional study is completed and these issues are addressed, antifouling hull paints are considered ineffective at controlling the arrival of reed sweetgrass at the CAWS due to fouled vessels.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS through aquatic pathways. Agency monitoring could be conducted to determine the current range of existing populations and identify the establishment of new populations followed by rapid implementation of ANS control methods, such as the application of aquatic herbicides and manual and/or mechanical harvesting, to manage the species. Once the species is managed, education and outreach could control its future spread by recreational boaters and recreational waterway users. Laws and regulations could control the cultivation of this species and subsequent spread by the nursery industry. Voluntary occurrence reports and continued agency monitoring would evaluate the effectiveness of implemented ANS control methods and identify surviving populations requiring further management.

The Nonstructural Alternative reduces the likelihood of reed sweetgrass arriving at the pathway by reducing the current abundance and distribution of reed sweetgrass. However,

the Nonstructural Alternative's low probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0. The continued implementation of nonstructural measures is expected to reduce the likelihood of reed sweetgrass arriving at the aquatic pathway; therefore, the probability of arrival is reduced to low.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating[a]	Low	Low	Low	***Low***

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Uncertainty Rating

T_0: Reed sweetgrass is found on the banks of slow-moving waters; Lake Michigan has a high-energy shoreline, and there is no emergent wetland habitat documented in the vicinity of the BSBH. Human-mediated transport of the species is poorly documented but is highly unlikely (section 2b). There is also little potential for movement into Wilmette Harbor from Lake Michigan because of the unsuitability of the shoreline of Lake Michigan. The species can have a rapid invasion rate, but this has not been evidenced in the Great Lakes.

The Nonstructural Alternative is expected to affect the arrival of reed sweetgrass at the CAWS through aquatic pathways. Therefore, uncertainty is low.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0. Implementation of the Nonstructural Alternative by local, state, and federal agencies is expected to slow the arrival of this species at the CAWS through aquatic pathways; therefore, uncertainty is low.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Reed sweetgrass has a potentially rapid invasion speed once it encounters a new habitat (NatureServe 2010). The species colonizes new areas by growing roots and rhizomes and by dispersing floating fragments and seeds (DPIWE 2002). A single rootstock may cover 25 m^2 (269 ft^2) in 3 years (NatureServe 2010). The species is considered an aggressive invasive species (Washington State Noxious Weed Control Board 2012).

Lambert (1947) states that "in reed swamp, dispersal of grains probably takes place mainly by water transport." Seeds may be spread on water, in mud on machinery, on livestock, and to a lesser extent by wind (DPIWE 2002). The majority of the seeds are able to germinate immediately, while others remain dormant for several years (DPIWE 2002).

The Nonstructural Alternative may manage rooted populations of reed sweetgrass; however, the natural dispersion (i.e., current-driven passage) of floating plant fragments and seeds would not be addressed. Therefore, the Nonstructural Alternative is not expected to control the natural dispersion of reed sweetgrass as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Reed sweetgrass spreads by seeds, roots, or rhizome fragments, which may be transported short distances by boats (DPIWE 2002). Most commercial vessel traffic to the BSBH is lakewise, and there is no commercial vessel traffic to inland ports in the CAWS from the BSBH (NBIC 2012). Recreational vessel traffic (e.g., canoe, kayak) could potentially transport this species to other areas of the CAWS where commercial and larger recreational vessels operate. In addition, some natural downstream dispersal would likely be required to reach the Brandon Road Lock and Dam. Hull-fouling could be an important vector for the secondary spread of established freshwater aquatic invasive species within the Great Lakes (Reid and Ruiz 2007). Recreational boating traffic through the BSBH, Burns Ditch, and the south branch of the Little Calumet River is very minor because of its shallow depth.

Antifouling hull paints are a possible measure for controlling reed sweetgrass on vessels. However, these paints are considered only temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion), which exposes unprotected surfaces. Other factors that influence effectiveness include the type of antifouling hull paint (toxic — with biocide — or nontoxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning); and development and compliance with future regulatory schemes that would require antifouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints because of their impact on biodiversity due to leaching.

The Nonstructural Alternative may manage the human-mediated transport of reed sweetgrass through the aquatic pathway by vessel-mediated transport and other forms of human-mediated transport; however, the passage of plant fragments and seeds of reed sweetgrass by natural downstream dispersal would not be addressed. Therefore, the Nonstructural Alternative is not expected to control the human-mediated transport of reed sweetgrass through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: The Lockport Lock and Dam and the Brandon Road Lock and Dam could act as barriers because the shoreline is heavily modified in these locations. Reed sweetgrass grows well in shallow water up to 1.5 m (4.9 ft) deep; in deeper water, the plant forms floating mats that remain partially attached to the banks of streams or ponds (Loo et al. 2009). High water levels limit distribution (Wei and Chow-Fraser 2006). The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically about 5 m (16.4 ft) (LimnoTech 2010).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Reed sweetgrass prefers nutrient-rich soil (NBII and ISSG 2008), and is found on the banks of slow-moving rivers, streams, and lakes (NBII and ISSG 2008; Washington State Noxious Weed Control Board 2012). Most flows in the CAWS were less than 0.15 m/s (0.49 ft/s); the highest was 0.27 m/s (0.89 ft/s) (LimnoTech 2010). Water flows out of the BSBH into Lake Michigan. The eastern segment of the south branch of the Little Calumet River also generally flows toward Lake Michigan, depending on location and water level in Lake Michigan (GSWMD 2008). Thus, reed sweetgrass would have to spread upstream in order to enter the CAWS and move to the Cal-Sag Channel.

The CAWS is a heavily modified channel with little floodplain connection and few shallow marshy areas. Sediment chemical data from the CAWS show the presence of a wide range of chemicals throughout the system, including pesticides, PCBs, and heavy metals. In Scotland, reed sweetgrass was dense in an area that received sewage (West 1910). The species was positively related to human population growth (Wei and Chow-Fraser 2006). The grass is phosphorus limited, so it would spread only into areas with adequate phosphorus levels (Haslam 1978). The CAWS has high nutrient inputs (LimnoTech 2010).

The banks of the BSBH are primarily riprap and vertical walls. The banks of the south leg of the Little Calumet River are vegetated, and sediments include plant debris, silt, sand, cobble, gravel, and boulders (Gallagher et al. 2011). Reed sweetgrass requires full sun and can tolerate only light shade (NBII and ISSG 2008; Loo et al. 2009). Occurrence is less likely under woody, riparian vegetation, especially dense vegetation (Loo et al. 2009). Inorganic silt and sludge sediments predominate in the Cal-Sag Channel (LimnoTech 2010), and it contains areas with potentially toxic sediment contaminant levels (Gallagher et al. 2011). In the CSSC, in-stream habitat varies by location but is generally limited, and vertical bank walls are common along the shoreline. Sediments in the CSSC vary but primarily consist of silt, sludge, bedrock, and sand, with scattered cobble (LimnoTech 2010). These habitats would not be suitable for this species. Suitable habitat in the CAWS may be intermittently present along some shallow shoreline areas and in debris accumulated near bridge abutments (LimnoTech 2010).

The Nonstructural Alternative is not expected to affect the availability of suitable habitat for reed sweetgrass within the CAWS.

T_{10}: See T_0.

T_{25}: See T_0. Upgrading wastewater treatment plants and the closing of two power plants should improve future water quality (Illinois Pollution Control Board 2012). Reed sweetgrass appears to benefit from some eutrophication; therefore, the suitability of water quality in the CAWS for reed sweetgrass may change. The availability of suitable substrate is not expected to increase.
T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	Medium
Nonstructural Alternative Rating	Low	Low	Medium	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Most of the CAWS, especially the CSSC, is too deep and lacks suitable sediments and riparian habitat for this species. The species can have a rapid invasion speed; however, the CAWS is heavily utilized by vessels and rooting by the reed sweetgrass may be disrupted by canal maintenance and barge wakes (section 3a). The lack of vessel traffic and the flow toward Lake Michigan in the BSBH and the south branch of the Little Calumet River would slow the spread of reed sweetgrass.

Before antifouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by reed sweetgrass. Until additional study is completed and these issues are addressed, antifouling hull paints are considered ineffective at controlling the passage of reed sweetgrass through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to reduce the likelihood of reed sweetgrass passing through the aquatic pathway. Therefore, the Nonstructural Alternative's low probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0. Over time, reed sweetgrass may be able to move upstream through the BSBH and the Little Calumet River using wind-driven currents and aquatic organisms. Despite the generally unfavorable habitat conditions, there may be sufficient time in this time step for the reed sweetgrass to establish and spread (via growing roots and rhizomes, floating fragments and seeds, and attachment to vessels) to suitable habitats, where available, through the CAWS.

The Nonstructural Alternative is not expected to reduce the likelihood of reed sweetgrass passing through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of reed sweetgrass by downstream passive transport of plant fragments and seeds to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's medium probability of passage rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Medium	Medium	Medium
Nonstructural Alternative Rating	Medium	Medium	Medium	Medium

Evidence for Uncertainty Rating

T_0: Vessel use and upkeep of the CAWS should remain the same over time. There is little information on long-distance transport of the species via vessel traffic. The lack of vessel traffic and the upstream movement required to move through the BSBH and the south branch of the Little Calumet River would slow passage to an uncertain degree. The availability of suitable habitat in the CAWS is not documented.

The Nonstructural Alternative is not expected to affect the passage of reed sweetgrass through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. The ability of reed sweetgrass to move upstream through the BSBH and the Little Calumet River remains uncertain. Although this species may spread through the CAWS over time, improvements in future water quality in the CAWS could affect the reed sweetgrass in ways that are uncertain (section 3d).

T_{50}: See T_{25}.

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. **P(spreads) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

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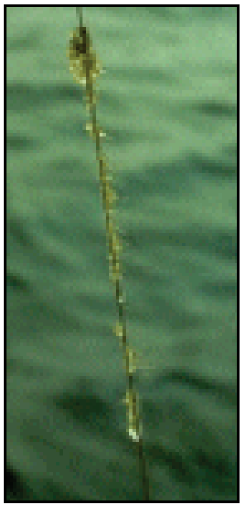
E.2.2.3 Crustaceans

E.2.2.3.1 Fishhook Waterflea (Cercopagis pengoi)



NONSTRUCTURAL ALTERNATIVE

This alternative would potentially include the implementation of a combination of the following measures that can be implemented at time step 0 (T_0, in units of years) by local, state, and federal agencies and the public. The Nonstructural Alternative would include the development of a monitoring and response program.

Nonstructural Alternative Measures for the Fishhook Waterflea

Option or Technology	Description
Education and Outreach	• Signage, pamphlets, brochures on how to identify and control the spread of ANS; promote national campaigns (i.e., “Stop Aquatic Hitchhikers”) • Education of recreational waterway users
Anti-Fouling Hull Paints	• Education of vessel owners and operators to promote use of anti-fouling paints
Ballast/Bilge-water Exchange	• Ballast/bilge-water exchange
Monitoring	• Agency monitoring • Voluntary occurrence reporting
Laws and Regulations	• USFWS Lacey Act listing • Mandatory watercraft inspection and decontamination

PATHWAY 1

WILMETTE PUMPING STATION (WPS) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Medium	Low	Medium	Medium	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**P**	**U**	**P**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Medium	Low	Medium	Medium	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the WPS and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The fishhook waterflea is planktonic and makes daily vertical migrations in the water column (Benson et al. 2012; NBII and ISSG 2010). Eggs are brooded until hatching, after which they are planktonic. The fishhook waterflea has a very rapid invasion speed. It spread to three Great Lakes within 2 years and inland to six of New York's Finger Lakes within 1 year (Sea Grant New York 2012). As Makarewicz et al. (2001) point out, asexual reproduction, high fecundity, the production of resting eggs, a "sticky" caudal process, viability during unfavorable periods, and rapid dispersal all promote rapid population growth.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea from natural dispersion (i.e., passive drift) through aquatic pathways to the Chicago Area Waterway System (CAWS).

b. Human-Mediated Transport through Aquatic Pathways

The species' invasion of Lake Michigan during 1999 almost certainly resulted from the movement of contaminated Lake Ontario ballast water by commercial vessels. Ships that discharge cargo at a Lake Ontario port will often load lake water as ballast prior to upbound movement on the Great Lakes. This water is subsequently discharged at the terminal port-of-call and replaced with cargo for the out-bound voyage. WPS is not a port; therefore, vessels will not release ballast water at this pathway (USACE 2011a,b). Local dispersal mechanisms potentially include small boat traffic (Makarewicz et al. 2001). The WPS is not a port and does not have cargo vessel traffic. However, there is recreational boat use in the Wilmette Harbor that could potentially transport this species from the Great Lakes to the WPS.

Anti-fouling hull paints are a possible measure for controlling the fishhook waterflea on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS from human-mediated transport through aquatic pathways.

c. *Current Abundance and Reproductive Capacity*

T_0: Female fishhook waterfleas reproduce parthenogenically during the summer and gametogenically later in the year (NBII and ISSG 2010). Following sexual reproduction, sexual females produce between one and four resting eggs, while parthenogenic females produce between one and 24 embryos (NBII and ISSG 2010). The species produces resting eggs any time during the year when environmental conditions become inhospitable (Benson et al. 2012). Resting eggs are resistant to desiccation, freeze drying, and ingestion by predators, and they replenish the population after hatching in the spring (Benson et al. 2012). Resting eggs can hatch regardless of whether the carrier female is alive or dead (Benson et al. 2012). In southern Lake Michigan, densities can reach more than 100 per m^2 during the late summer peak (Charlebois et al. 2001; Cavaletto et al. 2010; Witt et al. 2005).

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of the fishhook waterflea.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. *Existing Physical Human/Natural Barriers*

T_0: None. The species is close to or at the WPS pathway entrance (Benson et al. 2012).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: None.
T_{25}: None.
T_{50}: None.

e. *Distance from Pathway*

T_0: The fishhook waterflea was established in Lake Michigan, north of Chicago, Illinois, in 1999 (Benson et al. 2012). The exact location and distance from the WPS are uncertain, but this species may be at the WPS.

The Nonstructural Alternative is not expected to limit the movement of the fishhook waterflea outside of its current distribution.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Suitable habitats include estuarine habitats, lakes, marine habitats, water courses, and wetlands (NBII and ISSG 2010). Location may be variable: some studies found the species at higher densities in central regions of lakes compared with coastal areas (Ojaveer et al. 2001). However, the species is more likely to invade clear, large lakes (Muirhead et al. 2011). In Lake Michigan, the fishhook waterflea is confined largely to near-shore waters (Pichlova-Ptacnikova and Vanderploeg 2009). The species does prefer to inhabit pelagic zones (Crosier and Molloy). The preferred temperature range for the fishhook waterflea is 16–26°C (60.8–78.8°F) (NBII and ISSG 2010), although studies have found a range of 3–38°C (37.4–100.4°F) (Gorokhova et al. 2000). The majority of individuals were found within the warm, uppermost 20-m (65.6-ft) water layer during both day and night (Ojaveer et al. 2001). Less than 3% of the population occurred at depths greater than 40 m (131 ft) (Ojaveer et al. 2001).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the fishhook waterflea in southern Lake Michigan.

T_{10}: See T_0. There are no predicted significant differences in habitat components along Lake Michigan in the near or foreseeable future that would affect the arrival of this species.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The species is established very close to the WPS pathway entrance (section 2e). Suitable habitat is present (section 2f). Given its time in southern Lake Michigan, this species may be at the pathway entrance. Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by fishhook waterflea. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of the fishhook waterflea at the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The fishhook waterflea has been documented to be close to the pathway entrance and may drift to the entrance of the WPS via current or attachment to recreational vessels entering Wilmette Harbor.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

3. P(passage) T_0-T_{50}: LOW-HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The fishhook waterflea is planktonic and makes daily vertical migrations in the water column (Benson et al. 2012; NBII and ISSG 2010). Eggs are brooded until hatching, after which they are planktonic (NBII and ISSG 2010). As Makarewicz et al. (2001) point out, asexual reproduction, high fecundity, the production of resting eggs, a “sticky” caudal process, viability during unfavorable periods, and rapid dispersal all promote rapid population growth. However, although this species was first recorded in southern Lake Michigan in 1999, it has not been recorded in the Illinois River or the CAWS. No recent zooplankton surveys were found for these waterways; therefore, the species may be present but undetected. Once it enters the North Shore Channel, the fishhook waterflea could move toward Brandon Road Lock and Dam with the natural downstream flow.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., passive drift) of the fishhook waterflea through the aquatic pathway.

b. *Human-Mediated Transport through Aquatic Pathways*

The invasion of Lake Michigan by the species in 1999 almost certainly resulted from the movement of contaminated Lake Ontario ballast water by commercial vessels. The discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012), and there is no commercial vessel traffic in the North Shore Channel. It is not possible for any vessel to move from Wilmette Harbor to the North Shore Channel because the WPS separates Lake Michigan from the North Shore Channel. Local dispersal mechanisms for the fishhook waterflea potentially include small boat traffic (Makarewicz et al. 2001). The fishhook waterflea was found on commercial vessel hull scrapes (Sylvester and MacIsaac 2010), so vessel transport is possible through the portions of the CAWS with vessel traffic. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the fishhook waterflea into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River. The Nonstructural Alternative would not address the passage of fishhook waterflea by the Lake Michigan diversion through the CAWS.

Anti-fouling hull paints are a possible measure for controlling the fishhook waterflea on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of the fishhook waterflea through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: A sluice gate separates the WPS from Lake Michigan; the gate is periodically opened and closed. Water from Lake Michigan is periodically pumped into the North Shore Channel (LimnoTech 2010), which could transport this species into the channel. In lake studies, the fishhook waterflea was found mainly down to a depth of 20 m (65.6 ft) (Bielecka and Mudrak 2010). Deep (greater than 100 m [328 ft]) and shallow (less than 10 m; 32.8 ft) stations had significantly lower abundances of the fishhook waterflea than stations of intermediate depth (less than 100 m [328 ft]) (Gorokhova et al. 2000). The maximum depth in the CAWS is about 10 m (32.8 ft); depth is typically around 5 m (16.4 ft) (LimnoTech 2010). Surface water is present year-round, and water depth is adequate throughout the CAWS (LimnoTech 2010).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: The fishhook waterflea appears to prefer lentic systems, but it has also established in rivers; the species has successfully invaded the Rhine River (Cristescu et al. 2001). The low current velocity in the CAWS may be favorable because the fishhook waterflea is typically a lake species. The preferred temperature range for the fishhook waterflea is 16–26°C (60.8–78.8°F) (NBII and ISSG 2010). Studies have found a range of 3–38°C (37.4–100.4°F) (Gorokhova et al. 2000). The water temperature in the CAWS averages 11.3 to 19.3°C (52.3 to 66.7°F) (MWRD 2010). The fishhook waterflea is likely to invade low-turbidity water systems, with 4.37–105.16 nephelometric turbidity units (NTU) (Muirhead et al. 2011). The CAWS is turbid (LimnoTech 2010). Based on invaded lakes in the United States, the fishhook waterflea was found in waters with a dissolved oxygen (DO) range of 7.67–14.07 mg/L and pH of 7.32–8.39 (Muirhead et al. 2011). Annual mean DO in the CAWS typically exceeds 6 mg/L, although seasonal hypoxia may occur in portions of the CAWS (MWRD 2010).

The Nonstructural Alternative is not expected to affect habitat suitability for the fishhook waterflea in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0. Future water quality in the CAWS may improve with current plans to close two power plants and update wastewater treatment (Illinois Pollution Control Board 2012).

T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	High
Nonstructural Alternative Rating	Low	Low	Medium	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Dispersal by ballast water is unlikely within the CAWS, although transport on boat hulls is possible (section 3b). Natural downstream dispersal would likely be required in the North Shore Channel (section 3b). The fishhook waterflea is typically found in lakes, although it has invaded rivers (section 3d). Depth in the CAWS may be shallower than this species prefers (section 3d). Suitable temperature is present for the fishhook waterflea in the CAWS (section 3d). The CAWS is a turbid water system; the fishhook waterflea is likely to invade only low-turbidity water systems (section 3d). This species was first recorded in southern Lake Michigan in 1999, and has not been recorded in the Illinois River (section 3a).

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by the fishhook waterflea. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of the fishhook waterflea through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the fishhook waterflea by the Lake Michigan diversion, downstream passive transport, or hull fouling to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's low probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0. Given time to disperse naturally or by vessel traffic, this species is more likely to pass through the aquatic pathway.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's medium probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{50}: See T_{25}. The probability of passage is likely to increase with time. The fishhook waterflea has been documented to invade rivers.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: The depth and water quality suitability of the CAWS are uncertain (section 3d). The fishhook waterflea is a lake species so its potential to exist in canals is uncertain. There is no documentation of the speed of natural dispersal of the fishhook waterflea. The probability and speed of vessel transport are not well documented. Although the potential for passage exists, it is uncertain why this species has not been recorded in the Illinois River despite being in southern Lake Michigan since 1999.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. The habitat suitability of the CAWS remains uncertain. However, this species has been documented to move through canals, and this species is more certain to pass through the CAWS in 25 years compared with the previous time step. Water quality improvements may also promote the passage of this species, although this is uncertain.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{50}: See T_{25}.

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. **P(spreads) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 2

CHICAGO RIVER CONTROLLING WORKS (CRCW) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Medium	Low	Medium	Medium	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Medium	Low	Medium	Medium	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the CRCW and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The fishhook waterflea is planktonic and makes daily vertical migrations in the water column (Benson et al. 2012; NBII and ISSG 2010). Eggs are brooded until hatching, after which they are planktonic. The fishhook waterflea has a very rapid invasion speed. It spread to three Great Lakes within 2 years and inland to six of New York's Finger Lakes within 1 year (Sea Grant New York 2012). As Makarewicz et al. (1999) point out, asexual reproduction, high fecundity, the production of resting eggs, a "sticky" caudal process, viability during unfavorable periods, and rapid dispersal promote rapid population growth.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS from natural dispersion (i.e., passive drift) through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

The species' invasion of Lake Michigan during 1999 almost certainly resulted from the movement of contaminated Lake Ontario ballast water by commercial vessels. Ships that discharge cargo at a Lake Ontario port will often load lake water as ballast prior to upbound movement on the Great Lakes. This water is subsequently discharged at the terminal port of call and replaced with cargo for the outbound voyage. There is commercial and recreational vessel traffic to the CRCW from the Great Lakes (USACE 2011a,b), and many of these boats discharge ballast water from other ports in the Great Lakes (NBIC 2012). The fishhook waterflea was also found on commercial vessel hull scrapes (Sylvester and MacIsaac 2010), so vessel transport may be possible. Local dispersal mechanisms potentially include small boat traffic (Makarewicz et al. 2001).

Anti-fouling hull paints are a possible measure for controlling the fishhook waterflea on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS from human-mediated transport through aquatic pathways.

c. *Current Abundance and Reproductive Capacity*

T_0: Female fishhook waterfleas reproduce parthenogenically during the summer and gametogenically later in the year (NBII and ISSG 2010). Following sexual reproduction, sexual females produce between one and four resting eggs, while parthenogenic females produce between one and 24 embryos (NBII and ISSG 2010). The species produces resting eggs any time during the year when environmental conditions become inhospitable (Benson et al. 2012). Resting eggs are resistant to desiccation, freeze drying, and ingestion by predators, and they replenish the population after hatching in the spring (Benson et al. 2012). Resting eggs can hatch regardless of whether the carrier female is alive or dead (Benson et al. 2012). In southern Lake Michigan, densities may reach more than 100 per m^2 during the late summer peak (Charlebois et al. 2001; Cavaletto et al. 2010; Witt et al. 2005).

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of the fishhook waterflea.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Existing Physical Human/Natural Barriers*

T_0: None. The species is close to or at the CRCW pathway entrance (Benson et al. 2012).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. *Distance from Pathway*

T_0: The fishhook waterflea was established in Lake Michigan, north of Chicago, Illinois, in 1999 (Benson et al. 2012). The exact location and distance from the CRCW are uncertain, but this species may be at the CRCW.

The Nonstructural Alternative is not expected to limit the movement of the fishhook waterflea outside of its current distribution.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Suitable habitats include estuarine habitats, lakes, marine habitats, water courses, and wetlands (NBII and ISSG 2010). Locations may be variable: some studies found the species at higher densities in central regions of lakes compared with coastal areas (Ojaveer et al. 2001); however, this species is more likely to invade clear, large lakes (Muirhead et al. 2011). In Lake Michigan, the fishhook waterflea is confined largely to near-shore waters (Pichlova-Ptacnikova and Vanderploeg 2009). The species prefers to inhabit pelagic zones (Crosier and Molloy). The preferred temperature range for the fishhook waterflea is 16–26°C (60.8–78.8°F) (NBII and ISSG 2010), although studies have found a range of 3–38°C (37.4–100.4°F) (Gorokhova et al. 2000). The majority of individuals were found within the warm, uppermost 20-m (65.6-ft) water layer during both day and night (Ojaveer et al. 2001). Less than 3% of the population occurred at depths greater than 40 m (131 ft) (Ojaveer et al. 2001).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the fishhook waterflea in southern Lake Michigan.

T_{10}: See T_0. There are no predicted significant differences in habitat components along Lake Michigan in the near or foreseeable future that would affect the arrival of this species.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The species is established very close to the CRCW pathway entrance (section 2e). Suitable habitat is present (section 2d). Given that the fishhook waterflea has been established in southern Lake Michigan since 1999 (Benson et al. 2012), this species may be at the pathway entrance.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by the fishhook waterflea. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of the fishhook waterflea at the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The fishhook waterflea has been documented to be close to the pathway entrance and may drift to the entrance of the CRCW via current, vessel-mediated transport, or other human-mediated transport means.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

3. P(passage) T_0-T_{50} : LOW-HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The fishhook waterflea is planktonic and makes daily vertical migrations in the water column (Benson et al. 2012; NBII and ISSG 2010). Eggs are brooded until hatching, after which they are planktonic (NBII and ISSG 2010). As Makarewicz et al. (1999) point out; asexual reproduction, high fecundity, the production of resting eggs, a “sticky” caudal process, viability during unfavorable periods, and rapid dispersal rates promote rapid population growth. However, although this species was first recorded in southern Lake Michigan in 1999, it has not been recorded in the Illinois River or the CAWS. No recent zooplankton surveys were found for these waterways; therefore, the species may be present but undetected. Once it enters the Chicago River, the fishhook waterflea could move toward Brandon Road Lock and Dam with the natural downstream flow.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., passive drift) of the fishhook waterflea through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the fishhook waterflea as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

The species' invasion of Lake Michigan during 1999 almost certainly resulted from movement of contaminated Lake Ontario ballast water by commercial vessels. There is some commercial vessel traffic between the CRCW and Brandon Road Lock and Dam (USACE 2011a; NBIC 2012), although the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). Local dispersal mechanisms for the fishhook waterflea potentially include small boat traffic (Makarewicz et al. 2001). The fishhook waterflea was found on commercial vessel hull scrapes (Sylvester and MacIsaac 2010), so vessel transport is possible through the portions of the CAWS with vessel traffic. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Anti-fouling hull paints are a possible measure for controlling the fishhook waterflea on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of the fishhook waterflea through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: In lake studies, the fishhook waterflea was found mainly down to a depth of 20 m (65.6 ft) (Bielecka and Mudrak 2010). Deep (greater than 100 m [328 ft]) and shallow (less than 10 m [32.8 ft]) stations had significantly lower abundances of the fishhook waterflea than stations of intermediate depth (less than 100 m [328 ft]) (Gorokhova et al. 2000). The maximum depth in the CAWS is about 10 m (32.8 ft); depth is typically around 5 m (16.4 ft) (LimnoTech 2010). Surface water is present all year-round and water depth is adequate throughout the CAWS (LimnoTech 2010).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The fishhook waterflea appears to prefer lentic systems, but has also established in rivers (Cristescu et al. 2001); the species has successfully invaded the Rhine River (Cristescu et al. 2001). Low current velocity in the CAWS may be favorable because it is typically a lake species. The preferred temperature range for the fishhook waterflea is

16–26°C (60.8–78.8°F) (NBII and ISSG 2010). Studies have found a range of 3–38°C (37.4–100.4°F) (Gorokhova et al. 2000). The water temperature in the CAWS averages from 11.3 to 19.3°C (52.3 to 66.7°F) (MWRD 2010). The fishhook waterflea is likely to invade low turbidity water systems, 4.37–105.16 NTU (Muirhead et al. 2011). The CAWS is turbid (LimnoTech 2010). Based on invaded lakes in the United States, the fishhook waterflea was found in waters with DO range of 7.67–14.07 mg/L and pH of 7.32–8.39 (Muirhead et al. 2011). Annual mean DO in the CAWS typically exceeds 6 mg/L although seasonal hypoxia may occur in portions of the CAWS (MWRD 2011).

The Nonstructural Alternative is not expected to affect habitat suitability for the fishhook waterflea in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0. Future water quality in the CAWS may improve with current plans to close two power plants and update wastewater treatment (Illinois Pollution Control Board 2012).

T_{50}: See T_{25}.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Medium	High
Nonstructural Alternative Rating	Low	Low	Medium	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Dispersal by human-mediated transport via ballast water is unlikely within the CAWS, although transport on boats is possible (section 3b). The fishhook waterflea is typically found in lakes, although it has invaded rivers (section 3d). Depth in the CAWS may be shallower than this species prefers (section 3d). Suitable temperature is present for the fishhook waterflea in the CAWS (section 3d). The CAWS is a turbid water system, the fishhook waterflea is likely to invade only low-turbidity water systems (section 3d). This species was first recorded in southern Lake Michigan in 1999, and has not been recorded in the Illinois River (section 3a).

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by the fishhook waterflea. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of the fishhook waterflea through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the fishhook waterflea by the Lake Michigan diversion, downstream passive transport, or hull fouling to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's low probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0. Given time to disperse naturally or by vessel traffic, this species is more likely to pass through the CAWS.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's medium probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{50}: See T_{25}. The probability of passage is likely to increase with time. The fishhook waterflea has been documented to invade rivers.

The Nonstructural Alternative is not expected to control the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: The fishhook waterflea has been documented to be close to the pathway entrance and has been established in Lake Michigan since 1999; however, it has not been recorded in the Illinois River despite the potential for passage existing. The probability and speed of vessel transport is not well documented. The depth and water quality suitability of the CAWS are uncertain (section 3d). There is no documentation of the speed of natural dispersal of the fishhook waterflea.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0.
T_{25}: See T_0. The habitat suitability of the CAWS remains uncertain. However, this species has been documented to move through canals, and this species is more certain to pass through the CAWS in 25 years compared to the previous time step. Water quality improvements may also promote the passage of this species, although this is uncertain.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 3

CALUMET HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Medium	Low	Medium	Medium	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Medium	Low	Medium	Medium	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Calumet Harbor and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative is not expected to impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The fishhook waterflea is planktonic and makes daily vertical migrations in the water column (Benson et al. 2012; NBII and ISSG 2010). Eggs are brooded until hatching, after which they are planktonic. The fishhook waterflea has a very rapid invasion speed. It spread to three Great Lakes within 2 years and inland to six of New York's Finger Lakes within 1 year (Sea Grant New York 2012). As Makarewicz et al. (2001) point out, asexual reproduction, high fecundity, the production of resting eggs, a "sticky" caudal process, viability during unfavorable periods, and rapid dispersal promote rapid population growth.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS from natural dispersion (i.e., passive drift) through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

The 1999 invasion of Lake Michigan by the species almost certainly resulted from the movement of contaminated Lake Ontario ballast water by commercial vessels. Ships that discharge cargo at a Lake Ontario port will often load lake water as ballast prior to upbound movement on the Great Lakes. This water is subsequently discharged at the terminal port-of-call and replaced with cargo for the outbound voyage. There is heavy commercial vessel traffic to the Calumet Harbor from Lake Michigan (USACE 2011a). Many of these boats discharge ballast water from other ports in the Great Lakes (NBIC 2012). The fishhook waterflea was also found on commercial vessel hull scrapes (Sylvester and MacIsaac 2010), so vessel transport may be possible. Local dispersal mechanisms potentially include small boat traffic (Makarewicz et al. 2001).

Anti-fouling hull paints are a possible measure for controlling the fishhook waterflea on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS from human-mediated transport through aquatic pathways.

c. *Current Abundance and Reproductive Capacity*

T_0: Female fishhook waterfleas reproduce parthenogenically during the summer and gametogenically later in the year (NBII and ISSG 2010). Following sexual reproduction, sexual females produce one to four resting eggs, while parthenogenic females produce between one and 24 embryos (NBII and ISSG 2010). The species produces resting eggs any time during the year when environmental conditions become inhospitable (Benson et al. 2012). Resting eggs are resistant to desiccation, freeze drying, and ingestion by predators, and they replenish the population after hatching in the spring (Benson et al. 2012). Resting eggs can hatch regardless of whether the carrier female is alive or dead (Benson et al. 2012). In southern Lake Michigan, densities can reach greater than 100 per m^2 during the late summer peak (Charlebois et al. 2001; Cavaletto et al. 2010; Witt et al. 2005).

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of the fishhook waterflea.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. *Existing Physical Human/Natural Barriers*

T_0: None. The species is close to or at the Calumet Harbor pathway entrance (Benson et al. 2012).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. *Distance from Pathway*

T_0: The fishhook waterflea was established in Lake Michigan, north of Chicago, Illinois, in 1999 (Benson et al. 2012). The exact location and distance from the Calumet Harbor are uncertain, but this species may be at Calumet Harbor.

The Nonstructural Alternative is not expected to limit the movement of the fishhook waterflea outside of its current distribution.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Suitable habitats include estuarine habitats, lakes, marine habitats, water courses, and wetlands (NBII and ISSG 2010). Location for this species is variable: some studies found the species at higher densities in central regions of lakes compared with coastal areas (Ojaveer et al. 2001); however, the fishhook waterflea is more likely to invade clear, large lakes (Muirhead et al. 2011). In Lake Michigan, the fishhook waterflea is confined largely to near-shore waters (Pichlova-Ptacnikova and Vanderploeg 2009). The species prefers to inhabit pelagic zones (Crosier and Molloy). The preferred temperature range for the fishhook waterflea is 16–26°C (60.8–78.8°F) (NBII and ISSG 2010), although studies have found a range of 3–38°C (37.4–100.4°F) (Gorokhova et al. 2000). The majority of individuals were found within the warm, uppermost 20-m (65.6-ft) water layer during both day and night (Ojaveer et al. 2001). Less than 3% of the population occurred at depths greater than 40 m (131 ft) (Ojaveer et al. 2001).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the fishhook waterflea in southern Lake Michigan.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The species is established very close to the Calumet Harbor pathway entrance. Suitable habitat is present (section 2d). Given its time in southern Lake Michigan, this species may be at the pathway entrance.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by the fishhook waterflea. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of the fishhook waterflea at the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.

T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The fishhook waterflea has been documented to be close to the pathway entrance and may drift to the entrance of the Calumet Harbor pathway via current. Given its time in southern Lake Michigan, this species may be at the pathway entrance.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

3. P(passage) T_0-T_{50}: LOW-HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The fishhook waterflea is planktonic and makes daily vertical migrations in the water column (Benson et al. 2012; NBII and ISSG 2010). Eggs are brooded until hatching, after which they are planktonic (NBII and ISSG 2010). As Makarewicz et al. (2001) point out, asexual reproduction, high fecundity, the production of resting eggs, a “sticky” caudal process, viability during unfavorable periods, and rapid dispersal promote rapid population growth. However, although this species was first recorded in southern Lake Michigan in 1999, it has not been recorded in the Illinois River or the CAWS. No recent zooplankton surveys were found for these waterways; therefore, the species may be present but undetected. Once it enters Calumet Harbor, the fishhook waterflea could move toward Brandon Road Lock and Dam with the natural downstream flow.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., passive drift) of the fishhook waterflea through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

The species’ invasion of Lake Michigan in 1999, almost certainly resulted from the movement of contaminated Lake Ontario ballast water by commercial vessels. Although there is little commercial river traffic through Calumet Harbor (NBIC 2012), there is heavy commercial vessel traffic between Brandon Road Lock and Dam and T.J. O'Brien Lock and Dam, which is approximately 8 km (5 mi) south of Calumet Harbor (USACE 2011a; NBIC 2012). Discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). Local dispersal mechanisms for the fishhook waterflea potentially include small boat traffic (Makarewicz et al. 2001). The fishhook waterflea was found on commercial vessel hull scrapes (Sylvester and MacIsaac 2010), so vessel transport is possible through the portions of the CAWS with vessel traffic. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the fishhook waterflea into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Anti-fouling hull paints are a possible measure for controlling the fishhook waterflea on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of the fishhook waterflea through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: In lake studies, the fishhook waterflea was found mainly down to a depth of 20 m (Bielecka and Mudrak 2010). Deep (greater than 100 m [328 ft]) and shallow (less than 10 m [32.8 ft]) stations had significantly lower abundances of the fishhook waterflea than stations of intermediate depth (less than 100 m [328 ft]) (Gorokhova et al. 2000). The maximum depth in the CAWS is about 10 m (32.8 ft); depth is typically around 5 m (16.4 ft) (LimnoTech 2010). Surface water is present year-round, and water depth is adequate throughout the CAWS (LimnoTech 2010).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The fishhook waterflea appears to prefer lentic systems, but it has also established in rivers (Cristescu et al. 2001); the species successfully invaded the Rhine River (Cristescu et al. 2001). The low current velocity in the CAWS may be favorable because the fishhook waterflea is typically a lake species. The preferred temperature range for the fishhook waterflea is 16–26 °C (60.8–78.8°F) (NBII and ISSG 2010), although studies have found a range of 3–38°C (37.4–100.4°F) (Gorokhova et al. 2000). The water temperature in the CAWS averages from 11.3°C to 19.3°C (52.3°F to 66.7°F) (MWRD 2010). The fishhook waterflea is likely to invade low-turbidity water systems, with NTUs of 4.37–105.16 (Muirhead et al. 2011). The CAWS is turbid (LimnoTech 2010). Based on invaded lakes in the United States, the fishhook waterflea was found in waters with a DO range of 7.67–14.07 mg/L and pH of 7.32–8.39 (Muirhead et al. 2011). Annual mean DO in the CAWS typically exceeds 6 mg/L, although seasonal hypoxia may occur in portions of the CAWS (MWRD 2011).

The Nonstructural Alternative is not expected to affect habitat suitability for the fishhook waterflea in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Medium	High
Nonstructural Alternative Rating	Low	Low	Medium	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Dispersal by human-mediated transport via ballast water is unlikely within the CAWS, although transport on boats is possible (section 3b). The fishhook waterflea is typically found in lakes, although it has invaded rivers (section 3d). Depth in the CAWS may be shallower than this species prefers (section 3d). The CAWS is a turbid water system; the fishhook waterflea is likely to invade only low-turbidity water systems (section 3d). This species was first recorded in southern Lake Michigan in 1999, and has not been recorded in the Illinois River (section 3a).

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by the fishhook waterflea. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of the fishhook waterflea through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the fishhook waterflea by the Lake Michigan diversion, downstream passive transport, or hull fouling to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's low probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0. Given time to disperse naturally or by vessel traffic, this species is more likely to pass through the CAWS.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's medium probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{50}: See T_{25}. The probability of passage is likely to increase with time. The fishhook waterflea has been documented to invade rivers.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: The fishhook waterflea has been documented to be close to the pathway entrance and has been established in Lake Michigan since 1999 (section 3a); however, it has not been recorded in the Illinois River despite the potential for passage. The probability and speed of vessel transport are not well documented. The depth and water quality suitability of the CAWS are uncertain (section 3d).

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. The habitat suitability of the CAWS remains uncertain. However, this species has been documented to move through canals, and this species is more certain to pass through the CAWS in 25 years compared with the previous time step. Water quality improvements may also promote the passage of this species, although this is uncertain.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. **P(spreads) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 4

INDIANA HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Low	Low	Low	Low	High	Medium	High
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Low	Low	Low	Low	High	Medium	High
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Indiana Harbor and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative is not expected to impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. **P(arrival) T_0-T_{50}: HIGH**

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The fishhook waterflea is planktonic and makes daily vertical migrations in the water column (Benson et al. 2012; NBII and ISSG 2010). Eggs are brooded until hatching, after which they are planktonic. The fishhook waterflea has a very rapid invasion speed. It spread to three Great Lakes within 2 years and inland to six of New York's Finger Lakes within 1 year (Sea Grant New York 2012). As Makarewicz et al. (2001) point out, asexual reproduction, high fecundity, the production of resting eggs, a "sticky" caudal process, viability during unfavorable periods, and rapid dispersal all promote rapid population growth.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS from natural dispersion (i.e., passive drift) through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

The 1999 invasion of Lake Michigan by the species almost certainly resulted from the movement of contaminated Lake Ontario ballast water by commercial vessels. Ships that discharge cargo at a Lake Ontario port will often load lake water as ballast prior to upbound movement on the Great Lakes. This water is subsequently discharged at the terminal port-of-call and replaced with cargo for the outbound voyage. There is heavy commercial vessel traffic to the Indiana Harbor from Lake Michigan (USACE 2011a), and many of these boats discharge ballast water from other ports in the Great Lakes (NBIC 2012). The fishhook waterflea was found on commercial vessel hull scrapes (Sylvester and MacIsaac 2010), so vessel transport may be possible. Local dispersal mechanisms potentially include small boat traffic (Makarewicz et al. 2001).

Anti-fouling hull paints are a possible measure for controlling the fishhook waterflea on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS from human-mediated transport through aquatic pathways.

c. Current Abundance and Reproductive Capacity

T_0: Female fishhook waterfleas reproduce parthenogenically during the summer and gametogenically later in the year (NBII and ISSG 2010). Following sexual reproduction, sexual females produce between one and four resting eggs, while parthenogenic females produce between one and 24 embryos (NBII and ISSG 2010). The species produces resting eggs any time during the year when environmental conditions become inhospitable (Benson et al. 2012). Resting eggs are resistant to desiccation, freeze drying, and ingestion by predators, and they replenish the population after hatching in the spring (Benson et al. 2012). Resting eggs can hatch regardless of whether the carrier female is alive or dead (Benson et al. 2012). In southern Lake Michigan, densities can reach more than 100 per m^2 during the late summer peak (Charlebois et al. 2001; Cavaletto et al. 2010; Witt et al. 2005).

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of the fishhook waterflea.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The species is close to or at the Indiana Harbor pathway entrance (Benson et al. 2012).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: The fishhook waterflea was established in Lake Michigan, north of Chicago, Illinois, in 1999 (Benson et al. 2012). The exact location and distance from Indiana Harbor are uncertain, but this species may be at the Indiana Harbor.

The Nonstructural Alternative is not expected to limit the movement of the fishhook waterflea outside of its current distribution.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Suitable habitats include estuarine habitats, lakes, marine habitats, water courses, and wetlands (NBII and ISSG 2010). Location appears to be variable: some studies found the species at higher densities in central regions of lakes compared with coastal areas (Ojaveer et al. 2001); however, this species is more likely to invade clear, large lakes (Muirhead et al. 2011). In Lake Michigan, the fishhook waterflea is confined largely to near-shore waters (Pichlova-Ptacnikova and Vanderploeg 2009). The species prefers to inhabit pelagic zones (Crosier and Molloy). The preferred temperature range for the fishhook waterflea is 16°C –26°C (60.8°F –78.8°F) (NBII and ISSG 2010), although studies have found a range of 3°C –38°C (37.4°F –100.4°F) (Gorokhova et al. 2000). The majority of individuals were found within the warm, uppermost 20-m (65.6-ft) water layer during both day and night (Ojaveer et al. 2001). Less than 3% of the population occurred at depths greater than 40 m (131 ft) (Ojaveer et al. 2001).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the fishhook waterflea in southern Lake Michigan.

T_{10}: See T_0. There are no predicted significant differences in habitat components along Lake Michigan in the near or foreseeable future that would affect the arrival of this species.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The species is established very close to the Indiana Harbor pathway entrance. Suitable habitat is present (section 2d). Given that the fishhook waterflea has been established in southern Lake Michigan since 1999 (Benson et al. 2012), this species may be at the pathway entrance.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by the fishhook waterflea. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of the fishhook waterflea at the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The fishhook waterflea has been documented to be close to the pathway entrance and may drift to the entrance of Indiana Harbor via current, vessel-mediated transport, or other human-mediated transport means.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The fishhook waterflea is planktonic and makes daily vertical migrations in the water column (Benson et al. 2012; NBII and ISSG 2010). Eggs are brooded until hatching, after which they are planktonic (NBII and ISSG 2010). As Makarewicz et al. (2001) point out, asexual reproduction, high fecundity, the production of resting eggs, a “sticky” caudal process, viability during unfavorable periods, and rapid dispersal all promote rapid population growth. However, although this species was first recorded in southern Lake Michigan in 1999, it has not been recorded in the Illinois River or the CAWS. No recent zooplankton surveys were found for these waterways; therefore, the species may be present but undetected. Once it enters Indiana Harbor, the fish-hook waterflea could move toward Brandon Road Lock and Dam with the natural downstream flow.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., passive drift) of the fishhook waterflea through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

The invasion of the fishhook waterflea in Lake Michigan during 1999 almost certainly resulted from the movement of contaminated Lake Ontario ballast water by commercial vessels. Although fishhook waterflea can be transported in ballast water (Benson et al. 2012), the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). Most commercial vessel traffic to Indiana Harbor is lake wise, and there is no commercial vessel traffic to inland ports in the CAWS from Indiana Harbor (NBIC 2012). There is little, if any, vessel traffic in the Grand Calumet River because of the shallow depth. Local dispersal mechanisms for the fishhook waterflea potentially include small boat traffic (Makarewicz et al. 2001). The fishhook waterflea was found on commercial vessel hull scrapes (Sylvester and MacIsaac 2010), so vessel transport is possible through the portions of the CAWS with vessel traffic.

Anti-fouling hull paints are a possible measure for controlling the fishhook waterflea on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of the fishhook waterflea through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: In lake studies, the fishhook waterflea was found mainly down to a depth of 20 m (65.6 ft) (Bielecka and Mudrak 2010). Deep (greater than 100 m [328 ft]) and shallow (less than 10 m [32.8 ft]) stations had significantly lower abundances of the fishhook waterflea than stations of intermediate depth (less than 100 m [328 ft]) (Gorokhova et al. 2000). The maximum depth in the CAWS is about 10 m (32.8 ft); depth is typically around 5 m (16.4 ft), with very shallow depths in the Grand Calumet River (LimnoTech 2010). Surface water is present year-round, and water depth is adequate throughout the CAWS (LimnoTech 2010).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The fishhook waterflea appears to prefer lentic systems, but it has also established in rivers; the species has successfully invaded the Rhine River (Cristescu et al. 2001). Low current velocity in the CAWS may be favorable because the fishhook waterflea is typically a lake species. However, water flows out of the Indiana Harbor into Lake Michigan. West of the Indiana Harbor Canal, the easternmost segment of the Grand Calumet River also generally flows toward Lake Michigan, while other sections can flow east or west, depending on location (Weiss et al. 1997). Thus, the fishhook waterflea would have to swim upstream to enter the CAWS and move to the Calumet Sag Channel. The preferred temperature range for the fishhook waterflea is 16°C–26°C (60.8°F–78.8°F) (NBII and ISSG 2010); although studies have found a range of 3°C–38°C (37.4°F–100.4°F) (Gorokhova et al. 2000). The water temperature in the CAWS averages from 11.3°C to 19.3°C (52.3°F to 66.7°F) (MWRD 2010). The fishhook waterflea is likely to invade low-turbidity water systems with NTUs ranging from 4.37–105.16 (Muirhead et al. 2011). The CAWS is turbid (LimnoTech 2010). Based on invaded lakes in the United States, the fishhook waterflea was found in waters with a DO range of 7.67–14.07 mg/L and pH of 7.32–8.39 (Muirhead et al. 2011). Annual mean DO in the CAWS typically exceeds 6 mg/L, although seasonal hypoxia may occur in portions of the CAWS (MWRD 2011).

The Nonstructural Alternative is not expected to affect habitat suitability for the fishhook waterflea in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating	Low	Low	Low	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: The fishhook waterflea is typically found in lakes, but it has invaded rivers as well (section 3d). Dispersal by human-mediated transport via ballast water is not possible through the Indiana Harbor because the passage is too shallow for vessels (section 3b). Depth in the CAWS may be shallower than this species prefers (section 3d). The CAWS is a turbid water system; the fishhook waterflea is only likely to invade low-turbidity water systems (section 3d). The fishhook waterflea is a zooplankton, and is not likely to swim upstream through Indiana Harbor and the Grand Calumet River. This species was first recorded in southern Lake Michigan in 1999, and it has not been recorded in the Illinois River (section 3a).

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by the fishhook waterflea. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of the fishhook waterflea through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the fishhook waterflea by downstream passive transport or hull fouling to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's low probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. The probability of passage is likely to increase with time. The fishhook waterflea may pass through the CAWS given 50 years.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's medium probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	High	High
Nonstructural Alternative Rating	Low	Low	High	High

Evidence for Uncertainty Rating

T_0: The depth and water quality suitability of the CAWS are uncertain (section 3d). The fishhook waterflea does not actively swim, and the upstream flow direction and lack of vessel transport in the Grand Calumet River would inhibit dispersal of this species to Brandon Road Lock and Dam (section 3d).

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains low.

T_{10}: See T_0.

T_{25}: See T_0. It is uncertain how long it would take the fishhook waterflea to pass upstream through Indiana Harbor and the Grand Calumet River or whether the species is capable of such movement.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains high.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 5

BURNS SMALL BOAT HARBOR (BSBH) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Low	Low	Low	Low	High	Medium	High
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Low	Low	Low	Low	High	Medium	High
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the BSBH and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative is not expected to impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The fishhook waterflea is planktonic and makes daily vertical migrations in the water column (Benson et al. 2012; NBII and ISSG 2010). Eggs are brooded until hatching, after which they are planktonic. The fishhook waterflea has a very rapid invasion speed. It spread to three Great Lakes within 2 years and inland to six of New York's Finger Lakes within 1 year (Sea Grant New York 2012). As Makarewicz et al. (2001) point out, asexual reproduction, high fecundity, production of resting eggs, a "sticky" caudal process, viability during unfavorable periods, and rapid dispersal promote rapid population growth.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS from natural dispersion (i.e., passive drift) through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

The 1999 invasion of Lake Michigan by the species almost certainly resulted from the movement of contaminated Lake Ontario ballast water by commercial vessels. Ships that discharge cargo at a Lake Ontario port will often load lake water as ballast prior to upbound movement on the Great Lakes. This water is subsequently discharged at the terminal port-of-call and replaced with cargo for the outbound voyage. The BSBH is not a port; therefore, vessels will not release ballast water at this pathway (USACE 2011a). There is no commercial vessel traffic from the Great Lakes to the BSBH; however, there is heavy commercial traffic to the adjacent Burns Harbor. The fishhook waterflea was also found on commercial vessel hull scrapes (Sylvester and MacIsaac 2010), so vessel transport may be possible. Local dispersal mechanisms potentially include small boat traffic (Makarewicz et al. 2001).

Anti-fouling hull paints are a possible measure for controlling the fishhook waterflea on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS from human-mediated transport through aquatic pathways.

c. Current Abundance and Reproductive Capacity

T_0: Female fishhook waterfleas reproduce parthenogenically during the summer and gametogenically later in the year (NBII and ISSG 2010). Following sexual reproduction, females produce one to four resting eggs, while parthenogenic females produce between one and 24 embryos (NBII and ISSG 2010). The species produces resting eggs any time during the year when environmental conditions become inhospitable (Benson et al. 2012). Resting eggs are resistant to desiccation, freeze drying, and ingestion by predators, and they replenish the population after hatching in the spring (Benson et al. 2012). Resting eggs can hatch regardless of whether the carrier female is alive or dead (Benson et al. 2012). In southern Lake Michigan, densities can reach more than 100 per m^2 during the late summer peak (Charlebois et al. 2001; Cavaletto et al. 2010; Witt et al. 2005).

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of the fishhook waterflea.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: The fishhook waterflea was established in Lake Michigan, north of Chicago, Illinois, in 1999 (Benson et al. 2012). The exact location and distance from the BSBH are uncertain, but this species may be at the BSBH.

The Nonstructural Alternative is not expected to limit the movement of the fishhook waterflea outside of its current distribution.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Suitable habitats include estuarine habitats, lakes, marine habitats, water courses, and wetlands (NBII and ISSG 2010). Location may be variable: some studies found the species at higher densities in central regions of lakes compared with coastal areas (Ojaveer et al. 2001); however, the species is more likely to invade clear, large lakes (Muirhead et al. 2011). In Lake Michigan, the fishhook waterflea is confined largely to near-shore waters (Pichlova-Ptacnikova and Vanderploeg 2009). The species does prefer to inhabit the pelagic zone (Crosier and Molloy). The preferred temperature range for the fishhook waterflea is 16°C–26°C (60.8°F–78.8°F) (NBII and ISSG 2010), although studies have found a range of 3°C–38°C (37.4°F–100°F) (Gorokhova et al. 2000). The majority of individuals were found within the warm, uppermost 20-m (65.6-ft) water layer during both day and night (Ojaveer et al. 2001). Less than 3% of the population occurred at depths greater than 40 m (131 ft) (Ojaveer et al. 2001).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the fishhook waterflea in southern Lake Michigan.

T_{10}: See T_0. There are no predicted significant differences in habitat components along Lake Michigan in the near or foreseeable future that would affect the arrival of this species.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The species is established very close to the BSBH pathway entrance (section 2e). Suitable habitat is present (section 2d). Given its time in southern Lake Michigan, this species may be at the pathway entrance.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by the fishhook waterflea. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of the fishhook waterflea at the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterflea at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The fishhook waterflea has been documented to be close to the pathway entrance and may drift to the entrance of the BSBH via current, vessel-mediated transport, or other human-mediated transport means.

The Nonstructural Alternative is not expected to affect the arrival of the fishhook waterfle at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

3. P(passage) T_0-T_{50}: LOW-MEDIUM

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The fishhook waterflea is planktonic and makes daily vertical migrations in the water column (Benson et al. 2012; NBII and ISSG 2010). Eggs are brooded until hatching, after which they are planktonic (NBII and ISSG 2010). As Makarewicz et al. (2001) point out, asexual reproduction, high fecundity, production of resting eggs, a “sticky” caudal process, viability during unfavorable conditions, and rapid dispersal promote rapid population growth. However, although this species was first recorded in southern Lake Michigan in 1999, it has not been recorded in the Illinois River or the CAWS. No recent zooplankton surveys were found for these waterways; therefore, the species may be present but undetected. Once it enters the BSBH, the fishhook waterflea could move toward Brandon Road Lock and Dam with the natural downstream flow.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., passive drift) of the fishhook waterflea through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

The species’ invasion of Lake Michigan during 1999 almost certainly resulted from the movement of contaminated Lake Ontario ballast water by commercial vessels. The discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). The South Branch of the Little Calumet River is shallow and likely has only local, non-motorized vessel traffic, if any (Little Calumet and Grand Calumet River Corridor Technical Advisory Group and Northeastern Illinois Planning Commission 2011). Although the fishhook waterflea could move to Burns Harbor (which does have commercial vessel traffic), there is no commercial vessel traffic from Burns Harbor to inland ports in the CAWS (NBIC 2012). Local dispersal mechanisms for the fishhook waterflea potentially include small boat traffic (Makarewicz et al. 2001). The fishhook waterflea was found on commercial vessel hull scrapes (Sylvester and MacIsaac 2010), so vessel transport is possible through portions of the CAWS with vessel traffic.

Anti-fouling hull paints are a possible measure for controlling the fishhook waterflea on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of the fishhook waterflea through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: In lake studies, the fishhook waterflea was found mainly down to a depth of 20 m (65.6 ft) (Bielecka and Mudrak 2010). Deep (greater than 100 m [328 ft]) and shallow (less than 10 m [32.8 ft]) stations had significantly lower abundances of the fishhook waterflea than stations of intermediate depth (less than 100 m [328 ft]) (Gorokhova et al. 2000). The maximum depth in the CAWS is about 10 m (32.8 ft); depth is typically about 5 m (16.4 ft) (LimnoTech 2010). Surface water is present year-round, and water depth is adequate throughout the CAWS (LimnoTech 2010).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: The fishhook waterflea appears to prefer lentic systems, but it has also established in rivers (Cristescu et al. 2001). Low current velocity in the CAWS may be favorable, because the fishhook waterflea is typically a lake species. However, the water flows out of the BSBH into Lake Michigan. The eastern segment of the South Branch of the Little calumet River also generally flows toward Lake Michigan, depending on location and water level in Lake Michigan (GSWMD 2008). Thus, the fishhook waterflea would have to move upstream to enter the CAWS and move to the Cal-Sag Channel. The preferred temperature range for the fishhook waterflea is 16°C–26°C (60.8°F–78.8°F) (NBII and ISSG 2010), although studies have found a range of 3°C–38°C (37.4–100°F) (Gorokhova et al. 2000). The water temperature in the CAWS averages from 11.3°C–19.3°C (52.3°F–66.7°F) (MWRD 2010). The fishhook waterflea is likely to invade low-turbidity water systems with NTU ranges of 4.37–105.16 (Muirhead et al. 2011). The CAWS is turbid (LimnoTech 2010). Based on invaded lakes in the United States, the fishhook waterflea was found in waters with a DO range of 7.67–14.07 mg/L and pH of 7.32–8.39 (Muirhead et al. 2011). Annual mean DO in the CAWS typically exceeds 6 mg/L, although seasonal hypoxia may occur in portions of the CAWS (MWRD 2011).

The Nonstructural Alternative is not expected to affect habitat suitability for the fishhook waterflea in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating	Low	Low	Low	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: The fishhook waterflea is typically found in lakes, although it has invaded rivers (section 3d). Depth in the CAWS may be shallower than this species prefers (section 3d). Suitable temperature is present for the fishhook waterflea in the CAWS (section 3d). The CAWS is a turbid water system; the fishhook waterflea is likely to invade only low-turbidity water systems (section 3a). This species was first recorded in southern Lake Michigan in 1999, and it has not been recorded in the Illinois River (section 3d). The fishhook waterflea is not likely to move upstream through the BSBH and the South Branch of the Little Calumet River. The lack of vessel traffic on the Little Calumet would limit the potential for human-mediated transport through the upstream flow.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by the fishhook waterflea. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of the fishhook waterflea through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport.

The alternative does not include measures to address the passage of the fishhook waterflea by downstream passive transport or hull fouling to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's low probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. The probability of passage is likely to increase with time. The fishhook waterflea may pass through the passage, given 50 years.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's medium probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	High	High
Nonstructural Alternative Rating	Low	Low	High	High

Evidence for Uncertainty Rating

T_0: The depth and water quality suitability of the CAWS are uncertain (section 3d). The fishhook waterflea does not actively swim, and the upstream flow direction and lack of vessel transport in the South Branch of the Little Calumet River would inhibit dispersal of this species to Brandon Road Lock and Dam (section 3d).

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains low.

T_{10}: See T_0.

T_{25}: See T_0. It is uncertain how long it would take the fishhook waterflea to pass upstream through the BSBH and the Little Calumet River or whether the species is capable of such movement.

The Nonstructural Alternative is not expected to affect the passage of the fishhook waterflea through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains high.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: LOW

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E.2.2.3.2 Bloody Red Shrimp (Hemimysis anomala)

NONSTRUCTURAL ALTERNATIVE

This alternative would potentially include the implementation of a combination of the following measures that can be implemented at time step 0 (T_0, in units of years) by local, state, and federal agencies and the public. The Nonstructural Alternative would include the development of a monitoring and response program.

Nonstructural Alternative Measures for the Bloody Red Shrimp

Option or Technology	Description
Education & Outreach	• Signage, pamphlets, brochures on how to identify reducing aquatic nonindigenous species (ANS) and control the spread of ANS; promote national campaigns (i.e., "Stop Aquatic Hitchhikers") • Education of recreational waterway users
Ballast/Bilge-water Exchange	• Ballast/Bilge-water exchange
Monitoring	• Agency monitoring • Voluntary occurrence reporting
Laws & Regulations	• FWS Lacey Act listing • Mandatory watercraft inspection and decontamination

PATHWAY 1

WILMETTE PUMPING STATION (WPS) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)[a]	High	Low	High	Low	High	Low	High	Low
P(spreads)[a]	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between WPS and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not affect the pathway for the bloody red shrimp.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Bloody red shrimp is benthic and planktonic and makes daily vertical migrations in the water column (Kipp et al. 2011). Rapid growth and maturation facilitate the establishment of bloody red shrimp in new habitats (Pothoven et al. 2007). The species can naturally disperse through canals and river systems (Ricciardi et al. 2011). The species has a limited natural dispersal capacity, because it is an egg brooder (eggs are carried by adults, not free-floating) and can hardly swim upstream (Audzijonyte et al. 2008). It was reported for the first time in 2006 from Lake Ontario and from a channel connecting Muskegon Lake to Lake Michigan, and is now well distributed throughout at least four of the Great Lakes (Marty et al. 2010; Kipp et al. 2011).

The Nonstructural Alternative is not expected to affect the arrival of the bloody red at the CAWS shrimp from natural dispersion (i.e., swimming and passive drift) through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Vessel transport is the primary dispersal mechanism in the spread of bloody red shrimp. Initially, the species spread by intentional transfer to freshwater bodies within the former Soviet Union. More recently, it has spread unintentionally by shipping through rivers and canals, and in ballast water (Kipp et al. 2011). The species spread from Europe to the United Kingdom in less than 10 years via shipping (Ricciardi et al. 2011). The highest risk transport vector is ballast water movement (Reid et al. 2007). The vast majority of ballast water discharged at the CAWS ports along Lake Michigan is from other ports in all of the Great Lakes (NBIC 2012). WPS is not a port; therefore vessels will not release ballast water at this pathway. There is recreational but not commercial vessel traffic to the WPS from Lake Michigan (USACE 2011a,b). WPS is not a port with cargo vessel use; however, there is recreational boat use in the Wilmette Harbor that could potentially transport this species from locations within Lake Michigan to the WPS pathway.

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS from human-mediated transport through aquatic pathways.

c. Current Abundance and Reproductive Capacity

T_0: The species breeds from April to September/October (Kipp et al. 2011). Sexual maturity occurs in less than 45 days (Kipp et al. 2011). Females become ovigerous at 8–9°C (46.4–48.2°F) and produce two to four broods per year (Kipp et al. 2011). Brood size is correlated with female length and ranges from 6 to 70 embryos per individual (Ketelaars et al. 1999; Salemaa & Hietalahti 1993; Borcherding et al. 2006). Bloody red shrimp's relatively low fecundity (Ketelaars et al. 1999) suggests that it may have been present in the Great Lakes for a few years before being discovered.

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of the bloody red shrimp.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers; the species is likely already at the pathway.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: The species is established in Lake Michigan. The U.S. Geological Survey (USGS) documented the species one nautical mile (1.6 km) offshore of Jackson Harbor in 2007 and just south of Waukegan Harbor a half mile (0.8 km) offshore in 2006 (Kipp et al. 2011). Scientists believe the species has a wider distribution but has not been previously reported, because people either did not recognize it or simply did not see it. Bloody red shrimp are difficult to locate because they are nocturnal, preferring to hide in rocky cracks and crevices near the bottom along the shoreline during the day (Reid et al. 2007).

The Nonstructural Alternative is not expected to limit the movement of the bloody red shrimp outside of its current distribution.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Bloody red shrimp are normally found in lentic waters, although the bloody red shrimp has successfully established in European rivers (Kipp et al. 2011). The species prefers slow-moving waters, but has been found along rocky, wave-exposed shorelines (NOAA 2007). It inhabits a broad range of depths (Ricciardi et al. 2011), from 0.5–50 m (1.64–164 ft), although the species generally inhabits waters 6–10 m (19.7–32.8 ft) deep (Kipp et al. 2011). Water flow may limit the expansion of the organism; sampled areas where the bloody red shrimp was present had velocities ranging from 0–0.8 m/s (0–2.62 ft/s) (Marty 2007). The species prefers a temperature range of 9–20°C (48.2–68°F) (Marty 2007) and is mainly found near shore (Walsh et al. 2010). The species is less abundant or scarce in areas of dense vegetation or high siltation (Kipp et al. 2011; Wittmann & Ariani 2009). It occurs most frequently on hard bottom substrates including rocks; less frequently on sand, silt, or mud; and least frequently in the soft bottom profundal (Pothoven et al. 2007). Swarms are often found in shaded areas near piers and jetties (Ricciardi et al. 2011). During daylight hours, swarms may hide in rock crevices, boulders, piers, and jetties (Kipp et al. 2011). The bloody red shrimp can tolerate a broad range of physicochemical conditions (Ricciardi 2011).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the bloody red shrimp in southern Lake Michigan.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: There is a known establishment of bloody red shrimp less than 32 km (20 mi) from the WPS (section 2e). The rocky shoreline of the WPS is suitable habitat (section 2f). The species is documented to have a rapid invasion rate and the ability to disperse through the Great Lakes (section 2a). Human-mediated transport is not likely needed for the species to arrive at the WPS (section 2b). The bloody red shrimp has likely arrived at the WPS but has not yet been detected (section 2e).

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The species was identified as established in Lake Michigan in 2007 (Kipp et al. 2011). It has not yet been identified at WPS; however, whether the species has already arrived is unknown. Concealment behavior makes bloody red shrimp difficult to locate during the day, possibly explaining why it was not found earlier in the Great Lakes (section 2e).

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.

T_{10}: See T_0. The species may be at the pathway entrance. The species' nocturnal behavior inhibits its detection.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Bloody red shrimp is benthic and planktonic and makes daily vertical migrations in the water column (Kipp et al. 2011). Bloody red shrimp can disperse through canals and river systems (Ricciardi et al. 2011). They are documented to have spread from eastern European rivers to western European rivers and to the United Kingdom in less than a decade (Ricciardi et al. 2011). Rapid growth and maturation facilitate its establishment in new habitats (Pothoven et al. 2007).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the bloody red shrimp through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the bloody red shrimp as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Historically, the species has been transported via ballast water (Reid et al. 2007). However, there is no commercial vessel traffic into the North Shore Channel (USACE 2011a); therefore, some natural downstream dispersal would likely be required for the bloody red shrimp to reach Brandon Road Lock and Dam. There is vessel traffic from the Chicago River to the Brandon Road Lock and Dam that could transport this species. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the bloody red shrimp into the CAWS. The water is directed through the North Shore Channel, the Chicago River and the Calumet River.

The Nonstructural Alternative is not expected to address the human-mediated transport of the bloody red shrimp through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: The sluice gate at the WPS is a barrier that could retard natural dispersion. However, water is pumped from Lake Michigan into the North Shore Channel, which could transport the species. The maximum depth in the CAWS is about 10 m (32.8 ft) and depth is typically around 5 m (16.4 ft) (LimnoTech 2010). The bloody red shrimp inhabits a broad range of depths from 0.5–50 m (1.64–164 ft) (Ricciardi et al. 2011), although it generally inhabits waters 6–10 m (19.7–32.8 ft) in depth.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The bloody red shrimp prefers slow-moving waters but has been found along rocky, wave-exposed shorelines (NOAA 2007). The species has been identified in water currents of 0–0.8 m/s (0–2.62 ft/s) velocity (Marty 2007). Most flows in the CAWS were lower than 0.15 m/s (0.49 ft/s); the highest was 0.27 m/s (0.89 ft/s) (LimnoTech 2010). The habitat in the CAWS consists of mostly (about 75%) manmade waterways, which are designed to be straight and deep. The species prefers water temperatures of 9–20°C (48.2–68°F) (Kipp et al. 2011). The water temperature in the CAWS averages from 11.3–19.3°C (52.3–66.7°F) (MWRD 2010). The banks of the CAWS are typically a mix of stone blocks, steel sheet piling, and earthen banks with vegetation. Riprap banks are common throughout the CAWS. In the North Shore Channel and the upper North Branch of the Chicago River in-stream there are partly shaded banks with aquatic plants, tree roots, and brush debris jams, and sediments are silt and sand (LimnoTech 2010). Toward downtown Chicago and in the Chicago River there is a reduction in in-stream habitat and a change to concrete and steel vertical banks, with sediments of concrete, silt, or sludge. Toxic organic and inorganic pollutants are also present in the Chicago River (Gallagher et al. 2011). The Chicago Sanitary and Ship Canal has banks of bedrock and steel sheet piling leading to the Des Plaines River, which should be ideal habitat. Sediments in the CAWS can range from bedrock to soft sediment (LimnoTech 2010). The bloody red shrimp occurs most frequently on hard bottom substrates including rocks; less frequently on sand, silt, or mud; and least frequently in the soft bottom profundal (Pothoven et al. 2007). The species is less abundant or scarce in areas of dense vegetation or high siltation (Kipp et al. 2011; Wittmann and Ariani 2009). During daylight hours, swarms may hide in rock crevices, boulders, piers, and jetties (Kipp et al. 2011; Ricciardi et al. 2011). The concealment behavior of the species indicates a preference for slow-moving waters (Marty 2007). Swarms are often found in shaded areas near piers and jetties (Ricciardi 2011). The bloody red shrimp can tolerate a broad range of physicochemical conditions (Ricciardi 2011).

The Nonstructural Alternative is not expected to affect habitat suitability for the bloody red shrimp in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**

No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Water is pumped from Lake Michigan into the North Shore Channel, which could transport bloody red shrimp into the CAWS (section 3c). Natural dispersal would likely be required to move through the North Shore Channel (section 3b). The riparian banks of the North Shore Channel are not the ideal hard substrate habitat for the species; however, suitable habitat is present in most of the CAWS (section 3d). This species spread across several European rivers in less than a decade (section 3a).

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the bloody red shrimp by the Lake Michigan diversion or the downstream passive transport of the bloody red shrimp to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Low	Low	Low
Nonstructural Alternative Rating	Medium	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The downstream flow would assist the species in reaching suitable habitat. The potential for transport on boat hulls is uncertain. This species is documented to rapidly spread through canals (section 3a). However, the rate of spread through the CAWS is unknown.

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0. The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains low.
T_{25}: See T_{10}.
T_{50}: See T_{10}.

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. **P(spreads) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 2

CHICAGO RIVER CONTROLLING WORKS (CRCW) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)[a]	High	Low	High	Low	High	Low	High	Low
P(spreads)[a]	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the CRCW and Brandon Road Lock and Dam over the next 50 years. The Nonstructural Alternative does not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Bloody red shrimp is benthic and planktonic and makes daily vertical migrations in the water column (Kipp et al. 2011). Rapid growth and maturation facilitate the establishment of bloody red shrimp in new habitats (Pothoven et al. 2007). The species can naturally disperse through canals and river systems (Ricciardi et al. 2011). The species has a limited natural dispersal capacity, because it is an egg brooder (eggs are carried by adults, not free-floating) and can hardly swim upstream (Audzijonyte et al. 2008). Bloody red shrimp makes daily migrations in the water column. It was reported for the first time in 2006 from Lake Ontario and a channel connecting Muskegon Lake to Lake Michigan, and is now well distributed throughout at least four of the Great Lakes (Marty et al. 2010; Kipp et al. 2011).

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS from natural dispersion (i.e., swimming and passive drift) through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Vessel transport is the primary dispersal mechanism in the spread of bloody red shrimp. Initially, the species spread by intentional transfer to freshwater bodies within the former Soviet Union. More recently, it has spread unintentionally by shipping through rivers and canals, and in ballast water (Kipp et al. 2011). The species spread from Europe to the United Kingdom in less than 10 years via shipping (Ricciardi et al. 2011). There is commercial and recreational vessel traffic to the CRCW from the Great Lakes (USACE 2011a), and many of these boats discharge ballast water from other ports in the Great Lakes (NBIC 2012). Commercial and recreational vessel traffic could transport this species from locations within Lake Michigan to the CRCW pathway.

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS from human-mediated transport through aquatic pathways.

c. Current Abundance and Reproductive Capacity

T_0: The species breeds from April to September/October (Kipp et al. 2011). Sexual maturity occurs in less than 45 days (Kipp et al. 2011). Females become ovigerous at 8–9°C (46.4–48.2°F) and produce two to four broods per year (Kipp et al. 2011).

Brood size is correlated with female length and ranges from 6 to 70 embryos per individual (Ketelaars et al. 1999; Salemaa & Hietalahti 1993; Borcherding et al. 2006). Bloody red shrimp's relatively low fecundity (Ketelaars et al. 1999) suggests that it may have been present in the Great Lakes for a few years before being discovered.

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of the bloody red shrimp.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers; the species is likely already at pathway.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: The species is established in Lake Michigan. The USGS documented the species one nautical mile (1.6 km) offshore of Jackson Harbor in 2007 and just south of Waukegan Harbor a half mile (0.8 km) offshore in 2006 (Kipp et al. 2011). Scientists believe the species has a wider distribution but its presence has not been previously reported because people either did not recognize it or simply did not see it. Bloody red shrimp are difficult to locate because they are nocturnal, preferring to hide in rocky cracks and crevices near the bottom along the shoreline during the day (Reid et al. 2007).

The Nonstructural Alternative is not expected to limit the movement of the bloody red shrimp outside of its current distribution.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: This species is normally found in lentic waters, although the bloody red shrimp has successfully established in European rivers (Kipp et al. 2011). It prefers slow-moving waters, but has been found along rocky, wave-exposed shorelines (NOAA 2007). Bloody red shrimp inhabit a broad range of depths (Ricciardi et al. 2011) from 0.5–50 m (1.64 to 164 ft) (Kipp et al. 2011), although they generally inhabit waters 6–10 m deep (19.7–32.8 ft) (Kipp et al. 2011). Water flow may limit expansion of the organism; sampled areas where bloody red shrimp was present had velocities ranging from 0–0.8 m/s (0–2.62 ft/s) (Marty 2007). The species prefers temperature ranges of 9–20°C (48.2–68°F) (Marty 2007) and is mainly found near shore (Walsh et al. 2010). The species is less abundant or scarce in areas of dense vegetation or high siltation (Kipp et al. 2011). It occurs most frequently on hard bottom substrates including rocks; less frequently on sand, silt, or mud; and least frequently in the soft bottom profundal (Pothoven et al. 2007). Swarms are often found in shaded areas near piers and jetties (Ricciardi et al. 2011). During daylight hours, swarms may hide in rock crevices, boulders, piers, and jetties (Kipp et al. 2011). The bloody red shrimp can tolerate a broad range of physicochemical conditions (Ricciardi et al. 2011).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the bloody red shrimp in southern Lake Michigan.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: There is a known establishment of the species less than 32.2 km (10 mi) from CRCW near Jackson Harbor (section 2e). The piers and hard structures at the CRCW are ideal habitat (section 2f). The bloody red shrimp is documented to have a rapid invasion rate and the ability to disperse through the Great Lakes (section 2a). Human-mediated transport is not likely needed for the species to arrive at CRCW (section 2b) but may occur due to the high vessel traffic from the GL into the Chicago River (USACE 2011b). The bloody red shrimp has likely arrived at the CRCW but has not yet been detected (section 2e). The species is capable of passively drifting to the pathway if it hasn't arrived already.

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The species was identified as established in Lake Michigan in 2007 (Kipp et al. 2011). It has not yet been identified at the CRCW; however, whether the species has already arrived at the harbor is unknown. Concealment behavior makes the bloody red shrimp difficult to locate during the day, possibly explaining why it was not found earlier in the Great Lakes (section 2e).

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.

T_{10}: See T_0. The species may be at the pathway entrance. The species' nocturnal behavior inhibits its detection.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

3. P(passage) T_0-T_{50} : HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Bloody red shrimp is benthic and planktonic and makes daily vertical migrations in the water column (Kipp et al. 2011). The bloody red shrimp can disperse through canals and river systems (Ricciardi et al. 2011). They are documented to have spread from eastern European to western European rivers and to the United Kingdom in less than a decade (Ricciardi et al. 2011). Rapid growth and maturation rates facilitate its establishment in new habitats (Pothoven et al. 2007).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the bloody red shrimp through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the bloody red shrimp as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Historically, the species has been transported via ballast water (Reid et al. 2007). There is cargo vessel traffic between the CRCW and Brandon Road Lock and Dam (USACE 2011a). Ballast water is rarely discharged in inland ports of Illinois (NBIC 2012). The CRCW is heavily utilized by recreational, commercial, and cargo vessels. Based on averaging 2000 through 2010 data, the CRCW saw an average of 711,902 commercial passenger one-way trips and 41,071 non-cargo vessel one-way trips (USACE 2011b). In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the bloody red shrimp into the CAWS. The water is directed through the North Shore Channel, the Chicago River and the Calumet River.

The Nonstructural Alternative is not expected to address the human-mediated transport of the bloody red shrimp through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: There are no existing barriers. The maximum depth in the CAWS is about 10 m (32.8 ft) and depth is typically around 5 m (16.4 ft) (LimnoTech 2010). The bloody red shrimp inhabits a broad range of depths from 0.5 to 50 m (1.64–164 ft) (Ricciardi et al. 2011), although it generally inhabits waters 6–10 m (19.7–32.8 ft) deep.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: The bloody red shrimp prefers slow-moving waters but has been found along rocky, wave-exposed shorelines (NOAA 2007). The species has been identified in water currents of 0–0.8 m/s (0–2.62 ft/s) velocity (Marty 2007). Most flows in the CAWS were less than 0.15 m/s (0.49 ft/s); the highest was 0.27 m/s (0.89 ft/s) (LimnoTech 2010). The habitat in the CAWS consists of mostly (about 75%) manmade waterways, which are designed to be straight and deep. The species prefers water temperatures of 9–20°C (48.2–68°F) (Kipp et al. 2011). The water temperature in the CAWS averages from 11.3 to 19.3°C (52.3–66.7°F) (MWRD 2010). The banks of the CAWS are typically a mix of stone blocks, steel sheet piling, and earthen banks with vegetation. Riprap banks are common throughout the CAWS. In the Chicago River there is little in-stream habitat and the banks are typically concrete and steel vertical walls, with sediments of concrete, silt, or sludge (LimnoTech 2010). Toxic organic and inorganic pollutants are also present in the Chicago River (Gallagher et al. 2009). The CSSC has banks of concrete and steel sheet piling leading to the Des Plaines River, which should be ideal habitat. Sediments in the CAWS can range from bedrock to soft sediment (LimnoTech 2010). The bloody red shrimp occurs most frequently on hard bottom substrates including rocks; less frequently on sand, silt, or mud; and least frequently in the soft bottom profundal (Pothoven et al. 2007). The species is less abundant or scarce in areas of dense vegetation or high siltation (Kipp et al. 2011). During daylight hours, swarms may hide in rock crevices, boulders, piers, and jetties (Kipp et al. 2011; Ricciardi et al. 2011). The concealment behavior of the species indicates a preference for slow-moving waters (Marty 2007). The bloody red shrimp can tolerate a broad range of physicochemical conditions (Ricciardi et al. 2011).

The Nonstructural Alternative is not expected to affect habitat suitability for the bloody red shrimp in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: This species spread across several European rivers in less than a decade (section 3a). Suitable habitat is present in the CAWS (section 3d). Since the passage through the harbor is open water, the bloody red shrimp may be able to drift through the pathway with the current as documented in literature (section 3a).

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the bloody red shrimp by the Lake Michigan diversion or the downstream passive transport of the bloody red shrimp to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Low	Low	Low
Nonstructural Alternative Rating	Medium	Low	Low	Low

Evidence for Uncertainty Rating

T_0: There is heavy vessel traffic in the CAWS; however, the probability of hull fouling transport is not documented. This species is documented to rapidly spread through canals (section 3a). However, the rate of spread through the CAWS is uncertain.

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.
T_{10}: See T_0. Given time to naturally disperse, the bloody red shrimp is likely to pass through the pathway during this time step.

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the uncertainty remains low.

T_{25}: See T_{10}.
T_{50}: See T_{10}.

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. **P(spreads) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 3

CALUMET HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)[a]	High	Low	High	Low	High	Low	High	Low
P(spreads)[a]	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Calumet Harbor and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative is not expected to affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Bloody red shrimp is benthic and planktonic and makes daily vertical migrations in the water column (Kipp et al. 2011). Rapid growth and maturation facilitate the establishment of bloody red shrimp in new habitats (Pothoven et al. 2007). The species can naturally disperse through canals and river systems (Ricciardi et al. 2011). The species has a limited natural dispersal capacity, because it is an egg brooder (eggs are carried by adults, not free-floating) and can hardly swim upstream (Audzijonyte et al. 2008). Bloody red shrimp makes daily migrations in the water column. It was reported for the first time in 2006 from Lake Ontario and from a channel connecting Muskegon Lake to Lake Michigan, and is now well distributed throughout at least four of the Great Lakes (Marty et al. 2010; Kipp et al. 2011).

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS from natural dispersion (i.e., swimming and passive drift) through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Vessel transport is the primary dispersal mechanism in the spread of bloody red shrimp. Initially, the species spread by intentional transfer to freshwater bodies within the former Soviet Union. More recently, it has spread unintentionally by shipping through rivers and canals, and in ballast water (Kipp et al. 2011). It spread from Europe to the United Kingdom in less than 10 years via shipping (Ricciardi et al. 2011). The highest risk transport vector is ballast water movement (Reid et al. 2007). There is heavy commercial vessel traffic to Calumet Harbor from Lake Michigan (USACE 2011a), and many of these boats discharge ballast water from other ports in the Great Lakes (NBIC 2012). Recreational and commercial vessels could potentially transport this species to the Calumet Harbor pathway if it hasn't arrived already.

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS from human-mediated transport through aquatic pathways.

c. Current Abundance and Reproductive Capacity

T_0: The species breeds from April to September/October (Kipp et al. 2011). Sexual maturity occurs in less than 45 days (Kipp et al. 2011). Females become ovigerous at 8–9°C (46.4–48.2°F) and produce two to four broods per year (Kipp et al. 2011). Brood size is correlated with female length and ranges from 6 to 70 embryos per individual (Ketelaars et al. 1999; Salemaa & Hietalahti 1993; Borcherding et al. 2006). Bloody red shrimp's relatively low fecundity (Ketelaars et al. 1999) suggests that it may have been present in the Great Lakes for a few years before being discovered.

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of the bloody red shrimp.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. *Existing Physical Human/Natural Barriers*

T_0: There are no existing barriers; the species is likely already at the pathway.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. *Distance from Pathway*

T_0: The species is established in Lake Michigan. The USGS documented the species one nautical mile (1.6 km) offshore of Jackson Harbor in 2007 and just south of Waukegan Harbor a half mile (0.8 km) offshore in 2006 (Kipp et al. 2011). Scientists believe the species has a wider distribution, but its presence has not been previously reported because people either did not recognize it or simply did not see it. Bloody red shrimp are difficult to locate because they are nocturnal, preferring to hide in rocky cracks and crevices near the bottom along the shoreline during the day (Reid et al. 2007).

The Nonstructural Alternative is not expected to limit the movement of the bloody red shrimp outside of its current distribution.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: Bloody red shrimp are normally found in lentic waters, although the bloody red shrimp has successfully established in European rivers (Kipp et al. 2011). The species prefers slow-moving waters, but has been found along rocky, wave-exposed shorelines (NOAA 2007). It inhabits a broad range of depths from 0.5–50 m (1.64–164 ft) (Ricciardi et al. 2011), although the species generally inhabits waters 6–10 m (19.7–32.8 ft) in depth (Kipp et al. 2011). Water flow may limit expansion of the organism; sampled areas where the bloody shrimp was present had velocities ranging from 0 to 0.8 m/s (0–2.62 ft/s) (Marty 2007). The species prefers a temperature range of 9–20°C (48.2–68°F) (Marty 2007) and is mainly found near shore (Walsh et al. 2010). The species is less abundant or scarce in areas of dense vegetation or high siltation (Kipp et al. 2011; Wittmann & Ariani 2009). It occurs most frequently on hard bottom substrates including rocks; less frequently on sand, silt, or mud; and least frequently in the soft bottom profundal (Pothoven et al. 2007). Swarms are often found in shaded areas near piers and jetties (Ricciardi et al. 2011). During daylight hours, swarms may hide in rock crevices, boulders, piers, and jetties (Kipp et al. 2011). The bloody red shrimp can tolerate a broad range of physicochemical conditions (Ricciardi et al. 2011).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the bloody red shrimp in southern Lake Michigan.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: There is a known establishment of the species less than 32.2 km (10 mi) from Calumet Harbor near Jackson Harbor (section 2e). The rocky shores surrounding Calumet Harbor are ideal habitat (section 2f). The bloody red shrimp is documented to have a rapid invasion rate and the ability to disperse through the Great Lakes (section 2a). Human-mediated transport is not likely needed for the species to arrive at Calumet Harbor (section 2b). Bloody red shrimp may have already arrived at Calumet Harbor but not yet been detected (section 2e).

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The species was identified as established in Lake Michigan in 2007 (Kipp et al. 2011). It has not yet been identified at Calumet Harbor; however, whether the species has already arrived at the harbor is unknown. Concealment behavior makes the bloody red shrimp difficult to locate during the day, possibly explaining why it was not found earlier in the Great Lakes (section 2e).

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.
T_{10}: See T_0. The species may be at the pathway entrance. The species' nocturnal behavior inhibits its detection.
T_{25}: See T_{10}.
T_{50}: See T_{10}.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Bloody red shrimp is benthic and planktonic and makes daily vertical migrations in the water column (Kipp et al 2011). Bloody red shrimp can disperse through canals and river systems (Ricciardi et al. 2011). They are documented to have spread from eastern European to western European rivers and to the United Kingdom in less than a decade (Ricciardi et al. 2011). Rapid growth and maturation facilitate its establishment in new habitats (Pothoven et al. 2007).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the bloody red shrimp through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the bloody red shrimp as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

Historically, the species has been transported via ballast water (Reid et al. 2007). Commercial vessel traffic to Calumet Harbor is lakewise (NBIC 2012), but there is heavy commercial vessel traffic between Brandon Road Lock and Dam and T.J. O'Brien Lock and Dam, which is approximately 8 km (5 mi) south of Calumet Harbor (USACE 2011a; NBIC 2012). Although bloody red shrimp can be transported in ballast water (Kipp et al. 2011), the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). Evidence for the transport of the species on boat hulls was not found in the literature. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the bloody red shrimp into the CAWS. The water is directed through the North Shore Channel, the Chicago River and the Calumet River.

The Nonstructural Alternative is not expected to address the human-mediated transport of the bloody red shrimp through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers. The typical depth in the CAWS is around 5 m (16.4 ft), with the maximum depth at about 10 m (32.8 ft) (LimnoTech 2010). The bloody red shrimp inhabits a broad range of depths from 0.5–50 m (1.64–164 ft)

(Ricciardi et al. 2011), although it generally inhabits waters 6–10 m (19.7–32.8 ft) deep (Kipp et al. 2011).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The bloody red shrimp prefers slow-moving waters but has been found along rocky, wave exposed shorelines (NOAA 2007). The species has been identified in water currents with velocities of 0–0.8 m/s (0–2.62 ft/s) (Marty 2007). Most flows in the CAWS were less than 0.15 m/s (0.49 ft/s), with the highest at 0.27 m/s (0.89 ft/s) (LimnoTech 2010). The habitat in the CAWS consists of mostly (about 75%) manmade waterways, which are designed to be straight and deep. The species prefers water temperatures of 9–20°C (48.2–68°F) (Kipp et al. 2011). The water temperature in the CAWS averages from 11.3 to 19.3°C (52.3–66.7°F) (MWRD 2010). The banks of the CAWS are typically a mix of stone blocks, steel sheet piling, and earthen banks with vegetation. Riprap banks are common throughout the CAWS. In the Calumet River there is in-stream habitat for aquatic life in the form of boulders, logs, brush debris jams, overhanging terrestrial vegetation, and aquatic vegetation in some reaches. Urban industrial and commercial riparian land use is also present. Sediments in the Little Calumet River are primarily inorganic silt, but areas of sand and gravel are also present (LimnoTech 2010). The Calumet Sag Channel and Chicago Sanitary and Ship Canal have banks of bedrock and steel sheet piling leading to the Des Plaines River, which should be ideal habitat. Sediments in the CAWS can range from bedrock to soft sediment (LimnoTech 2010). The bloody red shrimp occurs most frequently on hard bottom substrates including rocks; less frequently on sand, silt, or mud; and least frequently in the soft bottom profundal (Pothoven et al. 2007). The species is less abundant or scarce in areas of dense vegetation or high siltation (Kipp et al. 2011; Wittmann & Ariani 2009). During daylight hours, swarms may hide in rock crevices, boulders, piers, and jetties (Kipp et al. 2011; Ricciardi et al. 2011). The concealment behavior of the species indicates a preference for slow-moving waters (Marty 2007). Swarms are often found in shaded areas near piers and jetties (Ricciardi et al. 2011). The bloody red shrimp can tolerate a broad range of physicochemical conditions (Ricciardi et al. 2011).

The Nonstructural Alternative is not expected to affect habitat suitability for the bloody red shrimp in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High

Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Cargo vessel traffic from T.J. O'Brien Lock and Dam south of Calumet Harbor may transport the species through the CAWS to Brandon Road Lock and Dam (section 3c). This species spread across several European rivers in less than a decade (section 3a). Suitable habitat is present in the CAWS (section 3d). Since the passage through the harbor is open water, the bloody red shrimp may be able to drift through the pathway with current as documented in literature (section 3a).

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the bloody red shrimp by the Lake Michigan diversion or the downstream passive transport of the bloody red shrimp to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Low	Low	Low
Nonstructural Alternative Rating	Medium	Low	Low	Low

Evidence for Uncertainty Rating

T_0: There is heavy vessel traffic in the CAWS; however, the probability and speed of vessel transport in the CAWS for bloody red shrimp is not documented. This species is documented to rapidly spread through canals (section 3a). However, the rate of spread through the CAWS is uncertain.

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0. Given time to naturally disperse, the bloody red shrimp is likely to pass through the pathway during this time step.

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the uncertainty remains low.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 4

INDIANA HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Low	Low	Low	Medium	High	High	High
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Low	Low	Low	Medium	High	High	High
P(colonizes)[a]	High	Low	High	Low	High	Low	High	Low
P(spreads)[a]	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Indiana Harbor and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative is not expected to affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Bloody red shrimp is benthic and planktonic and makes daily vertical migrations in the water column (Kipp et al. 2011). Rapid growth and maturation facilitate the establishment of bloody red shrimp in new habitats (Pothoven et al. 2007). The species can naturally disperse through canals and river systems (Ricciardi et al. 2011). The species has a limited natural dispersal capacity, because it is an egg brooder (eggs are carried by adults, not free-floating) and can hardly swim upstream (Audzijonyte et al. 2008). Bloody red shrimp makes daily migrations in the water column. It was reported for the first time in 2006 from Lake Ontario and from a channel connecting Muskegon Lake to Lake Michigan, and is now well distributed throughout at least four of the Great Lakes (Marty et al. 2010; Kipp et al. 2011).

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS from natural dispersion (i.e., swimming and passive drift) through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Vessel transport is the primary dispersal mechanism in the spread of bloody red shrimp. Initially, the species spread by intentional transfer to freshwater bodies within the former Soviet Union. More recently, it has spread unintentionally by shipping through rivers and canals, and in ballast water (Kipp et al. 2011). The species spread from Europe to the United Kingdom in less than 10 years via shipping (Ricciardi et al. 2011). The highest risk transport vector is ballast water movement (Reid et al. 2007). There is commercial vessel traffic to the Indiana Harbor from the Great Lakes (USACE 2011a), and many of these boats discharge ballast water from other ports in the Great Lakes (NBIC 2012). These vessels could potentially transport the species to the Indiana Harbor pathway.

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS from human-mediated transport through aquatic pathways.

c. Current Abundance and Reproductive Capacity

T_0: The species breeds from April to September/October (Kipp et al. 2011). Sexual maturity occurs in less than 45 days (Kipp et al. 2011). Females become ovigerous at 8–9°C (46.4–48.2°F) and produce two to four broods per year (Kipp et al. 2011). Brood size is correlated with female length and ranges from 6 to 70 embryos per individual (Ketelaars et al. 1999; Salemaa & Hietalahti 1993; Borcherding et al. 2006). Bloody red shrimp's relatively low fecundity (Ketelaars et al. 1999) suggests that it may have been present in the Great Lakes for a few years before being discovered.

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of the bloody red shrimp.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers; the species is likely already at pathway.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: The species is established in Lake Michigan. The USGS documented the species one nautical mile (1.6 km) offshore of Jackson Harbor in 2007 and just south of Waukegan Harbor a half mile (0.8 km) offshore in 2006 (Kipp et al. 2011). Scientists believe the species has a wider distribution, but its presence has not been previously reported because people either did not recognize it or simply did not see it. Bloody red shrimp are difficult to locate because they are nocturnal, preferring to hide in rocky cracks and crevices near the bottom along the shoreline during the day (Reid et al. 2007).

The Nonstructural Alternative is not expected to limit the movement of the bloody red shrimp outside of its current distribution.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The species is normally found in lentic waters, although the bloody red shrimp has successfully established in European rivers (Kipp et al. 2011). It prefers slow-moving waters, but has been found along rocky, wave-exposed shorelines (NOAA 2007). The species inhabits a broad range of depths (Ricciardi et al. 2011) from 0.5–50 m (1.64–164 ft) (Kipp et al. 2011), although it generally inhabits waters 6–10 m deep (19.7–32.8 ft) (Kipp et al. 2011). Water flow may limit the expansion of the organism; sampled areas where the bloody red shrimp was present had flow rates with velocities of 0–0.8 m/s (0–2.62 ft/s) (Marty 2007). The species prefers temperature ranges of 9–20°C (48.2–68°F) (Marty 2007) and is mainly found near shore (Walsh et al. 2010). The species is less abundant or scarce in areas of dense vegetation or high siltation (Kipp et al. 2011). It occurs most frequently on hard bottom substrates including rocks; less frequently on sand, silt, or mud; and least frequently in the soft bottom profundal (Pothoven et al. 2007). Swarms are often found in shaded areas near piers and jetties (Ricciardi et al. 2011). During daylight hours, swarms may hide in rock crevices, boulders, piers, and jetties (Kipp et al. 2011). The bloody red shrimp can tolerate a broad range of physicochemical conditions (Ricciardi et al. 2011).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the bloody red shrimp in southern Lake Michigan.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: There is a known establishment of the species less than 24.1 km (15 mi) from Indiana Harbor near Jackson Harbor, Illinois, (section 2e). The rock or hard shoreline around Indiana Harbor is ideal habitat (section 2f). The bloody red shrimp is documented to have a rapid invasion rate and the ability to disperse through the Great Lakes (section 2a). Human-mediated transport is not likely needed for the species to arrive at Indiana Harbor but may occur due to the high vessel traffic into Indiana Harbor (section 2b). Bloody red shrimp may have already arrived at Indiana Harbor but not yet been detected (section 2e).

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The species was identified as established in Lake Michigan in 2007 (Kipp et al. 2011). It has not yet been identified at Indiana Harbor; however, whether the species has already arrived at the harbor is unknown. Concealment behavior makes the bloody red shrimp difficult to locate during the day, possibly explaining why it was not found earlier in the Great Lakes (section 2e).

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.
T_{10}: See T_0. The species may be at the pathway entrance. The species' nocturnal behavior inhibits its detection.
T_{25}: See T_{10}.
T_{50}: See T_{10}.

3. P(passage) T_0-T_{50}: LOW-HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Bloody red shrimp is benthic and planktonic and makes daily vertical migrations in the water column (Kipp et al 2011). This species has limited dispersal capacity; it is an egg brooder, and can hardly swim upstream (Audzijonyte et al. 2008). However, the bloody red shrimp can disperse through canals and river systems (Ricciardi et al. 2011). They are documented to have spread from eastern European to western European rivers and to the United Kingdom in less than a decade (Ricciardi et al. 2011). Rapid growth and maturation rates facilitate its establishment in new habitats (Pothoven et al. 2007).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the bloody red shrimp through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the bloody red shrimp as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Historically, the species has been transported via ballast water (Reid et al. 2007). Most commercial vessel traffic to Indiana Harbor is lakewise and ballast water is rarely discharged in inland ports of Illinois (NBIC 2012). The Grand Calumet River is too shallow for vessel traffic. There is vessel traffic from the Calumet River to Brandon Road Lock and Dam (USACE 2011a,b). In addition, recreational vessel traffic (e.g., canoe, kayak) could potentially transport this species to other areas of the CAWS where commercial and larger recreational vessels operate.

The Nonstructural Alternative is not expected to address the human-mediated transport of the bloody red shrimp through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: None. The maximum depth in the CAWS is about 10 m (32.8 ft), and depth is typically around 5 m (16.4 ft) (LimnoTech 2010). The bloody red shrimp inhabits a broad range of depths from 0.5–50 m (1.64–164 ft) (Ricciardi et al. 2011), although it generally inhabits waters 6–10 m (19.7–32.8 ft) deep. Just to the west of its junction with the Indiana Harbor Canal, the Grand Calumet channel is blocked by sheet pile. However, this species could go around the sheet pile during flood conditions.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Water flows out of the Indiana Harbor into Lake Michigan. West of the Indiana Harbor Canal, the eastern-most sections of the Grand Calumet River also generally flow toward Lake Michigan, while other sections can flow east or west depending on location (Weiss et al. 1997). Thus the bloody red shrimp would have to swim upstream to enter the CAWS and move to the Calumet Sag Channel. The bloody red shrimp prefers slow-moving waters but has been found along rocky, wave-exposed shorelines (NOAA 2007). The species has been identified in water currents with velocities of 0–0.8 m/s (0–2.62 ft/s) (Marty 2007). Most flows in the CAWS were less than 0.15 m/s (0.49 ft/s); the highest was 0.27 m/s (0.89 ft/s) (LimnoTech 2010). The habitat in the CAWS consists of mostly (about 75%) manmade waterways, which are designed to be straight and deep. The species prefers water temperatures of 9–20°C (48.2–68°F) (Kipp et al. 2011). The water temperature in the CAWS averages from 11.3–19.3°C (52.3–66.7°F) (MWRD 2010). The banks of the CAWS are typically a mix of stone blocks, steel sheet piling, and earthen banks with vegetation. Riprap banks are common throughout the CAWS. Conditions at the Indiana Harbor are highly industrialized. In the east branch of the Grand Calumet River, biological integrity is poor and sediment toxicity is high (Gallagher et al. 2011). Sediments consist of primarily cobble, bedrock, or concrete, but silt, sludge, and plant debris are also present (Gallagher et al. 2011). The Calumet Sag Channel and the Little Calumet River also contain areas with potentially toxic sediment contaminant levels (Gallagher et al. 2011). The Calumet Sag Channel and Chicago Sanitary and Ship Canal have banks of bedrock and steel sheet piling leading to the Des Plaines River, which should be ideal habitat. Sediments in the CAWS can range from bedrock to soft sediment (LimnoTech 2010). The bloody red shrimp occurs most frequently on hard bottom substrates including rocks; less frequently on sand, silt, or mud; and least frequently in the soft bottom profundal (Pothoven et al. 2007). The species is less abundant or scarce in areas of dense vegetation or high siltation (Kipp et al. 2011; Wittmann & Ariani 2009). During daylight hours, swarms may hide in rock crevices, boulders, piers, and jetties (Kipp et al. 2011; Ricciardi et al. 2011). The concealment behavior of the species indicates a preference for slow-moving waters (Marty 2007). The bloody red shrimp can tolerate a broad range of physicochemical conditions (Ricciardi et al. 2011).

The Nonstructural Alternative is not expected to affect habitat suitability for the bloody red shrimp in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Medium	High
Nonstructural Alternative Rating	Low	Low	Medium	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Suitable habitat is present in the CAWS (section 3d); and the species has spread across several European rivers in less than a decade (section 3a). The bloody red shrimp is not likely to move upstream through Indiana Harbor and the Grand Calumet River (sections 3a, 3d). The lack of vessel transport on the Grand Calumet would limit the potential for human-mediated transport through the upstream flow.

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the bloody red shrimp by downstream passive transport to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's low probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0. Given time to disperse naturally or by vessel traffic (once it reaches the Calumet Sag Channel) the bloody red shrimp may pass at this time step. The species can actively swim and the low flow of the Grand Calumet may allow the species to traverse the upstream flow.

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's medium probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{50}: See T_{25}. The probability of passage is likely to increase with time. The bloody red shrimp may pass through the pathway given 50 years.

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	High	High
Nonstructural Alternative Rating	Low	Low	High	High

Evidence for Uncertainty Rating

T_0: The bloody red shrimp is not a strong swimmer, and the upstream flow direction and lack of vessel transport in the Grand Calumet River would inhibit dispersal toward Brandon Road Lock and Dam (section 3d).

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains low.

T_{10}: See T_0.

T_{25}: See T_0. It is uncertain how long it would take the bloody red shrimp to pass upstream through Indiana Harbor and the Grand Calumet River or if the species is capable of such movement.

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the uncertainty remains high.

T_{50}: See T_{25}.

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. **P(spreads) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 5

BURNS SMALL BOAT HARBOR (BSBH) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Low	Low	Low	Medium	High	High	High
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	Low	Low	Low	Low	Medium	High	High	High
P(colonizes)[a]	High	Low	High	Low	High	Low	High	Low
P(spreads)[a]	High	Low	High	Low	High	Low	High	Low
P(establishment)	Low	–[a]	Low	–	Medium	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between BSBH and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative is not expected to affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Bloody red shrimp is benthic and planktonic and makes daily vertical migrations in the water column (Kipp et al. 2011). Rapid growth and maturation facilitate the establishment of bloody red shrimp in new habitats (Pothoven et al. 2007). The species can naturally disperse through canals and river systems (Ricciardi et al. 2011). The species has a limited natural dispersal capacity, because it is an egg brooder (eggs are carried by adults, not free-floating) and can hardly swim upstream (Audzijonyte et al. 2008). It was reported for the first time in 2006 from Lake Ontario and from a channel connecting Muskegon Lake to Lake Michigan, and is now well distributed throughout at least four of the Great Lakes (Marty et al. 2010; Kipp et al. 2011).

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS from natural dispersion (i.e., swimming and passive drift) through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Vessel transport is the primary dispersal mechanism in the spread of bloody red shrimp. Initially, the species spread by intentional transfer to freshwater bodies within the former Soviet Union. More recently, it has spread unintentionally by shipping through rivers and canals, and in ballast water (Kipp et al. 2011). The species spread from Europe to the United Kingdom in less than 10 years via shipping (Ricciardi et al. 2011). The highest risk transport vector is ballast water movement (Reid et al. 2007). There is recreational but not commercial vessel traffic to the BSBH from Lake Michigan (USACE 2011a,b). However, there is heavy lakewise commercial traffic to the adjacent Burns Harbor which could potentially transport the species to the pathway.

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS from human-mediated transport through aquatic pathways.

c. Current Abundance and Reproductive Capacity

T_0: The species breeds from April to September/October (Kipp et al. 2011). Sexual maturity occurs in less than 45 days (Kipp et al. 2011). Females become ovigerous at 8–9°C (46.4–48.2°F) (Marty et al. 2010) and produce two to four broods per year (Kipp et al. 2011). Brood size is correlated with female length and ranges from 6 to 70 embryos per individual (Ketelaars et al. 1999; Salemaa and Hietalahti 1993; Borcherding et al. 2006). Bloody red shrimp's relatively low fecundity

(Ketelaars et al. 1999) suggests that it may have been present in the Great Lakes for a few years before being discovered.

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of the bloody red shrimp.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. *Existing Physical Human/Natural Barriers*

T_0: There are no existing barriers, as it is likely to have already arrived at the pathway.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. *Distance from Pathway*

T_0: The species is established in Lake Michigan. The U.S. Geological Survey (USGS) documented the species one nautical mile (1.6 km) offshore of Jackson Harbor in 2007 and just south of Waukegan Harbor a half mile (0.8 km) offshore in 2006 (Kipp et al. 2011). Scientists believe the species has a wider distribution but its presence has not been previously reported because people either did not recognize it or simply did not see it. Bloody red shrimp are difficult to locate because they are nocturnal, preferring to hide in rocky cracks and crevices near the bottom along the shoreline during the day (Reid et al. 2007).

The Nonstructural Alternative is not expected to limit the movement of the bloody red shrimp outside of its current distribution.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: Bloody red shrimp are normally found in lentic waters, although the shrimp has successfully established itself in European rivers (Kipp et al. 2011). The species prefers slow-moving waters, but has been found along rocky, wave-exposed shorelines (NOAA 2007). It inhabits a broad range of depths (Ricciardi et al. 2011) 0.5–50 m (1.64–164 ft), although it generally inhabits waters 6–10 m (19.7–32.8 ft) in depth (Kipp et al. 2011). Water flow may limit the expansion of the organism, with 0–0.8 m/s (0–2.62 ft/s) being the minimum and maximum velocities of sampled areas where the bloody red shrimp were present (Marty 2007). The species prefers temperatures in the range of 9–20°C (48.2–68°F) (Kipp et al. 2011) and is mainly found near shore (Walsh et al. 2010). The species is less abundant or scarce in areas of dense vegetation or high siltation (Kipp et al. 2011; Wittmann and Ariani 2009). It occurs most frequently on hard bottom substrates including rocks; less frequently on sand, silt, or mud; and least frequently in the soft bottom profundal (Pothoven et al. 2007). Swarms are often found in shaded areas near piers and jetties (Ricciardi et al. 2011). During daylight hours, swarms may hide in rock crevices, boulders, piers, and jetties (Kipp et al. 2011). The bloody red shrimp can tolerate a broad range of physicochemical conditions (Ricciardi et al. 2011).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the bloody red shrimp in southern Lake Michigan.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: There is a known establishment of the species less than 56.3 km (35 mi) from BSBH (section 2e). The rocky shore surrounding BSBH is ideal habitat (section 2f). The species is documented to have a rapid invasion rate and the ability to disperse through the Great Lakes (section 2a). Human-mediated transport is not likely needed for the species to arrive at BSBH (section 2b). Bloody red shrimp may have arrived at BSBH but not yet been detected (section 2e).

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The species was identified as established in Lake Michigan in 2007 (Kipp et al. 2011). It has not yet been identified at BSBH; however, whether the species has already arrived at the harbor is unknown. Concealment behavior makes the bloody red shrimp difficult to locate during the day, possibly explaining why it was not found earlier in the Great Lakes (section 2e).

The Nonstructural Alternative is not expected to affect the arrival of the bloody red shrimp at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.
T_{10}: See T_0. The species may be at the pathway entrance. The species' nocturnal behavior inhibits detection.
T_{25}: See T_{10}.
T_{50}: See T_{10}.

3. P(passage) T_0-T_{50}: LOW-HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

Bloody red shrimp is benthic and planktonic and makes daily vertical migrations in the water column (Kipp et al 2011). This species has limited dispersal capacity; it is an egg brooder, and can hardly swim upstream (Audzijonyte et al. 2008). However, the bloody red shrimp can disperse through canals and river systems (Ricciardi et al. 2011). They are documented to have spread from eastern European to western European rivers and to the United Kingdom in less than a decade (Ricciardi et al. 2011). Rapid growth and maturation facilitate its establishment in new habitats (Pothoven et al. 2007).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the bloody red shrimp through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the bloody red shrimp as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

Historically, the species has been transported via ballast water (Reid et al. 2007). Vessel traffic to BSBH is lakewise. Although bloody red shrimp could move to the adjacent Burns Harbor (which does have commercial vessel traffic), there is no commercial vessel from Burns Harbor to inland ports in the CAWS (NBIC 2012). Therefore, some natural downstream dispersal would likely be required to reach Brandon Road Lock and Dam. Recreational boating traffic through BSBH, Burns Ditch and the south branch of Little Calumet River is very minor due to the shallow depth. In addition, recreational vessel traffic (e.g., canoe, kayak) could potentially transport this species to other areas of the CAWS where commercial and larger recreational vessels operate.

The Nonstructural Alternative is not expected to address the human-mediated transport of the bloody red shrimp through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers. The maximum depth in the CAWS is about 10 m (32.8 m) and depth is typically around 5 m (16.4 ft) (LimnoTech 2010). The bloody red shrimp inhabits a broad range of depths from 0.5–50 m (1.64–164 ft)

(Ricciardi et al. 2011), although it generally inhabits waters 6–10 m (19.7–32.8 ft) in depth (Kipp et al. 2011).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Water flows out of BSBH into Lake Michigan. The eastern segment of the south branch Little Calumet River also generally flows toward Lake Michigan (GSWMD 2008). Thus the bloody red shrimp would have to swim upstream to enter the CAWS and move to the Calumet Sag Channel. The bloody red shrimp prefers slow-moving waters but has been found along rocky, wave-exposed shorelines (NOAA 2007). The species has been identified in water currents with velocities of 0–0.8 m/s (0–2.62 ft/s) (Marty 2007). Most flows in the CAWS were lower than 0.15 m/s (0.49 ft/s), and the highest was 0.27 m/s (0.89 ft/s) (LimnoTech 2010). The habitat in the CAWS consists of mostly (about 75%) manmade waterways, which are designed to be straight and deep (LimnoTech 2010). The species prefers water temperatures of 9–20°C (48.2–68°F) (Kipp et al. 2011). The water temperature in the CAWS averages from 11.3–19.3°C (52.3–66.7°F) (MWRD 2010). The banks of the CAWS are typically a mix of stone blocks, steel sheet piling, and earthen banks with vegetation. Riprap banks are common throughout the CAWS. The banks of the BSBH are primarily riprap and vertical walls. The banks of the south leg of the Little Calumet River are vegetated, and sediments include plant debris, silt, sand, cobble, gravel, and boulder (Gallagher et al. 2011). The Calumet Sag Channel and Chicago Sanitary and Ship Canal have banks of bedrock and steel sheet piling leading to the Des Plaines River, which should be ideal habitat. Sediments in the CAWS can range from gravel to soft sediment (LimnoTech 2010). The bloody red shrimp occurs most frequently on hard bottom substrates including rocks; less frequently on sand, silt, or mud; and least frequently in the soft bottom profundal (Pothoven et al. 2007). The species is less abundant or scarce in areas of dense vegetation or high siltation (Kipp et al. 2011; Wittmann & Ariani 2009). During daylight hours, swarms may hide in rock crevices, boulders, piers, and jetties (Kipp et al. 2011; Ricciardi et al. 2011). The concealment behavior of the species indicates a preference for slow-moving waters (Marty 2007). Swarms are often found in shaded areas near piers and jetties (Ricciardi et al. 2011). The bloody red shrimp can tolerate a broad range of physicochemical conditions (Ricciardi et al. 2011).

The Nonstructural Alternative is not expected to affect habitat suitability for the bloody red shrimp in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Medium	High
Nonstructural Alternative Rating	Low	Low	Medium	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Suitable habitat is present in the CAWS (section 3d). The bloody red shrimp is not likely to move upstream through BSBH and the south branch of the Little Calumet River. The lack of vessel traffic on the Little Calumet River would limit the potential for human-mediated transport through the upstream flow.

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the bloody red shrimp by downstream passive transport to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's low probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0. Given time to disperse naturally or by vessel traffic (once it reaches the Calumet Sag Channel) the bloody red shrimp may pass at this time step. The species can actively swim and the low flow of the Little Calumet may allow the species to traverse the upstream flow.

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's medium probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{50}: See T_{25}. The probability of passage is likely to increase with time. The bloody red shrimp may pass through the passage given 50 years.

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	High	High
Nonstructural Alternative Rating	Low	Low	High	High

Evidence for Uncertainty Rating

T_0: The bloody red shrimp is not a strong swimmer, and the upstream flow direction and lack of vessel transport in the south branch of the Little Calumet River would inhibit dispersal of this species to Brandon Road Lock and Dam (section 3d).

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains low.

T_{10}: See T_0.

T_{25}: See T_0. It is uncertain how long it would take the bloody red shrimp to pass upstream through the BSBH and the Little Calumet River or if the species is capable of such movement.

The Nonstructural Alternative is not expected to affect the passage of the bloody red shrimp through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the uncertainty remains high.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

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E.2.2.4 Fish

E.2.2.4.1 Threespine Stickleback (*Gasterosteus aculeatus*)


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NONSTRUCTURAL ALTERNATIVE

This alternative would potentially include the implementation of a combination of the following measures that may be implemented at time step 0 (T_0, in units of years) by local, state, and federal agencies and the public. The Nonstructural Alternative would include the development of a monitoring and response program.

Nonstructural Alternative Measures for the Threespine Stickleback

Option or Technology	Description
Education and Outreach	• Signage, pamphlets, and brochures on how to identify ANS and control the spread of ANS; promote national campaigns (i.e., "Stop Aquatic Hitchhikers") • Education of recreational waterway users
Ballast/Bilge-Water Exchange	• Ballast/bilge-water exchange
Monitoring	• Agency monitoring • Voluntary occurrence reporting
Laws and Regulations	• FWS Lacey Act listing • Mandatory watercraft inspection and decontamination • Prohibition of sale, husbandry, transport, and release • Quarantine-restricted site access

	ANS Controls	**ANS Factsheet**[a]
ANS Controls Methods	Piscicides	Piscicides
	Controlled Harvest and Overfishing	Controlled Harvest and Overfishing
	Desiccation (Water Drawdown)	Lethal Temperature

[a] For more information refer to GLMRIS Team (2012).

PATHWAY 1

WILMETTE PUMPING STATION (WPS) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Wilmette Pumping Station (WPS) and Brandon Road Lock and Dam over the next 50 years. The Nonstructural Alternative does not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The threespine stickleback is an actively swimming fish that forms schools. It lays eggs in a nest on the bottom of a water body (NatureServe 2010); therefore, eggs and larvae are not expected to be transported by currents unless resuspended into the water column by a disturbance. The threespine stickleback reached Illinois accidentally as the result of the Welland Canal, built in the 1820s (Laird and Page 1996).

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback from natural dispersion through aquatic pathways to the Chicago Area Water System (CAWS).

b. Human-Mediated Transport through Aquatic Pathways

There is recreational vessel traffic to the WPS (USACE 2011b). Although transport in ballast water is possible for this species, it was not described in the literature as a transport mechanism for the threespine stickleback.

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback from human-mediated transport.

c. Current Abundance and Reproductive Capacity

T_0: All eggs within a clutch are laid as a single batch in the nest of a single male (Wootton 2009). There may be 15 eggs in a very small female, to more than 1,000 eggs in exceptionally large females (Baker et al. 2008). Mean breeding season fecundity equals 2,060 eggs per female (Copp and Kovac 2003). Minimum population doubling time is less than 15 months (Fishbase undated). The threespine stickleback is considered established in southern Lake Michigan, and it has been found in the North Shore Channel, which connects to the WPS.

It is uncertain whether the Nonstructural Alternative may reduce the current abundance and reproductive capacity of the threespine stickleback in the Great Lakes.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The threespine stickleback has arrived at the WPS.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: In addition to being established in southern Lake Michigan, the threespine stickleback was found in the North Shore Channel in 1988 (Johnston 1991). The Illinois Natural History survey has found the threespine stickleback near Lockport Lock and Dam (INHS undated).

The Nonstructural Alternative is not expected to reduce the threespine stickleback's distance from the pathway. The threespine stickleback is already at the pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The threespine stickleback is found from Arctic to temperate climates. The native range of the threespine stickleback is Arctic and Atlantic drainages from Baffin Island and the western side of Hudson Bay to Cape Fear Estuary, North Carolina (Page and Burr 1991), and Pacific drainages from Alaska to Baja California (Fuller 2011). Eastern freshwater populations are found far inland, including Lake Ontario (Fuller 2011). In the Great Lakes, the species is native only below Niagara Falls (Smith 1985). The threespine stickleback inhabits coastal marine, brackish, and an array of freshwater habitats ranging from tiny ephemeral streams in arid desert regions to large Arctic lakes (Willacker et al. 2010); populations can be wholly marine, anadromous, or strict residents of freshwater (Willacker et al. 2010). The species is found in sluggish waters of lakes, ponds, large lowland rivers, estuaries, and marine coastlines. Freshwater populations usually inhabit shallow vegetated water (NatureServe 2010). All populations spawn in freshwater in shallow, soft bottoms (Laird and Page 1996). These fish are small (up to 10 cm [3.9 in.]), visual predators (Gill and Hart 1994) that feed on invertebrates such as crustaceans and insect larvae, as well as fish eggs, fish larvae, and plant matter (Wootton 1976). The species is found in a wide range of flowing and stillwater habitats (Rushbrook et al. 2010) but seems to prefer low velocities (Copp and Kovac 2003).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the threespine stickleback in southern Lake Michigan.

T_{10}: See T_0. Habitat is expected to remain suitable for the threespine stickleback.
T_{25}: See T_{10}.
T_{50}: See T_{10}.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The threespine stickleback is documented as established in southern Lake Michigan and has been found in the CAWS (Section 2e). Suitable habitat is present in the vicinity of the WPS, and this species has been found in the North Shore Channel (Section 2f).

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback at the CAWS through aquatic pathways. The species has already arrived at the pathway. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. No changes in the habitat of Lake Michigan are expected to alter the probability of arrival at the WPS.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: The species has been documented in the North Shore Channel, just beyond the entrance to the WPS pathway.

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback, which is already present at the pathway. Therefore, the uncertainty remains none.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The species is an actively swimming fish that forms schools. It lays eggs in a nest on the bottom of a water body (NatureServe 2010); therefore, eggs and larvae are not expected to be transported by currents unless resuspended into the water column by a disturbance.

The Nonstructural Alternative does not address natural dispersion (i.e., swimming and passive drift) of the threespine stickleback through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the threespine stickleback as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

Although not documented in the literature, the threespine stickleback potentially may be transported in ballast water. However, there is no commercial vessel traffic from the WPS (USACE 2011a,b). Threespine stickleback actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming would likely be the primary mechanism of movement through the CAWS. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the threespine stickleback into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

The Nonstructural Alternative is not expected to address the human-mediated transport of the threespine stickleback through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: There is a sluice gate separating Lake Michigan from the North Shore Channel. However, the gate is opened periodically, and water is pumped periodically from Lake Michigan into the North Shore Channel, which could transport this species. The threespine stickleback has been found within the North Shore Channel (Johnston 1991). The Electric Dispersal Barrier System located north of Lockport Lock and Dam may act as a barrier to some degree by repelling adult fish. However, the Electric Dispersal Barrier System does not appear to be highly effective against small fish. In addition, adult threespine sticklebacks that are shocked would flow downstream through the barrier. Thus, there is a high potential that adults may pass through the barrier at the current setting. Also, eggs/larvae that are resuspended in the water column by boat propellers may pass through the Electric Dispersal Barrier System. Brandon Road Lock and Dam and Lockport Lock and Dam are not expected to control the passage of this species through the pathway.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The threespine stickleback typically inhabits weedy pools or backwaters, or occurs among emergent plants at stream edges (NatureServe 2010). Although living, submerged aquatic vegetation is not common in the CAWS, it is found in the Chicago Sanitary and Ship Canal (CSSC) and the North Shore Channel in low density (LimnoTech 2010). Plant debris is present in the CAWS although it is not a dominant substrate component (LimnoTech 2010). The CAWS is a turbid water system with a low flow of 0.05–0.27 m/s (0.16–0.89 ft/s) (LimnoTech 2010). The species is found in a wide range of flowing and stillwater habitats (Rushbrook et al. 2010) but seems to prefer low velocities (Copp and Kovac 2003). Threespine stickleback have been recorded in the CAWS, including the North Shore Channel, CSSC, Burns Harbor, and Calumet Harbor (Johnston 1991; Barnes 1999), down to Lockport Lock and Dam (INHS undated). Therefore, habitat is assumed to be suitable in the CAWS.

The Nonstructural Alternative is not expected to affect habitat suitability for the threespine stickleback in the CAWS.

T_{10}: See T_0. Habitat in the CAWS is expected to remain suitable for the threespine stickleback.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The threespine stickleback has been found in multiple locations in the CAWS, therefore suitable habitat is present (Section 3d). It is found in the CSSC as far south as the Lockport Lock and Dam, which is less than 11.3 km (7 mi) from Brandon Road Lock and Dam. The species may be small enough to pass through the Electric Dispersal Barrier System, and no other barriers are expected to control the downstream movement of this species (section 3c).

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the threespine stickleback by natural dispersion to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Uncertainty of Passage,

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Low	Low	Low
Nonstructural Alternative Rating	Medium	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The threespine stickleback has been present in the CAWS since 1988, and there does not appear to be any significant barrier to passage. However, this species has yet to be identified in the Mississippi River Basin below Brandon Road Lock and Dam. Why this species has not established in the Mississippi River Basin is uncertain, although it may be present in the basin and not yet detected. Surveys of the lower Illinois River are required to determine whether the species is present at this time step.

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0. Given the documented proximity of this species to Brandon Road Lock and Dam and the lack of barriers to passage, it is more certain that over time, this species would pass downstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway. Overall, the uncertainty remains low.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 2

CHICAGO RIVER CONTROLLING WORKS (CRCW) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Chicago River Controlling Works (CRCW) and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The threespine stickleback is an actively swimming fish that forms schools. It lays eggs in a nest on the bottom of a water body (NatureServe 2010); therefore, eggs and larvae are not expected to be transported by currents unless resuspended into the water column by a disturbance. The threespine stickleback reached Illinois accidentally as the result of the Welland Canal, built in the 1820s (Laird and Page 1996).

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback at the CAWS from natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

There is commercial and recreational vessel traffic to the CRCW (USACE 2011a,b). Although transport in ballast water is possible for this species, it was not described in the literature as a transport mechanism for the threespine stickleback.

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback from human-mediated transport.

c. Current Abundance and Reproductive Capacity

T_0: All eggs within a clutch are laid as a single batch in the nest of a single male (Wootton 2009). There may be 15 eggs in a very small female, to more than 1,000 eggs in exceptionally large females (Baker et al. 2008). Mean breeding season fecundity equals 2,060 eggs per female (Copp and Kovac 2003). Minimum population doubling time is less than 15 months (Fishbase undated). Threespine stickleback is considered established in southern Lake Michigan, which connects to the CRCW.

It is uncertain whether the Nonstructural Alternative may reduce the current abundance and reproductive capacity of the threespine stickleback in the Great Lakes.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The threespine stickleback has arrived at the CRCW.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: The threespine stickleback is considered established in southern Lake Michigan (Johnston 1991). It was found near the CRCW in 1988 (Fuller 2011) and has been found in the CAWS (Johnston 1991; INHS undated; Wyffels et al. 2013).

The Nonstructural Alternative is not expected to reduce the threespine stickleback's distance from the pathway. The threespine stickleback is already at the pathway.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The threespine stickleback is found from Arctic to temperate climates. The native range of the threespine stickleback is Arctic and Atlantic drainages from Baffin Island and the western side of Hudson Bay, to the Cape Fear Estuary, North Carolina (Page and Burr 1991), and Pacific drainages from Alaska to Baja California (Fuller 2011). Eastern freshwater populations are found far inland, including Lake Ontario (Fuller 2011). In the Great Lakes, the species is native only below Niagara Falls (Smith 1985). The threespine stickleback inhabits coastal marine, brackish, and an array of freshwater habitats ranging from tiny ephemeral streams in arid desert regions to large Arctic lakes (Willacker et al. 2010); populations can be wholly marine, anadromous, or strict residents of freshwater (Willacker et al. 2010). The species is found in sluggish waters of lakes, ponds, large lowland rivers, estuaries, and marine coastlines. Freshwater populations usually inhabit shallow vegetated water (NatureServe 2010). All populations spawn in freshwater in shallow, soft bottoms (Laird and Page 1996). These fish are small (up to 10 cm [3.9 in]), visual predators (Gill and Hart 1994) that feed on invertebrates such as crustaceans and insect larvae, as well as fish eggs, fish larvae, and plant matter (Wootton 1976). The species is found in a wide range of flowing and stillwater habitats (Rushbrook et al. 2010) but seems to prefer low velocities (Copp and Kovac 2003).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the threespine stickleback in southern Lake Michigan.

T_{10}: See T_0. Habitat near the CRCW is expected to remain suitable for the threespine stickleback.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The threespine stickleback is documented as established in southern Lake Michigan and has been found in the CAWS (section 2e). Suitable habitat is present in the vicinity of the CRCW (section 2f).

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback at the CAWS through aquatic pathways. The species has already arrived at the pathway. Therefore, the Nonstructural Alternative’s high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. No changes in the habitat of Lake Michigan are expected to alter the probability of arrival at the CRCW.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: The species is documented near the CRCW pathway.

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback, which is already present at the pathway. Therefore, the uncertainty remains none.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

3. P(passage) T_0-T_{50} : LOW-HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The species is an actively swimming fish that forms schools. It lays eggs in a nest on the bottom of a water body (NatureServe 2010); therefore, eggs and larvae are not expected to be transported by currents unless resuspended into the water column by a disturbance.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the threespine stickleback through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the threespine stickleback as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

Although not documented in the literature, the threespine stickleback potentially may be transported in ballast water, and there is commercial and recreational vessel traffic from the CRCW to Brandon Road Lock and Dam (USACE 2011a,b). Threespine sticklebacks actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming would likely be the primary mechanism of movement through the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

The Nonstructural Alternative is not expected to address the human-mediated transport of the threespine stickleback through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: The threespine stickleback is found within the CAWS (Johnston 1991; Barnes 1999). Within the CAWS, the Electric Dispersal Barrier System located north of Lockport Lock and Dam may act as a barrier to some degree by repelling adult fish. However, the Electric Dispersal Barrier System does not appear to be highly effective against small fish. In addition, adult threespine sticklebacks that are shocked would flow downstream through the barrier. Thus, there is a high potential that adults may pass through the barrier at the current setting. In addition, eggs/larvae that are resuspended in the water column by boat propellers may pass through the Electric Dispersal Barrier System. Brandon Road Lock and Dam and Lockport Lock and Dam are not expected to control the passage of this species through the pathway.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The threespine stickleback typically inhabits weedy pools or backwaters, or occurs among emergent plants at stream edges (NatureServe 2010). Although living, submerged aquatic vegetation is not common in the CAWS, it is found in the CSSC in low density (LimnoTech 2010). Plant debris is present in the CAWS, although it is not a dominant substrate component (LimnoTech 2010). The CAWS is a turbid water system with a low flow of 0.05–0.27 m/s (0.16–0.89 ft/s) (LimnoTech 2010). The species is found in a wide range of flowing and stillwater habitats (Rushbrook et al. 2010) but seems to prefer low velocities (Copp and Kovac 2003). Threespine sticklebacks have been recorded in the CAWS, including the North Shore Channel, Calumet River, CSSC, Burns Harbor, and Calumet Harbor (Johnston 1991; Barnes 1999), down to Lockport Lock and Dam (INHS undated). Therefore, habitat is assumed to be suitable in the CAWS.

The Nonstructural Alternative is not expected to affect habitat suitability for the threespine stickleback in the CAWS.

T_{10}: See T_0. Habitat in the CAWS is expected to remain suitable for the threespine stickleback.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The threespine stickleback has been found in multiple locations in the CAWS; therefore suitable habitat is present (section 3d). It is found in the CSSC as far south as the Lockport Lock and Dam, which is less than 11.3 km (7 mi) from Brandon Road Lock and Dam. The species may be small enough to pass through the Electric Dispersal Barrier System, and no other barriers are expected to control the downstream movement of this species (section 3c).

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the threespine stickleback by natural dispersion to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Low	Low	Low
Nonstructural Alternative Rating	Medium	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The threespine stickleback has been present in the CAWS since 1988, and there does not appear to be any significant barriers to passage. However, this species has yet to be identified in the Mississippi River Basin below Brandon Road Lock and Dam. Why this species has not established in the Mississippi River Basin is uncertain, although it may be present in the basin but not yet detected. Surveys of the lower Illinois River are required to determine whether the species is present at this time step.

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0. Given the documented proximity of this species to Brandon Road Lock and Dam and the lack of barriers to passage, it is more certain that over time, this species would pass downstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 3

CALUMET HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Calumet Harbor and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The threespine stickleback is an actively swimming fish that forms schools. It lays eggs in a nest on the bottom of a water body (NatureServe 2010); therefore, eggs and larvae are not expected to be transported by currents unless resuspended into the water column by a disturbance. The threespine stickleback reached Illinois accidentally as the result of the Welland Canal, built in the 1820s (Laird and Page 1996).

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback at the CAWS from natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

There is heavy commercial vessel traffic to Calumet Harbor (USACE 2011a). Although transport in ballast water is possible for this species, it was not described in the literature as a significant transport mechanism for the threespine stickleback.

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback from human-mediated transport.

c. Current Abundance and Reproductive Capacity

T_0: All eggs within a clutch are laid as a single batch in the nest of a single male (Wootton 2009). There may be 15 eggs in a very small female, to more than 1,000 eggs in exceptionally large females (Baker et al. 2008). Mean breeding season fecundity equals 2,060 eggs per female (Copp and Kovac 2003). Minimum population doubling time is less than 15 months (Fishbase undated). The threespine stickleback is considered established in southern Lake Michigan, which connects to Calumet Harbor.

It is uncertain whether the Nonstructural Alternative may reduce the current abundance and reproductive capacity of the threespine stickleback in the Great Lakes.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The threespine stickleback has arrived at Calumet Harbor.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: The threespine stickleback is considered established in southern Lake Michigan. It was found near Calumet Harbor and within the Calumet River in 1988–1989 (Fuller 2011) and in Lake Calumet (Wyffels et al. 2013).

The Nonstructural Alternative is not expected to reduce the threespine stickleback's distance from the pathway. The threespine stickleback is already at the pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The threespine stickleback is found from Arctic to temperate climates. The native range of the threespine stickleback is Arctic and Atlantic drainages from Baffin Island and the western side of Hudson Bay, to Cape Fear Estuary, North Carolina (Page and Burr 1991), and Pacific drainages from Alaska to Baja California (Fuller 2011). Eastern freshwater populations are found far inland, including Lake Ontario (Fuller 2011). In the Great Lakes, the species is native only below Niagara Falls (Smith 1985). The threespine stickleback inhabits coastal marine, brackish, and an array of freshwater habitats ranging from tiny ephemeral streams in arid desert regions to large Arctic lakes (Willacker et al. 2010); populations can be wholly marine, anadromous, or strict residents of freshwater (Willacker et al. 2010). The species is found in sluggish waters of lakes, ponds, large lowland rivers, estuaries, and marine coastlines. Freshwater populations usually inhabit shallow vegetated water (NatureServe 2010). All populations spawn in freshwater in shallow, soft bottoms (Laird and Page 1996). These fish are small (up to 10 cm; 3.9 in.), visual predators (Gill and Hart 1994) that feed on invertebrates such as crustaceans and insect larvae, as well as fish eggs, fish larvae, and plant matter (Wootton 1976). The species is found in a wide range of flowing and stillwater habitats (Rushbrook et al. 2010) but seems to prefer low velocities (Copp and Kovac 2003).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the threespine stickleback in southern Lake Michigan.

T_{10}: See T_0. Habitat near Calumet Harbor is expected to remain suitable for the threespine stickleback.
T_{25}: See T_{10}.
T_{50}: See T_{10}.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The threespine stickleback is documented as established in southern Lake Michigan and has been found in the CAWS (section 2e). Suitable habitat is present in the vicinity of Calumet Harbor, and it has been documented at Calumet Harbor and the Calumet River (section 2f).

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback at the CAWS through aquatic pathways. The species has already arrived at the pathway. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. No changes in the habitat of Lake Michigan are expected to alter the probability of arrival at Calumet Harbor.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: The species is documented near the Calumet Harbor pathway. The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback, which is already present at the pathway. Therefore, the uncertainty remains none.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The species is an actively swimming fish that forms schools. It lays eggs in a nest on the bottom of a water body (NatureServe 2010); therefore, eggs and larvae are not expected to be transported by currents unless resuspended into the water column by a disturbance.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the threespine stickleback through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the threespine stickleback as it passes through the CAWS.

b. *Human-Mediated Transport through Aquatic Pathways*

Although not documented in the literature, the threespine stickleback may potentially be transported in ballast water, and there is commercial and recreational vessel traffic from Calumet Harbor to Brandon Road Lock and Dam (USACE 2011a,b). Threespine sticklebacks actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming would likely be the primary mechanism of movement through the CAWS. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the threespine stickleback into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

The Nonstructural Alternative is not expected to address the human-mediated transport of the threespine stickleback through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: The threespine stickleback is found within the CAWS, including Calumet Harbor and the Calumet River (Johnston 1991; Barnes 1999). Within the CAWS, the Electric Dispersal Barrier System located north of Lockport Lock and Dam may act as a barrier to some degree by repelling adult fish. However, the Electric Dispersal Barrier System does not appear to be highly effective against small fish. In addition, adult threespine sticklebacks that are shocked would flow downstream through the barrier. Thus, there is a high potential that adults may pass through the barrier at the current setting. Also, eggs/larvae that are resuspended in the water column by boat propellers may pass through the Electric Dispersal Barrier System. Brandon Road Lock and Dam and Lockport Lock and Dam are not expected to control the passage of this species through the pathway.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: The threespine stickleback typically inhabits weedy pools or backwaters, or occurs among emergent plants at stream edges (NatureServe 2010). Although living, submerged aquatic vegetation is not common in the CAWS, it is found in the CSSC in low density (LimnoTech 2010). Plant debris is present in the CAWS, although it is not a dominant substrate component (LimnoTech 2010). The CAWS is a turbid water system with a low flow of 0.05–0.27 m/s (0.16–0.89 ft/s) (LimnoTech 2010). The species is found in a wide range of flowing and stillwater habitats (Rushbrook et al. 2010) but seems to prefer low velocities (Copp and Kovac 2003). Threespine sticklebacks have been recorded in the CAWS, including the North Shore Channel, Calumet River, CSSC, Burns Harbor, and Calumet Harbor (Johnston 1991; Barnes 1999), down to Lockport Lock and Dam (INHS undated). Therefore, habitat is assumed to be suitable in the CAWS.

The Nonstructural Alternative is not expected to affect habitat suitability for the threespine stickleback in the CAWS.

T_{10}: See T_0. Habitat in the CAWS is expected to remain suitable for the threespine stickleback.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The threespine stickleback has been found in multiple locations in the CAWS; therefore suitable habitat is present (section 3d). It is found in the CSSC as far south as the Lockport Lock and Dam, which is less than 11.3 km (7 mi) from Brandon Road Lock and Dam. The species may be small enough to pass through the Electric Dispersal Barrier System, and no other barriers are expected to control the downstream movement of this species (section 3c).

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the threespine stickleback by natural dispersion to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Low	Low	Low
Nonstructural Alternative Rating	Medium	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The threespine stickleback has been present in the CAWS since 1988, and there does not appear to be any significant barriers to passage. However, this species has yet to be identified in the Mississippi River Basin below Brandon Road Lock and Dam. Why this species has not established in the Mississippi River Basin is uncertain, although it may be present in the basin but not yet detected. Surveys of the lower Illinois River are required to determine whether the species is present at this time step.

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0. Given the documented proximity of this species to Brandon Road Lock and Dam and the lack of barriers to passage, it is more certain that over time, this species would pass downstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 4

INDIANA HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–-

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Indiana Harbor and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The threespine stickleback is an actively swimming fish that forms schools. It lays eggs in a nest on the bottom of a water body (NatureServe 2010); therefore, eggs and larvae are not expected to be transported by currents unless resuspended into the water column by a disturbance. The threespine stickleback reached Illinois accidentally as the result of the Welland Canal, built in the 1820s (Laird and Page 1996).

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback at the CAWS from natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

There is heavy lakewise commercial vessel traffic to the Indiana Harbor (USACE 2011b). Although transport in ballast water is possible for this species, it was not described in the literature as a transport mechanism for the threespine stickleback.

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback from human-mediated transport.

c. Current Abundance and Reproductive Capacity

T_0: All eggs within a clutch are laid as a single batch in the nest of a single male (Wootton 2009). There may be 15 eggs in a very small female, to more than 1,000 eggs in exceptionally large females (Baker et al. 2008). Mean breeding season fecundity equals 2,060 eggs per female (Copp and Kovac 2003). Minimum population doubling time is less than 15 months (Fishbase undated). The threespine stickleback is considered established in southern Lake Michigan, which connects to Indiana Harbor.

It is uncertain whether the Nonstructural Alternative may reduce the current abundance and reproductive capacity of the threespine stickleback in the Great Lakes.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: The threespine stickleback has arrived at Indiana Harbor. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: The threespine stickleback is considered established in southern Lake Michigan. It was found near Indiana Harbor at the Indiana Dunes National Lakeshore, within the Calumet River (Fuller 2011) and in Lake Calumet (Wyffels et al. 2013).

The Nonstructural Alternative is not expected to reduce the threespine stickleback's distance from the pathway. The threespine stickleback is already at the pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The threespine stickleback is found from Arctic to temperate climates. The native range of the threespine stickleback is Arctic and Atlantic drainages from Baffin Island and the western side of Hudson Bay, to Cape Fear Estuary, North Carolina (Page and Burr 1991), and Pacific drainages from Alaska to Baja California (Fuller 2011). Eastern freshwater populations are found far inland, including Lake Ontario (Fuller 2011). In the Great Lakes, the species is native only below Niagara Falls (Smith 1985). The threespine stickleback inhabits coastal marine, brackish, and an array of freshwater habitats ranging from tiny ephemeral streams in arid desert regions to large Arctic lakes (Willacker et al. 2010); populations can be wholly marine, anadromous, or strict residents of freshwater (Willacker et al. 2010). The species is found in sluggish waters of lakes, ponds, large lowland rivers, estuaries, and marine coastlines. Freshwater populations usually inhabit shallow vegetated water (NatureServe 2010). All populations spawn in freshwater in shallow, soft bottoms (Laird and Page 1996). These fish are small (up to 10 cm [3.9 in.]), visual predators (Gill and Hart 1994) that feed on invertebrates such as crustaceans and insect larvae, as well as fish eggs, fish larvae, and plant matter (Wootton 1976). The species is found in a wide range of flowing and stillwater habitats (Rushbrook et al. 2010) but seems to prefer low velocities (Copp and Kovac 2003).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the threespine stickleback in southern Lake Michigan.

T_{10}: See T_0. Habitat near Indiana Harbor is expected to remain suitable for the threespine stickleback.
T_{25}: See T_{10}.
T_{50}: See T_{10}.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The threespine stickleback is documented as established in southern Lake Michigan, and it has been found in the CAWS (section 2e). Suitable habitat is present in the vicinity of Indiana Harbor, and it has been documented near Indiana Harbor (section 2f).

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback at the CAWS through aquatic pathways. The species has already arrived at the pathway. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. No changes in the habitat of Lake Michigan are expected to alter the probability of arrival at Indiana Harbor.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: The species is documented near the Indiana Harbor pathway (section 2e). The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback, which is already present at the pathway. Therefore, the uncertainty remains none.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The species is an actively swimming fish that forms schools. It lays eggs in a nest (NatureServe 2010); therefore, eggs and larvae are not expected to be transported by currents unless resuspended into the water column by a disturbance.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the threespine stickleback through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the threespine stickleback as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

Although not documented in the literature, the threespine stickleback may potentially be transported in ballast water, and there is only lakewise commercial vessel traffic to and from Indiana Harbor (USACE 2011a,b). Threespine sticklebacks actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming would likely be the primary mechanism of movement through the CAWS.

The Nonstructural Alternative is not expected to address the human-mediated transport of the threespine stickleback through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: The threespine stickleback is found within the CAWS and has been found as far south as Lockport (Johnston 1991; Barnes 1999; INHS undated). The Electric Dispersal Barrier System located north of Lockport Lock and Dam may act as a barrier within the CAWS by repelling adult fish. However, the Electric Dispersal Barrier System does not appear to be highly effective against small fish. In addition, adult threespine sticklebacks that are shocked would flow downstream through the barrier. Thus, there is a high potential that adults may pass through the barrier at the current setting. Also, eggs/larvae that are resuspended in the water column by boat propellers may pass through the Electric Dispersal Barrier System. Brandon Road Lock and Dam and Lockport Lock and Dam are not expected to control the passage of this species through the pathway.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The threespine stickleback typically inhabits weedy pools or backwaters, or occurs among emergent plants at stream edges (NatureServe 2010). Although living, submerged aquatic vegetation is not common in the CAWS, it is found in the CSSC in low density (LimnoTech 2010). Plant debris is present in the CAWS, although it is not a dominant substrate component (LimnoTech 2010). The CAWS is a turbid water system with a low flow of 0.05–0.27 m/s (0.16–0.89 ft/s) (LimnoTech 2010). The species is found in a wide range of flowing and stillwater habitats (Rushbrook et al. 2010) but seem to prefer low velocities (Copp and Kovac 2003). Threespine sticklebacks have been recorded in the CAWS, including the North Shore Channel, Calumet River, CSSC, Burns Harbor, and Calumet Harbor (Johnston 1991; Barnes 1999), down to Lockport Lock and Dam (INHS undated). Therefore, habitat is assumed to be suitable in the CAWS.

The Nonstructural Alternative is not expected to affect habitat suitability for the threespine stickleback in the CAWS.

T_{10}: See T_0. Habitat in the CAWS is expected to remain suitable for the threespine stickleback.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The threespine stickleback has been found in multiple locations in the CAWS; therefore, suitable habitat is present (section 3d). It is found in the CSSC as far south as the Lockport Lock and Dam, which is less than 11.3 km (7 mi) from Brandon Road Lock and Dam. The species may be small enough to pass through the Electric Dispersal Barrier System, and no other barriers are expected to control the downstream movement of this species (section 3c).

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the threespine stickleback by natural dispersion to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Low	Low	Low
Nonstructural Alternative Rating	Medium	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The threespine stickleback has been present in the CAWS since 1988, and there does not appear to be any significant barriers to passage. However, this species has yet to be identified in the Mississippi River Basin below Brandon Road Lock and Dam. Why this species has not established in the Mississippi River Basin is uncertain, although it may be present in the basin but not yet detected. Surveys of the lower Illinois River are required to determine whether the species is present at this time step.

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0. Given the documented proximity of this species to Brandon Road Lock and Dam and the lack of barriers to passage, it is more certain that over time, this species would pass downstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. **P(spreads) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

PATHWAY 5

BURNS SMALL BOAT HARBOR (BSBH) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge Water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to P(establishment) because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	None	High	None	High	None	High	None
P(passage)	High	Medium	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	High	Low	High	Low	High	Low	High	Low
P(establishment)	High	–[a]	High	–	High	–	High	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Burns Small Boat Harbor (BSBH) and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The threespine stickleback is an actively swimming fish that forms schools. It lays eggs in a nest on the bottom of a water body (NatureServe 2010); therefore, eggs and larvae are not expected to be transported by currents unless resuspended into the water column by a disturbance. The threespine stickleback reached Illinois accidentally as the result of the Welland Canal, built in the 1820s (Laird and Page 1996).

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback at the CAWS from natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

There is lakewise recreational vessel traffic to the BSBH (USACE 2011b). Although transport in ballast water is possible for this species, it was not described in the literature as a transport mechanism for the threespine stickleback.

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback from human-mediated transport.

c. Current Abundance and Reproductive Capacity

T_0: All eggs within a clutch are laid as a single batch in the nest of a single male (Wootton 2009). There may be 15 eggs in a very small female, to more than 1,000 eggs in exceptionally large females (Baker et al. 2008). Mean breeding season fecundity equals 2,060 eggs per female (Copp and Kovac 2003). Minimum population doubling time is less than 15 months (Fishbase undated). They are considered established in southern Lake Michigan, which connects to the BSBH.

It is uncertain whether the Nonstructural Alternative may reduce the current abundance and reproductive capacity of the threespine stickleback in the Great Lakes.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The threespine stickleback has arrived at the BSBH.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: The threespine stickleback is considered established in southern Lake Michigan and the CAWS. It was found near the BSBH at the Indiana Dunes National Lakeshore (Fuller 2011).

The Nonstructural Alternative is not expected to reduce the threespine stickleback's distance from the pathway. The threespine stickleback is already at the pathway.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The threespine stickleback is found from Arctic to temperate climates. The native range of the threespine stickleback is Arctic and Atlantic drainages from Baffin Island and the western side of Hudson Bay, to Cape Fear Estuary, North Carolina (Page and Burr 1991), and Pacific drainages from Alaska to Baja California (Fuller 2011). Eastern freshwater populations are found far inland, including Lake Ontario (Fuller 2011). In the Great Lakes, the species is native only below Niagara Falls (Smith 1985). The threespine stickleback inhabits coastal marine, brackish, and an array of freshwater habitats ranging from tiny ephemeral streams in arid desert regions to large Arctic lakes (Willacker et al. 2010); populations can be wholly marine, anadromous, or strict residents of freshwater (Willacker et al. 2010). The species is found in sluggish waters of lakes, ponds, large lowland rivers, estuaries, and marine coastlines. Freshwater populations usually inhabit shallow vegetated water (NatureServe 2010). All populations spawn in freshwater in shallow, soft bottoms (Laird and Page 1996). These fish are small (up to 10 cm [3.9 in]), visual predators (Gill and Hart 1994) that feed on invertebrates such as crustaceans and insect larvae, as well as fish eggs, fish larvae, and plant matter (Wootton 1976). The species is found in a wide range of flowing and stillwater habitats (Rushbrook et al. 2010) but seems to prefer low velocities (Copp and Kovac 2003).

The Nonstructural Alternative is not expected to reduce the habitat suitability for the threespine stickleback in southern Lake Michigan.

T_{10}: See T_0. Habitat near the BSBH is expected to remain suitable for the threespine stickleback.
T_{25}: See T_{10}.
T_{50}: See T_{10}.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The threespine stickleback is documented as established in southern Lake Michigan, and it has been found in the CAWS (section 2e). Suitable habitat is present in the vicinity of the BSBH (section 2f).

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback at the CAWS through aquatic pathways. The species has already arrived at the pathway. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. No changes in the habitat of Lake Michigan are expected to alter the probability of arrival at the BSBH.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	None	None	None	None
Nonstructural Alternative Rating	None	None	None	None

Evidence for Uncertainty Rating

T_0: The species is documented near the BSBH pathway and is established in the CAWS.

The Nonstructural Alternative is not expected to affect the arrival of the threespine stickleback, which is already present at the pathway. Therefore, the uncertainty remains none.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The species is an actively swimming fish that forms schools. It lays eggs in a nest on the bottom of a water body (NatureServe 2010); therefore, eggs and larvae are not expected to be transported by currents unless resuspended into the water column by a disturbance.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the threespine stickleback through the aquatic pathway;

therefore, this alternative is not expected to affect the mobility/invasion speed of the threespine stickleback as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

Although not documented in the literature, the threespine stickleback may potentially be transported in ballast water. There is only lakewise commercial vessel traffic to and from the BSBH (USACE 2011a,b). Threespine sticklebacks actively swim and do not require humans for dispersal. Therefore, natural dispersal by swimming would likely be the primary mechanism of movement through the CAWS

The Nonstructural Alternative is not expected to address the human-mediated transport of the threespine stickleback through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: The threespine stickleback is found within the CAWS (Johnston 1991; Barnes 1999). The Electric Dispersal Barrier System located north of Lockport Lock and Dam may act as a barrier within the CAWS by repelling adult fish. However, the Electric Dispersal Barrier System does not appear to be highly effective against small fish. In addition, adult threespine sticklebacks that are shocked would flow downstream through the barrier. Thus, there is a high potential that adults may pass through the barrier at the current setting. In addition, eggs/larvae that are resuspended in the water column by boat propellers may pass through the Electric Dispersal Barrier System. Brandon Road Lock and Dam and Lockport Lock and Dam are not expected to control the passage of this species through the pathway.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See $T_{0.}$

T_{25}: See $T_{0.}$

T_{50}: See $T_{0.}$

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The threespine stickleback typically inhabits weedy pools or backwaters, or occurs among emergent plants at stream edges (NatureServe 2010). Although living, submerged aquatic vegetation is not common in the CAWS, it is found in the CSSC in low density (LimnoTech 2010). Plant debris is present in the CAWS, although it is not a dominant substrate component (LimnoTech 2010). The CAWS is a turbid water system with a low flow of 0.05–0.27 m/s (0.16–0.89 ft/s) (LimnoTech 2010). The species is found in a wide range of flowing and stillwater habitats (Rushbrook et al. 2010) but seems to prefer low velocities (Copp and Kovac 2003). Threespine sticklebacks have been recorded in the CAWS, including the North Shore Channel, Calumet River, CSSC, Burns Harbor, and Calumet Harbor (Johnston 1991; Barnes 1999), down to Lockport Lock and Dam (INHS undated). Therefore, habitat is assumed to be suitable in the CAWS.

The Nonstructural Alternative is not expected to affect habitat suitability for the threespine stickleback in the CAWS.

T_{10}: See T_0. Habitat in the CAWS is expected to remain suitable for the threespine stickleback.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The threespine stickleback has been found in multiple locations in the CAWS; therefore suitable habitat is present (section 3d). It is found in the CSSC as far south as the Lockport Lock and Dam, which is less than 11.3 km (7 mi) from Brandon Road Lock and Dam. The species may be small enough to pass through the Electric Dispersal Barrier System, and no other barriers are expected to control the downstream movement of this species (section 3c).

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the threespine stickleback by natural dispersion to Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Low	Low	Low
Nonstructural Alternative Rating	Medium	Low	Low	Low

Evidence for Uncertainty Rating

T_0: The threespine stickleback has been present in the CAWS since 1988, and there does not appear to be any significant barriers to passage. However, this species has yet to be identified in the Mississippi River Basin below Brandon Road Lock and Dam. Why this species has not established in the Mississippi River Basin is uncertain, although it may be present in the basin but not yet detected. Surveys of the lower Illinois River are required to determine whether the species is present at this time step.

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0. Given the documented proximity of this species to Brandon Road Lock and Dam and the lack of barriers to passage, it is more certain that over time, this species would pass downstream of Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to affect the passage of the threespine stickleback through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Risk Assessment.

Uncertainty: LOW

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E.2.2.4.2 Ruffe (*Gymnocephalus cernuus*)

NONSTRUCTURAL ALTERNATIVE

This alternative would potentially include a combination of the following measures that may be implemented at time step 0 (T_0, in units of years) by local, state, and federal agencies and the public. The Nonstructural Alternative would include the development of a monitoring and response program.

Nonstructural Alternative Measures for the Ruffe

Option or Technology	Description	
Education and Outreach	• Signage, pamphlets, brochures addressing how to identify and control the spread of ANS; national campaigns/promotion (i.e., ”Stop Aquatic Hitchhikers”) • Education of recreational waterway users and bait shop owners	
Ballast/Bilge-water Exchange	• Ballast/bilge-water exchange	
Monitoring	• Agency monitoring • Voluntary occurrence reporting	
Laws and Regulations	• FWS Lacey Act listing • Mandatory watercraft inspection and decontamination • Prohibition of sale, husbandry, transport, release • Quarantine-restricted site access	
	ANS Controls	**ANS Fact Sheet**[a]
ANS Control Methods	Piscicides	Piscicides
	Controlled harvest and overfishing	Controlled harvest and overfishing
	Desiccation (water drawdown)	Lethal temperature

[a] For more information, refer to GLMRIS Team (2012).

PATHWAY 1

WILMETTE PUMPING STATION (WPS) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Medium	Low	Medium	Medium	High
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to P(establishment) because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Medium	Low	Medium	Medium	High
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Wilmette Pumping Station and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not impact the pathway for the ruffe.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW-MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The natural dispersion rates of the ruffe are not well known because ballast-water transport has been the key spread vector in the Great Lakes (FWS 1996). Ruffe can spread quickly by vessel transport and can quickly become abundant (FWS 1996; Bauer et al. 2007), having spread across the northern Great Lakes in a decade (Fuller et al. 2012). In the 9 years since its detection in Lake Michigan, the ruffe has not spread beyond Green Bay (Bowen and Goehle 2011). The eggs and larvae of the species are benthic, not free-floating (Ogle 1998), so the transport of eggs by currents is unlikely.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the Chicago Area Waterway System (CAWS) from natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Ruffe can spread quickly by vessel transport and can quickly become abundant (FWS 1996; Bauer et al. 2007); human-mediated transport is likely to be more important for arrival at the southern Great Lakes than natural dispersion. The species can be transported in ballast water (Pratt et al. 1992), but there is no cargo vessel traffic between northern Lake Michigan and the WPS (USACE 2011a). However, recreational boat traffic and lakewise commercial vessel traffic are present and ballast-water discharge occurs at other CAWS ports in southern Lake Michigan.

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting, which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular, piscicides. The implementation of a ballast/bilge-water exchange program, education and outreach, and laws and regulations may reduce the human-mediated transport of the ruffe to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: The species is not widespread, and there are no high-density populations in Lake Michigan (Bowen and Goehle 2011). Females produce up to 200,000 eggs in the first batch and up to 6,000 eggs per subsequent batch (Global Invasive Species Database 2006). The ruffe reaches sexual maturity in 2 or 3 years or in 1 year in warmer waters

(White 2002). Over the last decade, the abundance of ruffe has declined and/or leveled off in many locations where the fish is currently established (Bowen and Goehle 2011). Ruffe populations are currently monitored. Past control efforts, such as stocking of predators and removal by trawling, were not considered effective (Jensen 2006).

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular, piscicides. However, the ruffe population is currently too dispersed to be effectively controlled with occasional application of piscicides in localized areas.

If localized populations are found in shallow localized waters, desiccation (water drawdown) may be implemented. Desiccation is not expected to effectively control the ruffe, because the species is currently established in deep-water environments where implementation of such a control is not feasible. Because of the small size and widespread distribution of the ruffe, neither controlled harvest nor overfishing is expected to effectively control the arrival of the ruffe at the CAWS pathway.

T_{10}: See T_0. The abundance of the ruffe at its current locations could increase or decrease because of natural population fluctuations or interactions with other species, such as the round goby (Bowen and Goehle 2011).

T_{25}: See T_{10}.

T_{50}: See T_{10}. In the future, ruffe abundance could increase or decrease (Bowen and Goehle 2011). Examples of future changes potentially affecting the abundance of ruffe include natural population fluctuations, climate change, new diseases, and control measures.

d. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: None.

T_{25}: None.

T_{50}: None.

e. Distance from Pathway

T_0: The ruffe exists in northern Lake Michigan in Green Bay/Bay de Noc; it has not been detected outside of Green Bay (Bowen and Goehle 2011). The Nonstructural Alternative includes ballast/bilge-water exchange programs, which may increase the time for the ruffe to arrive at the CAWS pathway. Ruffe can spread quickly by vessel-mediated transport and can quickly become abundant (FWS 1996; Bauer et al. 2007), having spread across the northern Great Lakes in a decade (Fuller et al. 2012). Ballast/bilge-water transport is believed to assist the dispersion of the ruffe in the Great Lakes.

T_{10}: See T_0. Ruffe could move closer to the WPS by spreading through the suitable habitat along Lake Michigan or by vessel transport to southern Lake Michigan. Ballast/bilge-water exchange programs may increase the time it takes for the ruffe to arrive at the CAWS pathway.

T_{25}: See T_{10}.

T_{50}: See T_{10}. In the future, the distance of the ruffe from the CAWS could increase or decrease. Examples of future changes potentially affecting the distribution of ruffe in the Great Lakes include natural population growth, climate change, new diseases, and control measures.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: On the basis of its native distribution in northern Europe and Asia (Fuller and Jacobs 2011), the ruffe appears to be more of a cold-water species. Ruffe also prefer still or slow-moving water (FishBase 2010), and the exposed high-energy shoreline along most of Lake Michigan may not be suitable habitat. The numerous river mouths along the shoreline of Lake Michigan and deeper offshore waters would be suitable (White 2002; Peterson et al. 2011; Schleuter and Eckmann 2008). The harbor at the WPS may be a suitable habitat, as are other harbors in the Great Lakes. Rasmussen (2002) states that the ruffe is a true cool-water species (it prefers water temperatures between 10 and 20°C [50 and 68°F]) and that temperature preference may discourage movement south into the Illinois River.

The Nonstructural Alternative is not expected to reduce the habitat suitability for the ruffe in southern Lake Michigan.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Future climate change may alter the physical, hydraulic, chemical, and climatological suitability of the Great Lakes and their tributaries for the ruffe. Water temperatures and stream flows, in particular, may be altered, potentially affecting the distribution of this species. On the basis of its native distribution in northern Europe and Asia (Fuller and Jacobs 2011), the ruffe appears to be more of a cold-water species. Temperature increases related to future climate change (Wuebbles et al. 2010) may affect its spread south from the upper Great Lakes.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating	Low	Low	Low	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: Currently, this species is not located near the WPS and has not spread from Green Bay (sections 2d, 2e), suggesting that there is currently low propagule pressure for the species. However, suitable habitat is present near the WPS (sections 2c, 2f). Ruffe can potentially be transported via ballast water to southern Lake Michigan (sections 2a, 2b), but there is no cargo vessel traffic to the WPS (section 2b). However, ruffe could be transported to southern Lake Michigan by vessel traffic to other CAWS ports. Existing control measures are unlikely to reduce the abundance of ruffe in its current locations. This species is unlikely to spread from Green Bay to the WPS during the current time step, given that it has not been detected in southern Lake Michigan during a decade of monitoring (section 2a).

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's low probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Over 50 years, the probability increases that ruffe would have time to spread to the WPS by natural dispersion alone or by a combination of human-mediated transport to the southern Great Lakes and natural dispersion to the WPS.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's medium probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	High
Nonstructural Alternative Rating	Low	Medium	Medium	High

Evidence for Uncertainty Rating

T_0: The natural dispersal speed of the ruffe is not well characterized. It is uncertain why this species has not spread more widely into southern Lake Michigan. However, this species is not known to have spread into southern Lake Michigan over the last decade.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.

T_{10}: See T_0. The future population trends and future rate of spread of the ruffe are uncertain. The arrival of the ruffe at the WPS could increase or decrease over time, depending on the trends in the distribution and abundance of ruffe populations in the Great Lakes. The ruffe population has fluctuated over time, and the species is subject to control measures. Therefore, over time, trends in future populations and spread rates become less certain. Ruffe have not spread to southern Lake Michigan in the last decade, although they may move closer to the WPS with time.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, uncertainty remains medium.

T_{25}: See T_{10}.

T_{50}: See T_{10}. On the basis of its native distribution, the ruffe appears to be more of a cold-water species, and temperature increases related to climate change may affect its distribution (section 2f). Thus, climate change could limit the movement of the ruffe into southern Lake Michigan (section 2f).

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, uncertainty remains high.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The ruffe is a small fish. Rates of natural dispersion are not well known because ballast-water transport has been a key spread vector (FWS 1996). The species can quickly become abundant (FWS 1996; Bauer et al. 2007). The eggs and larvae of the species are benthic, not free-floating (Ogle 1998), so the transport of eggs by currents is unlikely.

The Nonstructural Alternative is not expected to address natural dispersion (i.e., swimming and passive drift) of the ruffe through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the ruffe as it passes through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

The distance from the WPS to the Brandon Road Lock and Dam is more than 64 km (40 mi). While the species can be transported in ballast water (Dawson et al. 2006), there is no commercial or recreational vessel traffic between the WPS and the Brandon Road Lock and Dam (USACE 2011a,b). Therefore, natural dispersal would likely be the primary mechanism of movement through the CAWS from the WPS. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the ruffe into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

The Nonstructural Alternative is not expected to address the human-mediated transport of the ruffe through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: Ruffe could be transported from Lake Michigan into the North Shore Channel via water pumped from the lake into the channel. Depending on its life stage (Kovac 1998) and the season and time of day (Brown et al. 1998; White 2002; Peterson et al. 2011), the ruffe moves from shallow (less than 10 m; 32.8 ft) to deep water (greater than 80 m; 262 ft). The water depth in the Chicago River and Chicago Sanitary and Ship Canal (CSSC) is less than 9.1 m (30 ft) and less than 4.6 m (15 ft), respectively, in many areas. The electric barrier dispersal system located north of the Lockport Lock and Dam may act as a barrier to some degree by repelling adult fish. However, electric barriers do not appear to be highly effective against the ruffe (Dawson et al. 2006), and adults that are shocked could flow downstream through the barrier. So there is a high potential that adults may pass the barrier at its current setting. Also, eggs/larvae that are re-suspended in the water column by boat propellers may pass through the electric barrier.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The North Shore Channel has riprap banks, macrophyte cover, and bank pocket areas (LimnoTech 2010) that could provide physical habitat suitable for the ruffe (Fullerton and Lamberti 2006; Bauer et al. 2007). The CAWS has abundant soft bottom and sand, which is the preferred substrate for this species (FishBase 2010). The ruffe prefers still or slow-flowing water (FishBase 2010), which is typical of the CAWS except during high flows. Generalist fish like the ruffe are found throughout the CAWS (LimnoTech 2010). Rasmussen (2002) states that the ruffe is a true cool-water species (it prefers water temperatures between 10 and 20°C [50 and 68°F]) and that temperature preference may discourage movement south into the Illinois River. Dissolved oxygen in the CAWS may be too low in certain areas or during certain times of the year, but overall dissolved oxygen is adequate (Crosier and Malloy 2005; MWRD 2010) and does not explain fish distribution well (LimnoTech 2010). The ruffe can spawn in multiple habitat types found in the CAWS, including submerged plants, logs, branches, gravel, and rocks (Ogle 1998; LimnoTech 2010). The ruffe likely expanded its range in Europe through canals, and it is found throughout canals in Europe (Indiana Department of Natural Resources 2005; Zoetemeyer 2007).

The Nonstructural Alternative is not expected to affect habitat suitability for the ruffe in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The sluice gate at the WPS would act as a temporary barrier, but water pumped from Lake Michigan into the North Shore Channel could transport ruffe into the CAWS. Human-mediated transport from the WPS to the Brandon Road Lock and Dam is unlikely (section 3b); Ruffe spread through canals (section 3d). Suitable adult and reproductive habitat is present throughout the CAWS (section 3e). The electric dispersal barrier system is not likely to control downstream passage (section 3c). However, the distance from the WPS to the Brandon Road Lock and Dam may be too long for the ruffe to travel within the current time step.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the ruffe by natural dispersion to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Over time, the ruffe has a higher probability of spreading through the aquatic pathway by natural dispersion.

T_{25}: See T_{10}. The ruffe has a higher probability of spreading through the aquatic pathway by natural dispersion over a 25-year time frame.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: The potential speed of natural dispersion through the CAWS is uncertain. Although habitat may not be optimal, it may not prohibit passage.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. The future rate of spread for this species is not well understood. However, habitat in the CAWS, although not optimal, may not prohibit passage, and it is more likely that ruffe would move through the CAWS to the Brandon Road Lock and Dam in 25 years compared with 10 years.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

PATHWAY 2

CHICAGO RIVER CONTROLLING WORKS (CRCW) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Medium	Low	Medium	Medium	High
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Medium	Low	Medium	Medium	High
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Chicago River Controlling Works (CRCW) and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW-MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Rates of natural dispersion of the ruffe are not well known because ballast-water transport has been the key spread vector in the Great Lakes (FWS 1996). Ruffe can spread quickly by vessel transport and can quickly become abundant (FWS 1996; Bauer et al. 2007), having spread across the northern Great Lakes in a decade (Fuller et al. 2012). However, within Lake Michigan the ruffe has not spread beyond Green Bay in the 9 years since its detection in that area (Bowen and Goehle 2011). Its eggs and larvae are benthic, not free-floating (Ogle 1998), so the transport of eggs by currents is unlikely.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS from natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Ruffe can spread quickly by vessel transport and can become abundant quickly (FWS 1996; Bauer et al. 2007); human-mediated transport is likely to be more important for its arrival at the southern Great Lakes than natural dispersion. This species can be transported in ballast water (Pratt et al. 1992), and there is vessel traffic between the CRCW and areas of the Great Lakes where the ruffe is located (USACE 2011a; NBIC 2012), and these vessels may discharge ballast water at the CRCW (NBIC 2012).

The Nonstructural Alternative may affect the arrival of the ruffe from human-mediated transport through aquatic pathways. Agency monitoring and voluntary occurrence reporting, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular, piscicides. The implementation of a ballast/bilge-water exchange program, education and outreach, and laws and regulations may reduce the human-mediated transport of the ruffe to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: The species is not widespread, and there are no high-density populations in Lake Michigan (Bowen and Goehle 2011). Females produce up to 200,000 eggs in the first batch, and up to 6,000 eggs per subsequent batch (Global Invasive Species Database 2006). The ruffe reaches sexual maturity in 2 or 3 years or in 1 year in warmer waters (White 2002). Over the last decade, the abundance of ruffe has declined and/or leveled off in many locations where the fish is currently established (Bowen and Goehle 2011).

Ruffe populations are currently monitored. Past control efforts, such as stocking of predators and removal by trawling, were not considered effective (Jensen 2006).

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular, piscicides. However, the ruffe population is currently too dispersed to be effectively controlled with occasional application of piscicides in localized areas.

If localized populations are found in shallow localized waters, desiccation (water drawdown) may be implemented. Desiccation is not expected to effectively control the ruffe, because the species is currently established in deep-water environments where implementation of such a control is not feasible. Because of the small size and widespread distribution of the ruffe, neither controlled harvest nor overfishing is expected to effectively control the arrival of the ruffe at the CAWS pathway.

T_{10}: See T_0. The abundance of the ruffe at its current locations could increase or decrease because of natural population fluctuations or interactions with other species, such as the round goby (Bowen and Goehle 2011).

T_{25}: See T_{10}.

T_{50}: See T_{10}. In the future, ruffe abundance could increase or decrease (Bowen and Goehle 2011). Examples of future changes potentially affecting the abundance of ruffe include natural population fluctuations, climate change, new diseases, and control measures.

d. *Existing Physical Human/Natural Barriers*

T_0: There are no existing barriers. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. *Distance from Pathway*

T_0: The ruffe exists in northern Lake Michigan in Green Bay/Bay de Noc, and has not been detected outside of Green Bay (Bowen and Goehle 2011).

The Nonstructural Alternative includes ballast/bilge-water exchange programs, which may increase the time for the ruffe to arrive at the CAWS pathway. Ruffe can spread quickly by vessel-mediated transport and can quickly become abundant (FWS 1996; Bauer et al. 2007), having spread across the northern Great Lakes in a decade (Fuller et al. 2012). Ballast/bilge-water transport is believed to assist dispersion of the ruffe in the Great Lakes.

T_{10}: See T_0. Ruffe could move closer to the CRCW by spreading through the suitable habitat along Lake Michigan or by vessel transport to southern Lake Michigan. Ballast/bilge-water exchange programs may increase the time it takes for the ruffe to arrive at the CAWS pathway.

T_{25}: See T_{10}.

T_{50}: See T_{10}. In the future, the distance of the ruffe from the CAWS could increase or decrease. Examples of future changes potentially affecting the distribution of ruffe in the Great Lakes include natural population growth, climate change, new diseases, and new aquatic nuisance species (ANS).

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: On the basis of its native distribution in northern Europe and Asia (Fuller and Jacobs 2011), the ruffe appears to be more of a cold-water species and prefers still or slow-moving water (FishBase 2010) The exposed high-energy shoreline along most of Lake Michigan may not be suitable habitat. The numerous river mouths along the shoreline of Lake Michigan and deeper offshore waters would be suitable (White 2002; Peterson et al. 2011; Schleuter and Eckmann 2008). The harbors around the CRCW may be suitable habitat, as are other harbors in the Great Lakes.

The Nonstructural Alternative is not expected to reduce the habitat suitability for the ruffe in southern Lake Michigan.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Future climate change may alter the physical, hydraulic, chemical, and climatological suitability of the Great Lakes and their tributaries for ruffe. Water temperature and stream flows, in particular, may be altered, potentially affecting the distribution of this species. On the basis of its native distribution in northern Europe and Asia (Fuller and Jacobs 2011), the ruffe appears to be more of a cold-water species, and temperature increases related to future climate change (Wuebbles et al. 2010) may affect its spread south from the upper Great Lakes.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating	Low	Low	Low	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: This species is not currently located near the CRCW and has not spread from Green Bay (sections 2d, 2e), suggesting that there is currently low propagule pressure for the species. However, suitable habitat is present near the CRCW (sections 2c, 2f). Ruffe can potentially be transported via ballast water to southern Lake Michigan (sections 2a, 2b), and there is cargo vessel traffic to the CRCW (section 2b). Existing control measures are unlikely to reduce the abundance of ruffe in its current locations. Natural dispersion is not well characterized, but this species is unlikely to spread from Green Bay to the CRCW during the current time step, given that it has not been detected in southern Lake Michigan during a decade of monitoring (section 2a).

The Nonstructural Alternative includes education and outreach, ballast/bilge-water exchange, monitoring, laws and regulations, and ANS control methods (e.g., piscicides, controlled harvest and overfishing, and desiccation). Overall, this alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's low probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Over 50 years, the probability increases that ruffe would have time to spread to the CRCW by natural dispersion alone or by a combination of human-mediated transport to the southern Great Lakes and natural dispersion to the CRCW.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's medium probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Medium	Medium	High
Nonstructural Alternative Rating	Low	Medium	Medium	High

Evidence for Uncertainty Rating

T_0: This species can be transported by ballast water; there is vessel traffic between the CAWS and areas where the ruffe is located. The potential for ruffe to be transported to the CRCW in ballast water is not well understood. Natural dispersal speed is not well characterized. It is uncertain why this species has not spread more widely into southern Lake Michigan. However, this species is not known to have spread into southern Lake Michigan over the last decade.

The Nonstructural Alternative includes education and outreach, ballast/bilge-water exchange, monitoring, laws and regulations, and ANS control methods (e.g., piscicides, controlled harvest and overfishing, and desiccation). Overall, this alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.

T_{10}: See T_0. The ruffe has spread across the northern Great Lakes in a decade by vessel traffic (section 2a), and there is known vessel traffic between the northern Great Lakes and the CRCW (section 2b). The future population trends and future rate of spread of the ruffe are uncertain. Therefore, the arrival of the ruffe at CRCW could increase or decrease over time, depending on the trends in the distribution and abundance of ruffe populations in the Great Lakes. However, ruffe has not spread to southern Lake Michigan in the last decade, although it may move closer to the CRCW with time.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, uncertainty remains medium.

T_{25}: See T_{10}.

T_{50}: See T_{10}. On the basis of its native distribution, the ruffe appears to be more of a cold-water species, and temperature increases related to climate change may affect its distribution (section 2f). Thus, climate change could limit the movement of the ruffe into southern Lake Michigan (section 2f).

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, uncertainty remains high.

3. P(passage) T_0-T_{50} : HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The ruffe is a small fish. The distance from the CRCW to the Brandon Road Lock and Dam is more than 64 km (40 mi). The rates of natural dispersion of the species are not well known because ballast-water transport has been a key spread vector (FWS 1996). This species is capable of becoming abundant quickly (FWS 1996; Bauer et al. 2007). Its eggs and larvae are benthic, not free-floating (Ogle 1998), so the transport of eggs by currents is unlikely.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the ruffe through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Ruffe can be transported in ballast water (Dawson et al. 2006), but there is little vessel traffic between the CRCW and the Brandon Road Lock and Dam (USACE 2011a), and ballast water originating from the Great Lakes is not likely to be discharged into inland ports of the Mississippi River Basin (NBIC 2012). In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the ruffe into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

The Nonstructural Alternative is not expected to address the human-mediated transport of the ruffe through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers. Depending on the life stage (Kovac 1998) season, and time of day (Brown et al. 1998; White 2002; Peterson et al. 2011), ruffe move from shallow (less than 10 m; 32.8 ft) to deep water (greater than 80 m; 262.5 ft). The water depth in the Chicago River and CSSC is less than 9.1 m (30 ft) and less than 4.6 m (15 ft), respectively, in many areas. The electric barrier dispersal system located north of the Lockport Lock and Dam may act as a barrier to some degree by repelling adult fish. However, electric barriers do not appear to be highly effective against ruffe (Dawson et al. 2006), and adults that are shocked could flow downstream through the barrier. So there is a high potential that adults may pass the barrier at its current setting. In addition, eggs/larvae that are re-suspended in the water column by boat propellers may pass through the electric barrier.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The CRCW is an urbanized area with primarily concrete or vertical steel walls lining the channel, but there are scattered areas of natural bank with rock and woody debris located in the south branch of the Chicago River. The CAWS has a soft silt and/or sand bottom, which are the preferred substrates for this species (LimnoTech 2010; FishBase 2010). Ruffe prefer eutrophic, still, or slow-flowing water (FishBase 2010), which is typical of the CAWS except during high flows (LimnoTech 2010). Generalist fish like the ruffe are found throughout the CAWS (LimnoTech 2010). Rasmussen (2002) states that the ruffe is a true cool-water species (it prefers water temperatures between 10 and 20°C [50 and 68°F]) and that temperature preference may discourage movement south into the Illinois River. Dissolved oxygen in the CAWS may be too low in certain areas or during certain times of the year, but overall dissolved oxygen is adequate (Crosier and Malloy 2005; MWRD 2010) and does not explain fish distribution well (LimnoTech 2010). The ruffe can spawn in multiple habitat types found in the CAWS, including submerged plants, logs, branches, gravel, and rocks (Ogle 1998; LimnoTech 2010). The ruffe likely expanded its range in Europe through canals, and it is found throughout canals in Europe (Indiana Department of Natural Resources 2005; Zoetemeyer 2007).

The Nonstructural Alternative is not expected to affect habitat suitability for the ruffe in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: It is more than 64 km (40 mi) from the CRCW to the Brandon Road Lock and Dam. It is unlikely that the ruffe would be transported through the CAWS by ballast water (section 3b); therefore, natural dispersion would be the most likely means of spreading to the Brandon Road Lock and Dam. The electric dispersal barrier system is not likely to control downstream passage (section 3c). Suitable habitat is present throughout the CAWS, but the distance from the CRCW to the Brandon Road Lock and Dam may be too far for the ruffe to travel within the current time step.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the ruffe by natural dispersion to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Over time, the ruffe has a high probability of spreading through the CAWS by natural dispersion. There do not appear to be any significant barriers to downstream movement.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{25}: See T_{10}. The ruffe has a high probability of spreading through the aquatic pathway by natural dispersion over a 25-year time frame.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: The effectiveness of the electric barrier on ruffe is not well understood. The potential speed of natural dispersion through the aquatic pathway is uncertain.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. The future rate of spread for this species is not well understood. However, habitat in the CAWS is suitable, and it is more likely that ruffe would move through the CAWS to the Brandon Road Lock and Dam in 25 years compared to 10 years.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{50}: See T_{25}.

4. **P(colonizes) T_0-T_{50}: MEDIUM**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

5. **P(spreads) T_0-T_{50}: MEDIUM**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

PATHWAY 3

CALUMET HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Medium	Low	Medium	Medium	High
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Medium	Low	Medium	Medium	High
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Calumet Harbor and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not impact the pathway for the ruffe.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW-MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The ruffe is a small fish. Its rate of natural dispersion is not well known because ballast-water transport has been a key spread vector (FWS 1996). Ruffe can spread quickly by vessel transport and quickly become abundant (FWS 1996; Bauer et al. 2007). However, within Lake Michigan, the ruffe has not spread beyond Green Bay in the 9 years since its detection in that area, and populations have been trending down (Bowen and Goehle 2011).

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS from natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

The ruffe can be transported in ballast water (Pratt et al. 1992), and there is vessel traffic between Calumet Harbor and areas of the Great Lakes where the ruffe is located (USACE 2011a; NBIC 2012); these vessels discharge ballast water at Calumet Harbor (NBIC 2012).

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular, piscicides. The implementation of a ballast/bilge-water exchange program, education and outreach, and laws and regulations may reduce the human-mediated transport of the ruffe to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: The species is not widespread, and there are no high-density populations in Lake Michigan (Bowen and Goehle 2011). Females produce up to 200,000 eggs in the first batch and up to 6,000 eggs per subsequent batch (Global Invasive Species Database 2006). The ruffe reaches sexual maturity in 2 or 3 years and in 1 year in warmer waters (White 2002). Over the last decade, the abundance of ruffe has declined and/or leveled off in many locations where it is currently established (Bowen and Goehle 2011). Ruffe populations are currently monitored. Past control efforts, such as stocking of predators and removal by trawling, were not considered effective (Jensen 2006).

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular, piscicides. However, the ruffe population is too dispersed to be effectively controlled with occasional application of piscicides in localized areas.

If localized populations are found in shallow localized waters, desiccation (water drawdown) may be implemented. Desiccation is not expected to effectively control the ruffe, because the species is currently established in deep-water environments where implementation of such a control is not feasible. Because of the small size and widespread distribution of the ruffe, neither controlled harvest nor overfishing is expected to effectively control the arrival of the ruffe at the CAWS pathway.

T_{10}: See T_0. The abundance of the ruffe at its current locations could increase or decrease because of natural population fluctuations or interactions with other species, such as the round goby (Bowen and Goehle 2011).

T_{25}: See T_{10}.

T_{50}: See T_{10}. In the future, ruffe abundance could increase or decrease (Bowen and Goehle 2011). Examples of future changes potentially affecting the abundance of ruffe include natural population fluctuations, climate change, new diseases, and control measures.

d. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: The ruffe exists in northern Lake Michigan in Green Bay/Bay de Noc and has not been detected outside of Green Bay (Bowen and Goehle 2011).

The Nonstructural Alternative includes ballast/bilge-water exchange programs, which may increase the time it takes for the ruffe to arrive at the CAWS pathway. Ruffe can spread quickly by vessel-mediated transport and can quickly become abundant (FWS 1996; Bauer et al. 2007), having spread across the northern Great Lakes in a decade (Fuller et al. 2012). Ballast/bilge-water transport is believed to assist the dispersion of the ruffe in the Great Lakes.

T_{10}: See T_0. Ruffe could move closer to Calumet Harbor by spreading through the suitable habitat along Lake Michigan or by vessel transport. Alternatively, its range could contract, decreasing the probability of arriving. Ballast/bilge-water exchange programs may increase the time it takes for the ruffe to arrive at the CAWS pathway.

T_{25}: See T_{10}.

T_{50}: See T_{10}. In the future, the distance of the ruffe from the CAWS could increase or decrease. Examples of future changes potentially affecting the distribution of ruffe in the Great Lakes include natural population growth, climate change, new diseases, and new ANS.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: On the basis of its native distribution in northern Europe and Asia (Fuller and Jacobs 2011), the ruffe appears to be more of a cold-water species that prefer still or slow-moving water (FishBase 2010). The exposed high-energy shoreline along most of Lake Michigan may not be suitable habitat. The numerous river mouths along the shoreline of Lake Michigan and deeper offshore waters would be suitable (White 2002; Peterson et al. 2011; Schleuter and Eckmann 2008). Calumet Harbor may be a suitable habitat, as are other harbors in the Great Lakes.

The Nonstructural Alternative is not expected to reduce the habitat suitability for the ruffe in southern Lake Michigan.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Future climate change may alter the physical, hydraulic, chemical, and climatological suitability of the Great Lakes and its tributaries for the ruffe. Water temperatures and stream flows, in particular, may be altered, potentially affecting the distribution of this species. On the basis of its native distribution in northern Europe and Asia (Fuller and Jacobs 2011), the ruffe appears to be more of a cold-water species, and temperature increases related to future climate change (Wuebbles et al. 2010) may affect its spread south from the upper Great Lakes.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating	Low	Low	Low	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: The species is not currently located near Calumet Harbor and has not spread from Green Bay (sections 2d, 2e), suggesting that there is currently low propagule pressure for the species. Existing control measures are unlikely to reduce the abundance of the ruffe in its current locations. Suitable habitat is present along the pathway (section 2f). Vessel transport via ballast water is a possibility (sections 2a, 2b). There is the potential for vessel-mediated transport to Calumet Harbor (section 2b). However, the ruffe is unlikely to spread from Green Bay to Calumet Harbor during the current time period, because this species has not been detected in southern Lake Michigan during a decade of monitoring (section 2a).

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's low probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0. Over 50 years, the probability increases that ruffe would have time to spread to Calumet Harbor by natural dispersion alone or by a combination of human-mediated transport to the southern Great Lakes and natural dispersion to Calumet Harbor.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's medium probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	High
Nonstructural Alternative Rating	Low	Medium	Medium	High

Evidence for Uncertainty Rating

T_0: This species can be transported by ballast water; there is vessel traffic between the CAWS and areas where the ruffe is located. The potential for ruffe to be transported to Calumet Harbor in ballast water is not well understood. The natural dispersal speed of the species is not well characterized. It is uncertain why this species has not spread more widely into southern Lake Michigan. However, this species is not known to have spread into southern Lake Michigan over the last decade.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.

T_{10}: See T_0. The future population trends and future rate of spread of the ruffe are uncertain. The probability of arrival of the ruffe at Calumet Harbor could increase or decrease over time, depending on the trends in the distribution and abundance of ruffe populations in the Great Lakes. Ruffe populations have fluctuated over time and are subject to control measures. Therefore, over time, trends in future populations and spread rates become less certain. The ruffe has not spread to southern Lake Michigan in the last decade, although it may move closer to Calumet Harbor with time.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the uncertainty remains medium.

T_{25}: See T_{10}.
T_{50}: See T_{10}. On the basis of its native distribution, ruffe appear to be more of a cold-water species, and temperature increases related to climate change may affect its distribution (section 2f). Thus, climate change could limit the movement of the ruffe into southern Lake Michigan (section 2f).

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the uncertainty remains high.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The ruffe is a small fish. The distance from Calumet Harbor to the Brandon Road Lock and Dam is more than 56.3 km (35 mi). The rate of natural dispersion of the ruffe is not well known because ballast-water transport has been a key spread vector (FWS 1996). The species can become abundant quickly (FWS 1996; Bauer et al. 2007).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the ruffe through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

There is a relatively small amount of southbound vessel traffic between Calumet Harbor and the Brandon Road Lock and Dam (USACE 2011a,b; NBIC 2012). There is heavy commercial vessel traffic between the Brandon Road Lock and Dam and the T.J. O'Brien Lock and Dam, which is approximately 8 km (5 mi) south of Calumet Harbor (USACE 2011a; NBIC 2012). Ruffe can be transported in ballast water (Dawson et al. 2006), but ballast water originating from the Great Lakes is not likely to be discharged into inland ports of the Mississippi River Basin (NBIC 2012). In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport the ruffe into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

The Nonstructural Alternative is not expected to address the human-mediated transport of the ruffe through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: The electric barrier dispersal system located north of the Lockport Lock and Dam may act as a barrier to some degree by repelling adult fish. However, electric barriers do not appear to be highly effective against ruffe (Dawson et al. 2006), and adults that are shocked could flow downstream through the barrier. So there is a high potential that adults may pass the barrier at the current setting. Also, eggs/larvae that are re-suspended in the water column by boat propellers may pass through the electric barrier.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Calumet Harbor is an industrial canal with primarily concrete or vertical steel banks, but unvegetated rocky shoreline and lake habitat are present close to the harbor. The

CAWS has a soft silt and/or sand bottom, which is the preferred substrate for this species (LimnoTech 2010; FishBase 2010). Ruffe prefers still or slow-flowing water (FishBase 2010), which is typical of the CAWS except during high flows (LimnoTech 2010). Generalist fish like the ruffe are found throughout the CAWS (LimnoTech 2010). Rasmussen (2002) states that the ruffe is a true cool-water species (it prefers water temperatures between 10 and 20°C [50 and 68°F]) and that temperature preference may discourage movement south into the Illinois River. Dissolved oxygen in the CAWS may be too low in certain areas or during certain times of the year, but overall dissolved oxygen is adequate (Crosier and Malloy 2005; MWRD 2010) and does not explain fish distribution well (LimnoTech 2010). The ruffe can spawn in multiple habitat types found in the CAWS, including submerged plants, logs, branches, gravel, and rocks (Ogle 1998; LimnoTech 2010). The ruffe likely expanded its range in Europe through canals, and it is found throughout canals in Europe (Indiana Department of Natural Resources; Zoetemeyer 2007).

The Nonstructural Alternative is not expected to affect habitat suitability for the ruffe in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: It is more than 48.3 km (30 mi) from Calumet Harbor to the Brandon Road Lock and Dam. It is unlikely that the ruffe would be transported through the CAWS by ballast water (section 3b); therefore, natural dispersion would be the most likely means of spreading from Calumet Harbor to the Brandon Road Lock and Dam. Suitable habitat is present throughout the CAWS, but the distance from Calumet Harbor to the Brandon Road Lock and Dam is substantial for the ruffe to travel within the current time step, and the electric barriers may slow, but not control, downstream movement.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the ruffe by natural dispersion to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Over time, the ruffe has a high probability of spreading through the aquatic pathway by natural dispersion. There do not appear to be any significant barriers to downstream movement.

T_{25}: See T_{10}. The ruffe has a high probability of spreading through the aquatic pathway by natural dispersion over a 25-year time frame.
T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: The effectiveness of the electric barrier on ruffe is not well understood. The potential speed of natural dispersion in the CAWS is unknown.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.
T_{10}: See T_0.
T_{25}: See T_0. The future rate of spread for this species is not known. However, habitat in the CAWS is suitable, and it is more certain that ruffe would move through the CAWS to the Brandon Road Lock and Dam in 25 years compared to 10 years.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.
T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

PATHWAY 4

INDIANA HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Medium	Low	Medium	Medium	High
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Medium	Low	Medium	Medium	High
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Indiana Harbor and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW-MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The ruffe is a small benthic fish. The eggs and larvae of the species are benthic, not free-floating (Ogle 1998), so the transport of eggs by currents is unlikely. Its rates of natural dispersion are not well known because ballast-water transport has been a key spread vector for the species (FWS 1996). The species can become abundant quickly (FWS 1996; Bauer et al. 2007). However, within Lake Michigan, the ruffe has not spread beyond Green Bay in the 9 years since its detection in that area, and populations have been trending down (Bowen and Goehle 2011).

The Nonstructural Alternative is not expected to affect the arrival of the ruffe from natural dispersion through aquatic pathways to the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

The ruffe can be transported in ballast water (Pratt et al. 1992), and there is vessel traffic between Indiana Harbor and areas of the Great Lakes where the ruffe is located (USACE 2011a; NBIC 2012). Although these vessels do discharge ballast water at Indiana Harbor (NBIC 2012), fewer than 120 vessels have done so, and most of these were not from areas where the ruffe is known to exist. However, vessels from ports along western Lake Michigan and Green Bay did discharge ballast water at Indiana Harbor (NBIC 2012).

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular, piscicides. The implementation of a ballast/bilge-water exchange program, education and outreach, and laws and regulations may reduce the human-mediated transport of the ruffe to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: The species is not widespread, and there are no high-density populations in Lake Michigan (Bowen and Goehle 2011). Females produce up to 200,000 eggs in the first batch and up to 6,000 eggs per subsequent batch (Global Invasive Species Database 2006). The ruffe reaches sexual maturity in 2 or 3 years and in 1 year in warmer waters (White 2002). Over the last decade, the abundance of ruffe has declined and/or leveled off in many locations where it is currently established (Bowen and Goehle 2011). Ruffe populations are currently monitored. Past control efforts, such as stocking of predators and removal by trawling, were not considered effective (Jensen 2006).

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular, piscicides. However, the current population of the ruffe is too dispersed to be effectively controlled with occasional application of piscicides in localized areas.

If populations are found in shallow localized waters, desiccation (water drawdown) may be implemented. Desiccation is not expected to effectively control the ruffe, because the species is currently established in deep-water environments where implementation of such a control is not feasible. Because of the small size and widespread distribution of the ruffe, neither controlled harvest nor overfishing is expected to effectively control the arrival of the ruffe at the CAWS pathway.

T_{10}: See T_0. The abundance of the ruffe at its current locations could increase or decrease because of natural population fluctuations or interactions with other species, such as the round goby (Bowen and Goehle 2011).

T_{25}: See T_{10}.

T_{50}: See T_{10}. In the future, ruffe abundance could increase or decrease (Bowen and Goehle 2011). Examples of future changes potentially affecting the abundance of ruffe include natural population fluctuations, climate change, new diseases, and control measures.

d. Existing Physical Human/Natural Barriers

T_0: There are no existing physical barriers. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: The ruffe exists in northern Lake Michigan in Green Bay/Bay de Noc and has not been detected outside of Green Bay (Bowen and Goehle 2011).

The Nonstructural Alternative includes ballast/bilge-water exchange programs, which may increase the time it takes for the ruffe to arrive at the CAWS pathway. Ruffe can spread quickly by vessel-mediated transport and can quickly become abundant (FWS 1996; Bauer et al. 2007), having spread across the northern Great Lakes in a decade (Fuller et al. 2012). Ballast/bilge-water transport is believed to assist dispersion of the ruffe in the Great Lakes.

T_{10}: See T_0. Ruffe could move closer to Indiana Harbor by spreading through the suitable habitat along Lake Michigan or by vessel transport. Alternatively, its range could contract, decreasing its probability of arriving. Ballast/bilge-water exchange programs may increase the time it takes for the ruffe to arrive at the CAWS pathway.

T_{25}: See T_{10}.

T_{50}: See T_{10}. In the future, the distance of the ruffe from the CAWS could increase or decrease. Examples of future changes potentially affecting the distribution of ruffe in the Great Lakes include natural population growth, climate change, new diseases, and new ANS.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: On the basis of its native distribution in northern Europe and Asia (Fuller and Jacobs 2011), the ruffe appears to be more of a cold-water species and prefers still or slow-moving water (FishBase 2010). The exposed high-energy shoreline along most of Lake Michigan may not be suitable habitat. The numerous river mouths along the shoreline of Lake Michigan and deeper offshore waters would be suitable (White 2002; Peterson et al. 2011; Schleuter and Eckmann 2008). Indiana Harbor may be suitable habitat, as are other harbors in the Great Lakes.

The Nonstructural Alternative is not expected to reduce the habitat suitability for the ruffe in southern Lake Michigan.

T_{10}: See T_0.

T_{25}: See T_0. Future climate change may alter the physical, hydraulic, chemical, and climatological suitability of the Great Lakes and its tributaries for the ruffe. Water temperatures, stream flows, and water depth in particular may be altered, potentially affecting the distribution of this species. On the basis of its native distribution in northern Europe and Asia (Fuller and Jacobs 2011), the ruffe appears to be more of a cold-water species, and temperature increases related to future climate change (Wuebbles et al. 2010) may affect its spread south from the upper Great Lakes.

T_{50}: See T_{25}.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating	Low	Low	Low	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: The species is not currently located near Indiana Harbor and has not spread from Green Bay (section 2e). On the basis of its restricted distribution, propagule pressure relative to the CAWS appears to be low (section 2d). Existing control measures are unlikely to reduce the abundance of ruffe in its current locations. Suitable habitat is present along the pathway (section 2f). Vessel transport via ballast water is a possibility (sections 2a, 2b). Despite the potential for vessel-mediated transport to the CAWS (section 2b), this species has not been detected in southern Lake Michigan since its discovery in Lake Michigan (section 2a).

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's low probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Given time to naturally disperse, the species may be able to reach the pathway over a 50-year period.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's medium probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	High
Nonstructural Alternative Rating	Low	Medium	Medium	High

Evidence for Uncertainty Rating

T_0: This species can be transported by ballast water; there is vessel traffic between the CAWS and areas where the ruffe is located, although the potential for ruffe to be transported to Indiana Harbor in ballast water is not well understood. It is uncertain why this species has not spread more widely into southern Lake Michigan. However, this species is not known to have spread into southern Lake Michigan over the last decade.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.

T_{10}: See T_0. The future population trends and future rate of spread of the ruffe are uncertain. The potential for arrival of the ruffe at Indiana Harbor could increase or decrease over time, depending on the trends in the distribution and abundance of ruffe populations in the Great Lakes. Ruffe populations have fluctuated over time and are subject to control measures. Therefore, over time, trends in future populations and spread rates become less certain. The ruffe has not spread to southern Lake Michigan in the last decade, although it may move closer to the Indiana Harbor with time.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, uncertainty remains medium.

T_{25}: See T_{10}.

T_{50}: See T_{25}. On the basis of its native distribution, the ruffe appears to be more of a cold-water species, and temperature increases related to climate change may affect its distribution (section 2f). Thus, climate change could limit the movement of ruffe into southern Lake Michigan (section 2f).

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, uncertainty remains high.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The ruffe is a small fish. The distance from Indiana Harbor to the Brandon Road Lock and Dam is more than 56.3 km (35 mi). Rates of natural dispersion for the species are not well known because ballast-water transport has been a key spread vector (FWS 1996). The ruffe can become abundant quickly (FWS 1996; Bauer et al. 2007).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the ruffe through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Most commercial vessel traffic to Indiana Harbor is lakewise (NBIC 2012). There is no vessel traffic in the Grand Calumet River east of Indiana Harbor. Ruffe can be transported in ballast water (Dawson et al. 2006), but ballast water originating from the Great Lakes is not likely to be discharged into inland ports of the Mississippi River Basin (NBIC 2012).

The Nonstructural Alternative is not expected to address the human-mediated transport of the ruffe through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: Just to the west of its junction with the Indiana Harbor Canal, the Grand Calumet channel is blocked by sheet pile. The electric barrier dispersal system located north of the Lockport Lock and Dam may act as a barrier to some degree by repelling adult fish. However, electric barriers do not appear to be highly effective against ruffe (Dawson et al. 2006), and adults that are shocked could flow downstream through the barrier. So there is a high potential that adults may pass the barrier at its current setting. In addition, eggs/larvae that are re-suspended in the water column by boat propellers may pass through the electric barrier.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Indiana Harbor is an industrial canal with primarily concrete or vertical steel banks, but there is vegetated and rocky shoreline close to the harbor. Overall, the CAWS has a soft bottom and sand, which are the preferred substrates for this species (LimnoTech 2010; FishBase 2010). The ruffe prefers still or slow-flowing water (FishBase 2010), which is typical of the CAWS except during high flows (LimnoTech 2010). Generalist fish like the ruffe are found throughout the CAWS (LimnoTech 2010). Rasmussen (2002) states that the ruffe is a true cool-water species (it prefers water temperatures between 10 and 20°C [50 and 68°F]) and that temperature preference may discourage movement south into the Illinois River. Dissolved oxygen in the CAWS may be too low in certain areas or during certain times of the year, but overall dissolved oxygen is adequate (Crosier and Malloy 2005; MWRD 2010) and does not explain fish distribution well (LimnoTech 2010). The ruffe can spawn in multiple habitat types found in the CAWS, including submerged plants, logs, branches, gravel, and rocks (Ogle 1998; LimnoTech 2010). The ruffe likely expanded its range in Europe through canals and it is found throughout canals in Europe (Indiana Department of Natural Resources 2005; Zoetemeyer 2007).

The Nonstructural Alternative is not expected to affect habitat suitability for the ruffe in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: It is more than 48.3 km (30 mi) from Indiana Harbor to the Brandon Road Lock and Dam. It is unlikely that the ruffe would be transported through the CAWS by ballast water (section 3b); therefore, natural dispersion would be the most likely means of spreading to the Brandon Road Lock and Dam. Suitable habitat is present throughout the CAWS, but the distance from Indiana Harbor to the Brandon Road Lock and Dam may be too far for the ruffe to travel within the current time step. The sheet pile in the Grand Calumet River and the variable flow direction may slow the initial spread of the ruffe toward the Brandon Road Lock and Dam (sections 3c, 3d).

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the ruffe by natural dispersion to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Over time, the ruffe has a high probability of spreading through the aquatic pathway by natural dispersion.

T_{25}: See T_{10}. The ruffe has a high probability of spreading through the aquatic pathway by natural dispersion over a 25-year time frame.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: The effectiveness of the electric barrier on ruffe is not well understood. The potential speed of natural dispersion through the aquatic pathway is uncertain.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. The future rate of spread for this species is not well understood. However, habitat in the CAWS is suitable, and it is more certain that the ruffe would move through the aquatic pathway to the Brandon Road Lock and Dam in 25 years compared to 10 years.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

PATHWAY 5

BURNS SMALL BOAT HARBOR (BSBH) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Medium	Low	Medium	Medium	High
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Low	Medium	Low	Medium	Medium	High
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Low	–	Low	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating:

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Burns Small Boat Harbor (BSBH) and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating:

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW-MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The ruffe is a small fish. Its rates of natural dispersion are not well known because ballast-water transport has been a key spread vector (FWS 1996). The ruffe can spread quickly by vessel transport and can become abundant quickly (FWS 1996; Bauer et al. 2007). However, within Lake Michigan, the ruffe has not spread beyond Green Bay in the 9 years since its detection in that area, and populations have been trending down (Bowen and Goehle 2011).

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS from natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

The ruffe can be transported in ballast water (Pratt et al. 1992). There is recreational but not commercial vessel traffic from the Great Lakes to the BSBH. There is commercial vessel traffic to Burns Harbor, which is adjacent to the BSBH (USACE 2011a,b). Since 2004, fewer than 110 vessels have discharged ballast water at Burns Harbor, and most of these were not from areas where ruffe is known to exist (NBIC 2012).

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular, piscicides. The implementation of a ballast/bilge-water exchange program, education and outreach, and laws and regulations may reduce the human-mediated transport of the ruffe to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: The species is not widespread, and there are no high-density populations in Lake Michigan (Bowen and Goehle 2011). Females produce up to 200,000 eggs in the first batch and up to 6,000 eggs per subsequent batch (Global Invasive Species Database 2006). The ruffe reaches sexual maturity in 2 or 3 years and in 1 year in warmer waters (White 2002). Over the last decade, the abundance of ruffe has declined and/or leveled off in many locations where it is currently established (Bowen and Goehle 2011). Ruffe populations are currently monitored. Past control efforts, such as stocking of predators and removal by trawling, were not considered effective (Jensen 2006).

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular, piscicides. However, the current ruffe population is too dispersed to be effectively controlled with occasional application of piscicides in localized areas.

If localized populations are found in shallow localized waters, desiccation (water drawdown) may be implemented. Desiccation is not expected to effectively control the ruffe, because the species is currently established in deep-water environments where implementation of such a control is not feasible. Because of the small size and widespread distribution of the ruffe, neither controlled harvest nor overfishing is expected to effectively control the arrival of the ruffe at the CAWS pathway.

T_{10}: See T_0. The abundance of the ruffe at its current locations could increase or decrease because of natural population fluctuations or interactions with other species, such as the round goby (Bowen and Goehle 2011).

T_{25}: See T_{10}.

T_{50}: See T_{10}. In the future, ruffe abundance could increase or decrease (Bowen and Goehle 2011). Examples of future changes potentially affecting the abundance of ruffe include natural population fluctuations, climate change, new diseases, and control measures.

d. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: The ruffe exists in northern Lake Michigan in Green Bay/Bay de Noc and has not been detected outside of Green Bay (Bowen and Goehle 2011).

The Nonstructural Alternative includes ballast/bilge-water exchange programs, which may increase the time it takes for the ruffe to arrive at the CAWS pathway. Ruffe can spread quickly by vessel-mediated transport and can quickly become abundant (FWS 1996; Bauer et al. 2007), having spread across the northern Great Lakes in a decade (Fuller et al. 2012). Ballast/bilge-water transport is believed to assist dispersion of the ruffe in the Great Lakes.

T_{10}: See T_0. Ruffe could come closer to the BSBH by spreading through the suitable habitat along Lake Michigan or by vessel transport. Alternatively, its range could contract, decreasing its probability of arriving. Ballast/bilge-water exchange programs may increase the time it takes for the ruffe to arrive at the CAWS pathway.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Ruffe prefer still or slow-moving water (FishBase 2010), and the exposed high-energy shoreline along most of Lake Michigan may not be suitable habitat. The numerous river mouths along the shoreline of Lake Michigan and deeper offshore waters would be suitable (White 2002; Peterson et al. 2011; Schleuter and Eckmann 2008). The BSBH may be suitable habitat, as would other harbors in the Great Lakes.

The Nonstructural Alternative is not expected to reduce the habitat suitability for the ruffe in southern Lake Michigan.

T_{10}: See T_0.

T_{25}: See T_{10}. Climate change may alter the physical, hydraulic, chemical, and climatological suitability of the Great Lakes and its tributaries for ruffe. Water temperatures, stream flows, and water depth, in particular, may be altered, potentially affecting the distribution of this species.

T_{50}: See T_{25}.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Medium
Nonstructural Alternative Rating	Low	Low	Low	Medium

Evidence for Probability Rating (Considering All Life Stages)

T_0: The species is not currently located near the BSBH and has not spread from Green Bay (section 2e), suggesting that there is currently low propagule pressure for the species. Existing control measures are unlikely to reduce the abundance of ruffe in its current locations. Suitable habitat is present along the pathway (section 2f). Despite the potential for vessel-mediated transport to the CAWS (section 2b), this species has not been detected in southern Lake Michigan since its discovery in Lake Michigan (section 2a).

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's low probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Over 50 years, the probability increases that ruffe would have time to spread to the BSBH by natural dispersion alone or by a combination of human-mediated transport to the southern Great Lakes and natural dispersion to the BSBH.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's medium probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Medium	Medium	High
Nonstructural Alternative Rating	Low	Medium	Medium	High

Evidence for Uncertainty Rating

T_0: This species can be transported by ballast water; there is vessel traffic between the CAWS and areas where the ruffe is located. The potential for ruffe to be transported to the BSBH in ballast water is not well understood. Natural dispersal speed of the species is not well characterized. It is uncertain why this species has not spread more widely into southern Lake Michigan. However, this species is not known to have spread into southern Lake Michigan over the last decade.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.

T_{10}: See T_0. The future population trends and future rate of spread of the ruffe are uncertain. The arrival of the ruffe at the BSBH could increase or decrease over time, depending on the trends in the distribution and abundance of ruffe populations in the Great Lakes. Ruffe populations have fluctuated over time and are subject to control measures. Therefore, over time, trends in future populations and spread rates become less certain. The ruffe has not spread to southern Lake Michigan in the last decade, although it may move closer to the BSBH with time.

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the uncertainty remains medium.

T_{25}: See T_{10}.

T_{50}: See T_{10}. Based on its native distribution, the ruffe appears to be more of a cold-water species, and temperature increases related to climate change may affect its distribution (section 2f). Thus, climate change could limit the movement of ruffe into southern Lake Michigan (section 2f).

The Nonstructural Alternative is not expected to affect the arrival of the ruffe at the CAWS through aquatic pathways. Therefore, the uncertainty remains high.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The ruffe is a small fish. The distance from the BSBH to the Brandon Road Lock and Dam is more than 64 km (40 mi). Rates of natural dispersion of the species are not well known because ballast-water transport has been a key spread vector (FWS 1996). The ruffe can become abundant quickly (FWS 1996; Bauer et al. 2007).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the ruffe through the aquatic pathway.

b. Human-Mediated Transport through Aquatic Pathways

Vessel traffic to the BSBH and the adjacent Burns Harbor is lakewise. Ruffe can be transported in ballast water (Dawson et al. 2006), but ballast water originating from the Great Lakes is not likely to be discharged into inland ports of the Mississippi River Basin (NBIC 2012). Consequently, some natural downstream dispersal would likely be necessary for the ruffe to reach the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to address the human-mediated transport of the ruffe through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: The electric barrier dispersal system located north of the Lockport Lock and Dam may act as a barrier to some degree by repelling adult fish. However, electric barriers do not appear to be highly effective against ruffe (Dawson et al. 2006), and adults that are shocked could flow downstream through the barrier. So there is a high potential that adults may pass the barrier at its current setting. Also, eggs/larvae that are re-suspended in the water column by boat propellers may pass through the electric barrier.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See $T_{0.}$

T_{25}: See $T_{0.}$

T_{50}: See $T_{0.}$

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The BSBH is an industrial canal with primarily concrete or vertical steel banks, but there is vegetated and rocky shoreline close to the harbor. Overall, the CAWS has a soft bottom and sand, which are the preferred substrates for this species (LimnoTech 2010; FishBase 2010). Ruffe prefer still or slow-flowing water (FishBase 2010), which is typical of the CAWS except during high flows (LimnoTech 2010). Generalist fish like the ruffe are found throughout the CAWS (LimnoTech 2010). Rasmussen (2002) states that the ruffe is a true cool-water species (it prefers water temperatures between 10 and 20°C [50 and 68°F]) and that temperature preference may discourage movement south into the Illinois River. Dissolved oxygen in the CAWS may be too low in certain areas or during certain times of the year, but overall dissolved oxygen is adequate (Crosier and Malloy 2005; MWRD 2010) and does not explain fish distribution well (LimnoTech 2010). The ruffe can spawn in multiple habitat types found in the CAWS, including submerged plants, logs, branches, gravel, and rocks (Ogle 1998; LimnoTech 2010). The ruffe likely expanded its range in Europe through canals, and it is found throughout canals in Europe (Indiana Department of Natural Resources 2005; Zoetemeyer 2007).

The Nonstructural Alternative is not expected to affect habitat suitability for the ruffe in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The distance from the BSBH to the Brandon Road Lock and Dam is more than 64 km (40 mi). It is unlikely that the ruffe would be transported through the CAWS by ballast water (section 3b); therefore, natural dispersion would be the most likely means of spreading to the Brandon Road Lock and Dam. Suitable habitat is present throughout the CAWS, but the distance from the BSBH to the Brandon Road Lock and Dam is substantial for the ruffe to travel within the current time step, and the electric barriers may slow its movement.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the ruffe by natural dispersion to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Over time, the ruffe has a high probability of spreading through the aquatic pathway by natural dispersion. There do not appear to be any significant barriers to downstream movement.

T_{25}: See T_{10}. The ruffe has a high probability of spreading through the aquatic pathway by natural dispersion over a 25-year time frame.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: The effectiveness of the electric barrier on ruffe is not well understood. The potential speed of natural dispersion through the aquatic pathway is uncertain.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. The future rate of spread for this species is not well understood. However, habitat in the CAWS is suitable, and it is more certain that ruffe would move through the CAWS to the Brandon Road Lock and Dam in 25 years compared to 10 years.

The Nonstructural Alternative is not expected to affect the passage of the ruffe through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{50}: See T_{25}.

4. **P(colonizes) T_0-T_{50}: MEDIUM**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

5. **P(spreads) T_0-T_{50}: MEDIUM**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

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E.2.2.4.3 Tubenose Goby (*Proterorhinus semilunaris*)


Foto: Harka A.

NONSTRUCTURAL ALTERNATIVE

This alternative would potentially include the implementation of a combination of the following measures that may be implemented at time step 0 (T_0, in units of years) by local, state, and federal agencies and the public. The nonstructural alternative would include the development of a monitoring and response program.

Nonstructural Alternative Measures for the Tubenose Goby

Option or Technology	Description	
Education & Outreach	• Signage, pamphlets, brochures on how to identify ANS and control the spread of ANS; promote national campaigns (i.e., "Stop Aquatic Hitchhikers") • Education of recreational waterway users	
Ballast/Bilge-Water Exchange	• Ballast/bilge-water exchange	
Monitoring	• Agency monitoring • Voluntary occurrence reporting	
Laws & Regulations	• FWS Lacey Act listing • Mandatory watercraft inspection and decontamination • Prohibition of sale, husbandry, transport, release • Quarantine-restricted site access	
	ANS Controls	**ANS Factsheet[a]**
ANS Control Methods	Piscicides	Piscicides
	Controlled harvest and overfishing	Controlled harvest and overfishing
	Desiccation (water drawdown)	Lethal temperature

[a] For more information, refer to GLMRIS Team (2012).

PATHWAY 1

WILMETTE PUMPING STATION (WPS) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, Laws & Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Rating Summary[a]

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	***Low***	Medium	Medium	Medium	Medium	Medium
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[b]	***Low***	–	Medium	–	Medium	–

[a] The highlighted table cells indicate a rating change in the probability element.

[b] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Wilmette Pumping Station (WPS) and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW-MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The tubenose goby is a small, benthic fish. The tubenose goby exhibits a slow invasion speed and has not spread rapidly in the Great Lakes Basin (Vanderploeg et al. 2002; Rasmussen 2002; Fuller et al. 2012). The species invaded the Laurentian Great Lakes in the 1990s, presumably via ballast water from transoceanic cargo ships (Jude et al. 1992). Jump dispersal by the tubenose goby from the lower Great Lakes to Lake Superior can be explained by ship transport (Dopazo et al. 2008). This species is less successful than the round goby, *Neogobius melanostomus*, in terms of spread and population growth (Dillon and Stepien 2001). The decline in wetland habitat may explain the low occurrence of tubenose goby in the Great Lakes (Dopazo et al. 2008).

The Nonstructural Alternative is not expected to affect the arrival of the tubenose goby at the Chicago Area Waterway System (CAWS) via natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Tubenose goby actively swim and do not require humans for dispersal; however, human-mediated transport is likely to be a faster mechanism than natural dispersion for the spread of the species. The species can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992), but there is no cargo vessel traffic to the WPS (USACE 2011a). There is heavy commercial vessel traffic between Duluth-Superior (where this species is located) and ports in southern Lake Michigan (NBIC 2012) that could transport this species closer to the WPS.

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting, which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular piscicides. The implementation of a ballast/bilge-water exchange program, education and outreach, and laws and regulations may reduce the human-mediated transport of the tubenose goby to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: There is a low abundance of the species in the Great Lakes Basin (Dopazo et al. 2008). The tubenose goby has spread throughout Lake St. Clair in Michigan and its tributaries (Jude et al. 1992), as well as the Detroit River system, and is commonly collected in the Duluth-Superior harbor of Lake Superior (Kocovsky et al. 2011). A population of tubenose gobies has become established and self-sustaining in the western basin of Lake Erie (Kocovsky et al. 2011). Tubenose gobies reach maturity in 1–2 years (Freyhof and Kottelat 2008). The females of the species spawn more than once during a season (Freyhof and Kottelat 2008) and likely have a protracted spawning period (Leslie et al. 2002).

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting, which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular piscicides. However, the current distribution of the tubenose goby is too dispersed to be effectively controlled with occasional application of piscicides in localized areas.

If localized populations are found in shallow localized waters, desiccation (water drawdown) may be implemented to control isolated populations. Owing to the tubenose goby's small size and widespread distribution, controlled harvest and overfishing are not expected to be effective control measures to impact the arrival of the tubenose goby at the CAWS pathway.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: None.

T_{25}: None.

T_{50}: None.

e. Distance from Pathway

T_0: Tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), Lake St. Clair (Jude et al. 1992), and the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). It is commonly collected in the Duluth-Superior harbor of Lake Superior (Kocovsky et al. 2011). No records were found that indicated collection of this species in Lake Michigan. The U.S. Environmental Protection Agency (EPA 2008) states that the species may be able to occupy all shallow waters of all five Great Lakes.

The Nonstructural Alternative includes ballast/bilge-water exchange programs, which may increase the time the tubenose goby takes to arrive at the pathway. The species invaded the Laurentian Great Lakes in the 1990s, presumably via ballast water from transoceanic cargo ships (Jude et al. 1992). Jump dispersal by the tubenose goby from the lower Great Lakes to Lake Superior can be explained by ship transport (Dopazo et al. 2008). Ballast/bilge-water transport is thought to assist the tubenose goby's dispersion in the Great Lakes.

T_{10}: See T_0. Tubenose goby could become closer to the WPS by vessel transport or natural dispersion to southern Lake Michigan. The species may be able to occupy shallow waters of all five Great Lakes (EPA 2008). Ballast/bilge-water exchange programs may increase the time the tubenose goby takes to arrive at the CAWS pathway.

T_{25}: See T_{10}.

T_{50}: See T_{10}. In the future, the distance of the species from the CAWS could increase or decrease. Examples of future changes potentially affecting the distribution of tubenose goby in the Great Lakes include natural population growth, climate change, and new aquatic nuisance species (ANS).

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The native range of tubenose goby includes slightly brackish to fresh waters of Eurasia, primarily in rivers and estuaries of the Black Sea Basin and rivers of the northern Aegean (Fuller et al. 2012; Neilson and Stepien 2009). The species is considered a cool-water species, preferring temperatures ranging from 10 to 20°C (50 to 68°F). Rasmussen (2002) and the EPA (2008) suggested that southern Lake Michigan may be suitable, on the basis of temperature preferences. Tubenose goby prefer benthic habitats in low-salinity estuaries, lakes, rivers, and wetlands (Dopazo et al. 2008); they typically dwell in shallow near-shore waters (Dopazo et al. 2008). Adults of this species inhabit waters less than 5 m (16.4 ft) in depth (Fuller et al. 2012), with maximum densities in western Lake Erie being reached in waters less than 1.5 m (4.9 ft) deep (Kocovsky et al. 2011). Densities of the species were significantly greater in riprap habitat than in sandy and macrophyte habitats (Jude and DeBoe 1996). Leslie et al. (2002) collected the species in water with no or slow flow. Tubenose goby spawn on the underside of fixed objects like rocks (Kocovsky et al. 2011); there is rocky habitat in the vicinity of the WPS, as well as sandy habitat and Cladophora beds (MTRI 2012) that may be suitable.

The Nonstructural Alternative is not expected to reduce the habitat suitability for the tubenose goby in southern Lake Michigan.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Low	***Low***	Medium	Medium

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Probability Rating (Considering All Life Stages)

T_0: This species is not currently located in Lake Michigan and is reported to have a slow rate of spread and low abundance (Fuller et al. 2012; Vanderploeg et al. 2002). Tubenose goby can be transported via ballast water (sections 2a, 2b), but there is no cargo vessel traffic to the WPS, so some natural dispersion may be required. Natural dispersion for this species is not well characterized in the Great Lakes, but this species is unlikely to spread from its current locations during the current time step, given that it has not yet been detected in southern Lake Michigan despite being detected in the Great Lakes since the 1990s (section 2a).

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway.

The Nonstructural Alternative reduces the likelihood of the tubenose goby arriving at the CAWS aquatic pathway. However, the Nonstructural Alternative's low probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. The tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), Lake St. Clair (Jude et al. 1992), and the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). The species can be transported in ballast water (Dopazo et al. 2008, Jude et al. 1992), which likely provides a faster mechanism than natural dispersion for the spread of the species.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the probability of arrival is reduced to low.

T_{25}: See T_{10}. There is no commercial vessel transport to the WPS, and the implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. However, over time, the probability increases that the species would have time to spread to the CAWS by human-mediated transport to ports in southern Lake Michigan coupled with natural dispersion to the CAWS. Therefore, its probability of arrival remains medium.

T_{50}: See T_{25}.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Low	Medium	Medium	Medium

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Uncertainty Rating

T_0: There is no commercial vessel traffic between Lake Michigan and the WPS, so the potential for ballast-water transport is low. In addition, the natural dispersion speed of the tubenose goby is not well characterized, but the species has low abundance where established and has been slow to spread in the Great Lakes compared to other invasive gobies.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the uncertainty is low.

T_{10}: See T_0. The tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), Lake St. Clair (Jude et al. 1992), and the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). . The species can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992), which likely provides a faster mechanism than natural dispersion for the spread of the species.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the uncertainty is medium.

T_{25}: See T_{10}. The tubenose goby may be able to reach the WPS within 10 years. However, this species is documented to be relatively uncommon in the Great Lakes Basin. This species has been established in the Great Lakes Basin since the 1990s, and it is uncertain why it has not been detected in southern Lake Michigan despite the presence of suitable habitat.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. However, over time, trends in future populations and spread rates become less certain. Therefore, the uncertainty remains medium.

T_{50}: See T_{25}. The tubenose goby may be more certain to reach the WPS over 50 years. However, on the basis of their native distribution, tubenose goby appear to be more of a cool-water species, and temperature increases related to future climate change may affect their distribution (section 2f). Thus, future climate change could affect the movement of tubenose goby into southern Lake Michigan, depending on whether the environment becomes more or less favorable to this species.

3. P(passage) T_0-T_{50}: LOW-HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The tubenose goby is a small fish. Little is known about the species in the Great Lakes because of its low abundance (Dopazo et al. 2008). The invasion of the species into the Laurentian Great Lakes presumably occurred via ballast water from transoceanic cargo ships (Jude et al. 1992). Eggs are laid on the undersides of fixed objects like rocks (Kocovsky et al. 2011), making transport by currents unlikely; it has also been reported that tubenose lay their eggs in eel grass (Dopazo et al. 2008) and that eggs attached to vegetation can be transported when the vegetation is uprooted. In its invasion of the River Rhine Basin, this species exhibited active upstream migration across large dam and lock systems (Von Landwust 2006).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the tubenose goby through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the tubenose goby as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

The distance from the WPS to the Brandon Road Lock and Dam is more than 64 km (40 mi). While the tubenose goby can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992), there is no commercial vessel traffic from the WPS (USACE 2011a,b). In addition, the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). In addition, water from Lake Michigan is periodically diverted into the CAWS, and this diversion could transport the tubenose goby into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

The Nonstructural Alternative is not expected to address the human-mediated transport of the tubenose goby through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: A sluice gate separates Lake Michigan from the CAWS. However, tubenose goby could be transported from Lake Michigan into the North Shore Channel via water pumped from the lake into the channel. This species prefers waters less than 5 m (16.4 ft) in depth (Fuller et al. 2012). The water depth in the Chicago River and the Chicago Sanitary and Ship Canal (CSSC) is less than 9.1 m (30 ft) and less than 4.6 m (15 ft) in many areas. The Electric Dispersal Barrier System, located north of the Lockport Lock and Dam, may act as a barrier to some degree by repelling adult fish. However, adults that are shocked and early life stages could float downstream through the barrier. Tubenose goby eggs are benthic, but they could move through the barrier if resuspended in the water column. So there is a high potential that adults and early life stages may pass the barrier at the current setting. In its invasion of the River Rhine Basin, this species exhibited active upstream migration across large dam and lock systems (Von Landwust 2006). Therefore, the Lockport Lock and Dam and the Brandon Road Lock and Dam are not expected to be a barrier to passage.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0. No changes in human or natural barriers are expected.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Tubenose goby are found along rocky and/or vegetated shallow waters as well as on sandy sediment. All these habitats are present in the CAWS (LimnoTech 2010). The North Shore Canal has riprap banks (LimnoTech 2010), which are a preferred habitat of the species (Jude and DeBoe 1996; Von Landwust 2006) and also a preferred spawning habitat (Kocovsky et al. 2011). The upper north branch of the Chicago River and the North Shore Channel are more natural habitat, with cobble banks and woody debris (LimnoTech 2010). The Chicago River is more than 90% vertical wall and has a sludge or silt bottom. The banks of the CSSC are composed of vertical walls, rock, and some vegetative debris. Sediments in the CSSC can range from rock to soft sediment and sand. Submerged aquatic vegetation is also present in portions of the CSSC (LimnoTech 2010). Tubenose goby prefer still or slow-flowing water (Dopazo et al. 2008), which is typical of the CAWS except during high flows. The tubenose goby is considered a cool-water species, preferring waters within the temperature range of 10 to 20°C (50 to 68 °F) (Rasmussen 2002), although the western basin of Lake Erie, where this species has become successfully established, regularly exceeds this temperature range in summer (20–25°C [68–77°F]) (EPA Great Lakes National Program Office, unpublished data). Therefore, water in the CAWS would be suitable at least seasonally.

The Nonstructural Alternative is not expected to affect habitat suitability for the tubenose goby in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: The sluice gate at the WPS would act as a temporary barrier, but water pumped from Lake Michigan into the North Shore Channel could transport tubenose goby into the CAWS. It is more than 64 km (40 mi) from the WPS to the Brandon Road Lock and Dam. Suitable adult and reproductive habitat is present throughout the CAWS (section 3e). The Electric Dispersal Barrier System is not likely to reduce downstream movement (section 3c). It is unlikely that the tubenose goby would be transported through the CAWS by ballast water (section 3b).

The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the tubenose goby by natural dispersion to the Brandon Road Lock and Dam. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Over time, the tubenose goby has a higher probability of spreading through the CAWS by natural dispersion. There do not appear to be any significant barriers to downstream movement.

T_{25}: See T_{10}. The tubenose goby has a higher probability of spreading through the CAWS by natural dispersion over a 25-year time frame.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: The tubenose goby may be able to pass through the Brandon Road Lock and Dam during this time step, but this species' potential speed of natural dispersion through the CAWS is uncertain, as is the potential for passive transport of adults and early life stages through the electric barrier system.

The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. The future rate of spread for this species is not well understood. However, habitat in the CAWS is suitable, and it is more certain that the tubenose goby would move through the CAWS to the Brandon Road Lock and Dam in 25 years compared to 10 years.

The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

PATHWAY 2

CHICAGO RIVER CONTROLLING WORKS (CRCW) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Rating Summary [a]

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	***Low***	Medium	Medium	Medium	Medium	Medium
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[b]	***Low***	–	Medium	–	Medium	–

[a] The highlighted table cells indicate a rating change in the probability element.

[b] "-" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the CRCW and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW-MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The tubenose goby is a small, benthic fish. The tubenose goby exhibits a slow invasion speed and has not spread rapidly in the Great Lakes Basin (Vanderploeg et al. 2002; Rasmussen 2002; Fuller et al. 2012). The species invaded the Laurentian Great Lakes in the 1990s, presumably via ballast water from transoceanic cargo ships (Jude et al. 1992). Jump dispersal by the tubenose goby from the lower Great Lakes to Lake Superior can be explained by ship transport (Dopazo et al. 2008). This species is less successful than the round goby, *Neogobius melanostomus*, in terms of spread and population growth (Dillon and Stepien 2001). The decline in wetland habitat may explain the low occurrence of tubenose gobies in the Great Lakes (Dopazo et al. 2008).

The Nonstructural Alternative is not expected to affect the arrival of the tubenose goby at the CAWS via natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Tubenose goby actively swim and do not require humans for dispersal; however, human-mediated transport is likely to be a faster mechanism than natural dispersion in the spread of this species. The species can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992), and there is recreational and cargo vessel traffic between northern Lake Michigan and the CRCW (USACE 2011a). There is also heavy commercial vessel traffic between Duluth-Superior (where this species is located) and ports in southern Lake Michigan (including the CRCW) (NBIC 2012) that could transport this species closer to the CRCW.

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting, which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular piscicides. The implementation of a ballast/bilge-water exchange program, education and outreach, and laws and regulations may reduce the human-mediated transport of the tubenose goby to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: There is a low abundance of the species in the Great Lakes Basin (Dopazo et al. 2008). The tubenose goby has spread throughout Lake St. Clair in Michigan and its tributaries (Jude et al. 1992), as well as the Detroit River system, and is commonly collected in the Duluth-Superior Harbor of Lake Superior (Kocovsky et al. 2011). A population of tubenose gobies has become established and self-sustaining in the western basin of Lake Erie (Kocovsky et al. 2011). Tubenose gobies reach maturity in 1–2 years (Freyhof and Kottelat 2008). The females of the species spawn more than once during a season (Freyhof and Kottelat 2008) and likely have a protracted spawning period (Leslie et al. 2002).

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting, which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular piscicides. However, the current distribution of the tubenose goby is too dispersed to be effectively controlled with occasional application of piscicides in localized areas.

If localized populations are found in shallow localized waters, desiccation (water drawdown) may be implemented to control isolated populations. Owing to the tubenose goby's small size and widespread distribution, controlled harvest and overfishing are not expected to be effective control measures to impact the arrival of the tubenose goby at the CAWS pathway.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: Tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), Lake St. Clair (Jude et al. 1992), and the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). It is commonly collected in the Duluth-Superior Harbor of Lake Superior (Kocovsky et al. 2011). No records were found that indicated collection of this species in Lake Michigan. The U.S. Environmental Protection Agency (EPA 2008) states that the species may be able to occupy all shallow waters of all five Great Lakes.

The Nonstructural Alternative includes ballast/bilge-water exchange programs, which may increase the time the tubenose goby takes to arrive at the CAWS pathway. The species invaded the Laurentian Great Lakes in the 1990s, presumably via ballast water from transoceanic cargo ships (Jude et al. 1992). Jump dispersal by the tubenose goby from the lower Great Lakes to Lake Superior can be explained by ship transport (Dopazo et al. 2008). Ballast/bilge water transport is thought to assist the tubenose goby's dispersion in the Great Lakes.

T_{10}: See T_0. Tubenose goby could become closer to the CRCW by vessel transport or natural dispersion to southern Lake Michigan. The species may be able to occupy shallow waters of all five Great Lakes (EPA 2008). Ballast/bilge water exchange programs may increase the time the tubenose goby takes to arrive at the CAWS pathway.

T_{25}: See T_{10}.

T_{50}: See T_{10}. In the future, the distance of the species from the CAWS could increase or decrease. Examples of future changes potentially affecting the distribution of tubenose goby in the Great Lakes include natural population growth, climate change, and new ANS.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The native range of tubenose goby includes slightly brackish to fresh waters of Eurasia, primarily in rivers and estuaries of the Black Sea Basin and rivers of the northern Aegean Sea (Fuller et al. 2012; Neilson and Stepien 2009). The species is considered a cool-water species, preferring temperatures ranging from 10 to 20°C (50 to 68°F). Rasmussen (2002) and the EPA (2008) suggested that southern Lake Michigan may be suitable, on the basis of temperature preferences. Tubenose goby prefers benthic habitats in low-salinity estuaries, lakes, rivers, and wetlands (Dopazo et al. 2008); it typically dwells in shallow nearshore waters (Dopazo et al. 2008). Adults of this species inhabit waters less than 5 m (16.4 ft) in depth (Fuller et al. 2012), with maximum densities in western Lake Erie being reached in waters less than 1.5 m (4.9 ft) deep (Kocovsky et al. 2011). Densities of the species were significantly greater in riprap habitat than in sandy and macrophyte habitats (Jude and DeBoe 1996). Leslie et al. (2002) collected the species in water with no or slow flow. Tubenose goby spawns on the underside of fixed objects like rocks (Kocovsky et al. 2011); there is rocky habitat in the vicinity of the CRCW, as well as sandy habitat and Cladophora beds (MTRI 2012) that may be suitable.

The Nonstructural Alternative is not expected to reduce the habitat suitability for the tubenose goby in southern Lake Michigan.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Low	***Low***	Medium	Medium

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Probability Rating (Considering All Life Stages)

T_0: This species is not currently in Lake Michigan and is reported to have a slow rate of spread and low abundance (Fuller et al. 2012; Vanderploeg et al. 2002). Tubenose goby can be transported via ballast water (sections 2a, 2b), and there is cargo vessel traffic to the CRCW that could transport this species. Natural dispersion for this species in the Great Lakes is not well characterized, but this species is unlikely to spread from its current locations during the current time step, given that it has not yet been detected in southern Lake Michigan despite being detected in the Great Lakes since the 1990s (section 2a).

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway.

The Nonstructural Alternative reduces the likelihood of the tubenose goby arriving at the CAWS aquatic pathway. However, the Nonstructural Alternative's low probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. The tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), Lake St. Clair (Jude et al. 1992), and the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). The species can be transported in ballast water (Dopazo et al. 2008, Jude et al. 1992), which likely provides a faster mechanism than natural dispersion for the spread of the species.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the probability of arrival is reduced to low.

T_{25}: See T_{10}. There is commercial vessel transport to the CRCW from ports where the tubenose goby is located (section 2b).

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. However, over time, the probability increases that the species would have time to spread by human-mediated transport to ports in southern Lake Michigan, coupled with natural dispersion to the CRCW. Therefore, its probability of arrival remains medium.

T_{50}: See T_{25}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating	Low	Medium	Medium	Medium

Evidence for Uncertainty Rating

T_0: There is commercial vessel traffic between areas where the tubenose goby is located and the CRCW, so the potential for ballast-water transport is high. However, the tubenose goby has not been documented in Lake Michigan, and the natural dispersion speed of the tubenose goby is not well characterized. The tubenose goby is documented to have low abundance where established, and has been slow to spread in the Great Lakes compared to other invasive gobies.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the uncertainty is low.

T_{10}: See T_0. The tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), Lake St. Clair (Jude et al. 1992), and the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). The species can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992), which likely provides a faster mechanism than natural dispersion for the spread of the species.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the uncertainty is medium.

T_{25}: See T_{10}. With the heavy vessel traffic to the CRCW, the tubenose goby may be able to reach the CRCW within 10 years. However, this species is documented to be relatively uncommon in the Great Lakes Basin. This species has been established in the Great Lakes Basin since the 1990s, and it is uncertain why it has not been detected in southern Lake Michigan despite the presence of suitable habitat.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. However, over time, trends in future populations and spread rates become less certain. Therefore, the uncertainty remains medium.

T_{50}: See T_{25}. The tubenose goby may be more certain to reach the CRCW over 50 years. However, on the basis of its native distribution, tubenose goby appears to be more of a cool-water species, and temperature increases related to future climate change may affect its distribution (section 2f). Thus, future climate change could affect the movement of tubenose goby into southern Lake Michigan, depending on whether the environment becomes more or less favorable to this species.

3. P(passage) T_0-T_{50}: LOW-HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The tubenose goby is a small fish. Little is known about the species in the Great Lakes because of its low abundance (Dopazo et al. 2008). The invasion of the species into the Laurentian Great Lakes presumably occurred via ballast water from transoceanic cargo ships (Jude et al. 1992). Eggs are laid on the undersides of fixed objects like rocks

(Kocovsky et al. 2011), making transport by currents unlikely; it has also been reported that tubenose goby lay their eggs in eel grass (Dopazo et al. 2008) and that eggs attached to vegetation can be transported when the vegetation is uprooted. In its invasion of the River Rhine Basin, this species exhibited active upstream migration across large dam and lock systems (Von Landwust 2006).

The Nonstructural Alternative is not expected to address the natural dispersion of the tubenose goby through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the tubenose goby as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

The distance from the CRCW to the Brandon Road Lock and Dam is greater than 64 km (40 mi). The tubenose goby can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992), and there is commercial vessel traffic from the CRCW to the Brandon Road Lock and Dam (USACE 2011a,b). However, the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). In addition, water from Lake Michigan is periodically diverted into the CAWS; this diversion could transport the tubenose goby into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

The Nonstructural Alternative is not expected to address the human-mediated transport of the tubenose goby through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: This species prefers waters less than 5 m (16.4 ft) in depth (Fuller et al. 2012). The water depth in the Chicago River and the CSSC is less than 9.1 m (30 ft), and less than 4.6 m (15 ft) in many areas. The Electric Dispersal Barrier System, located north of the Lockport Lock and Dam, may act as a barrier to some degree by repelling adult fish. However, the barrier may not be effective in shocking small fish like the tubenose goby, and adults that are shocked and early life stages could flow downstream through the barrier. Tubenose goby eggs are benthic, but they could move through the barrier if resuspended in the water column. So there is a high potential that adults and early life stages may pass the barrier at the current setting. In its invasion of the River Rhine Basin, this species exhibited active upstream migration across large dam and lock systems (Von Landwust 2006). Therefore, the Lockport Lock and Dam and the Brandon Road Lock and Dam are not expected to be barriers to passage.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Tubenose goby is found along rocky and/or vegetated shallow waters as well as on sandy sediment. All these habitats are present in the CAWS (LimnoTech 2010). The

Chicago River and the south branch of the Chicago River are more than 90% vertical wall and have a concrete, sludge, or silt bottom. The banks of the CSSC are composed of vertical walls, rock, and some vegetative debris. Sediments in the CSSC can range from rock to soft sediment and sand. Submerged aquatic vegetation is also present in portions of the CSSC (LimnoTech 2010). Tubenose goby prefers still or slow-flowing water (Dopazo et al. 2008), which is typical of the CAWS except during high flows. The tubenose goby is considered a cool-water species, preferring waters within the temperature range of 10 to 20°C (50 to 68°F) (Rasmussen 2002), although the western basin of Lake Erie, where this species has become successfully established, regularly exceeds this temperature range in summer (20–25°C [68-77°F]) (EPA Great Lakes National Program Office, unpublished data). Therefore, water temperatures in the CAWS may not be suitable during the warmest months of the year.

The Nonstructural Alternative is not expected to affect habitat suitability for the tubenose goby in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: It is more than 64 km (40 mi) from the CRCW to the Brandon Road Lock and Dam. Suitable adult and reproductive habitat is present throughout the CAWS (section 3e). It is unlikely that the tubenose goby would be transported through the CAWS by ballast water (section 3b). The Electric Dispersal Barrier System is not likely to reduce downstream movement (section 3c).

The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the tubenose goby to the Brandon Road Lock and Dam by natural dispersion. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Over time, the tubenose goby has a higher probability of spreading through the CAWS by natural dispersion. There do not appear to be any significant barriers to downstream movement.

T_{25}: See T_{10}. The tubenose goby has a higher probability of spreading through the CAWS by natural dispersion over a 25-year time frame.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: The tubenose goby may be able to pass through the Brandon Road Lock and Dam during this time step, but this species' potential speed of natural dispersion through the CAWS is uncertain, as is the potential for passive transport of adults and early life stages through the electric barrier system.

The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. The future rate of spread for this species is not well understood. However, habitat in the CAWS is suitable, and it is more certain that the tubenose goby would move through the CAWS to the Brandon Road Lock and Dam in 25 years compared to 10 years. Therefore, the uncertainty of its passage decreases to low during this time step.

The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

PATHWAY 3

CALUMET HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Rating Summary[a]

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	***Low***	Medium	Medium	Medium	Medium	Medium
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[b]	***Low***	–	Medium	–	Medium	–

[a] The highlighted table cells indicate a rating change in the probability element.

[b] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Calumet Harbor and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW-MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The tubenose goby is a small, benthic fish. The tubenose goby exhibits a slow invasion speed and has not spread rapidly in the Great Lakes Basin (Vanderploeg et al. 2002; Rasmussen 2002; Fuller et al. 2012). The species invaded the Laurentian Great Lakes in the 1990s, presumably via ballast water from transoceanic cargo ships (Jude et al. 1992). Jump dispersal by the tubenose goby from the lower Great Lakes to Lake Superior can be explained by ship transport (Dopazo et al. 2008). This species is less successful than the round goby, *Neogobius melanostomus*, in terms of spread and population growth (Dillon and Stepien 2001). The decline in wetland habitat may explain the low occurrence of tubenose gobies in the Great Lakes (Dopazo et al. 2008).

The Nonstructural Alternative is not expected to affect the arrival of the tubenose goby at the CAWS via natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Tubenose goby actively swim and do not require humans for dispersal; however human-mediated transport is likely to be a faster mechanism than natural dispersion for the spread of this species. The species can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992). There is recreational and cargo vessel traffic to Calumet Harbor, and there is commercial vessel traffic between Lake Erie (where this species is located) and ports in southern Lake Michigan (including Calumet Harbor) (USACE 2011a; NBIC 2012) that could transport this species closer to Calumet Harbor.

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting, which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular piscicides. The implementation of a ballast/bilge-water exchange program, education and outreach, and laws and regulations may reduce the human-mediated transport of the tubenose goby to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: There is a low abundance of the species in the Great Lakes Basin (Dopazo et al. 2008). The tubenose goby has spread throughout Lake St. Clair in Michigan and its tributaries (Jude et al. 1992), as well as the Detroit River system, and is commonly collected in the Duluth-Superior Harbor of Lake Superior (Kocovsky et al. 2011). A population of tubenose gobies has become established and self-sustaining in the western basin of Lake Erie (Kocovsky et al. 2011). Tubenose gobies reach maturity in 1–2 years (Freyhof and Kottelat 2008). The females of the species spawn more than once during a season (Freyhof and Kottelat 2008), and likely have a protracted spawning period (Leslie et al. 2002).

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting, which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular piscicides. However, the current distribution of the tubenose goby is too dispersed to be effectively controlled with occasional application of piscicides in localized areas.

If localized populations are found in shallow localized waters, desiccation (water drawdown) may be implemented to control isolated populations. Owing to the tubenose goby's small size and widespread distribution, controlled harvest and overfishing are not expected to be effective control measures to impact the arrival of the tubenose goby at the CAWS pathway.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: There are no existing barriers. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: Tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), Lake St. Clair (Jude et al. 1992), and the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). It is commonly collected in the Duluth-Superior Harbor of Lake Superior (Kocovsky et al. 2011). No records were found that indicated collection of this species in Lake Michigan. The U.S. Environmental Protection Agency (EPA 2008) states that the species may be able to occupy all shallow waters of all five Great Lakes.

The Nonstructural Alternative includes ballast/bilge-water exchange programs which may increase the time the tubenose goby takes to arrive at the CAWS pathway. The species invaded the Laurentian Great Lakes in the 1990s, presumably via ballast water from transoceanic cargo ships (Jude et al. 1992). Jump dispersal by the tubenose goby from the lower Great Lakes to Lake Superior can be explained by ship transport (Dopazo et al. 2008). Ballast/bilge water transport is thought to assist the tubenose goby's dispersion in the Great Lakes.

T_{10}: See T_0. Tubenose goby could move closer to Calumet Harbor by vessel transport or natural dispersion to southern Lake Michigan. The species may be able to occupy shallow waters of all five Great Lakes (EPA 2008). Ballast/bilge water exchange programs may increase the time the tubenose goby takes to arrive at the CAWS pathway.

T_{25}: See T_{10}.

T_{50}: See T_{10}. In the future, the distance of the species from the CAWS could increase or decrease. Examples of future changes potentially affecting the distribution of tubenose goby in the Great Lakes include natural population growth, climate change, and new ANS.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The native range of tubenose goby includes slightly brackish to fresh waters of Eurasia, primarily in rivers and estuaries of the Black Sea Basin and rivers of the northern Aegean Sea (Fuller et al. 2012; Neilson and Stepien 2009). The species is considered a cool-water species, preferring temperatures ranging from 10 to 20°C (50 to 68°F) (Rasmussen 2002). Rasmussen (2002) and the EPA (2008) suggested that southern Lake Michigan may be suitable on the basis of temperature preferences. Tubenose goby prefers benthic habitats in low-salinity estuaries, lakes, rivers, and wetlands (Dopazo et al. 2008); it typically dwells in shallow near-shore waters (Dopazo et al. 2008). Adults of this species inhabit waters less than 5 m (16.4 ft) in depth (Fuller et al. 2012), with maximum densities in western Lake Erie being reached in waters less than 1.5 m (4.9 ft) deep (Kocovsky et al. 2011). Densities of the species were significantly greater in riprap habitat than in sandy and macrophyte habitats (Jude and DeBoe 1996). Leslie et al. (2002) collected the species in water with no or slow flow. Tubenose goby spawn on the underside of fixed objects like rocks (Kocovsky et al. 2011); there is rocky habitat in the vicinity of Calumet Harbor, as well as sandy habitat and Cladophora beds (MTRI 2012) that may be suitable.

The Nonstructural Alternative is not expected to reduce the habitat suitability for the tubenose goby in southern Lake Michigan.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Low	***Low***	Medium	Medium

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Probability Rating (Considering All Life Stages)

T_0: This species is not currently in Lake Michigan and is reported to have a slow rate of spread and low abundance (Fuller et al. 2012; Vanderploeg et al. 2002). Tubenose goby can be transported via ballast water (sections 2a, 2b), and there is cargo vessel traffic to Calumet Harbor that could transport this species (section 2b). Natural dispersion for this species in the Great Lakes is not well characterized, but this species is unlikely to spread from its current locations during the current time step, given that it has not yet been detected in southern Lake Michigan despite being in the Great Lakes since the 1990s (section 2a).

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway.

The Nonstructural Alternative reduces the likelihood of the tubenose goby arriving at the CAWS aquatic pathway. However, the Nonstructural Alternative's low probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. The tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), Lake St. Clair (Jude et al. 1992), and the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). The species can be transported in ballast water (Dopazo et al. 2008, Jude et al. 1992), which likely provides a faster mechanism than natural dispersion for the spread of the species.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the probability of arrival is reduced to low.

T_{25}: See T_{10}. The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. However, over time, the probability increases that the species would have time to spread by human-mediated transport to ports in southern Lake Michigan, coupled with natural dispersion to Calumet Harbor. Therefore, the probability of arrival remains medium.

T_{50}: See T_{25}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating	Low	Medium	Medium	Medium

Evidence for Uncertainty Rating

T_0: There is commercial vessel traffic between areas where the tubenose goby is located and Calumet Harbor, so the potential for ballast-water transport is high. However, despite being present in the Great Lakes since the 1990s, the tubenose goby has not been documented in Lake Michigan, and the natural dispersion speed of the tubenose goby is not well characterized. The tubenose goby is documented to have low abundance where established and has been slow to spread in the Great Lakes compared to other invasive gobies.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the uncertainty is low.

T_{10}: See T_0. The tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), Lake St. Clair (Jude et al. 1992), and the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). The species can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992), which likely provides a faster mechanism than natural dispersion for the spread of the species.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the uncertainty is medium.

T_{25}: See T_{10}. With the heavy vessel traffic to Calumet Harbor, the tubenose goby may be able to reach Calumet Harbor within 10 years. However, this species is documented to be relatively uncommon in the Great Lakes Basin. This species has been established in the Great Lakes Basin since the 1990s, and it is uncertain why it has not been detected in southern Lake Michigan despite the presence of suitable habitat.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. However, over time, trends in future populations and spread rates become less certain. Therefore, the uncertainty remains medium.

T_{50}: See T_{25}. The tubenose goby may be more certain to reach Calumet Harbor over 50 years. However, on the basis of its native distribution, tubenose goby appears to be more of a cool-water species, and temperature increases related to future climate change may affect its distribution (section 2f). Thus, future climate change could affect the movement of tubenose goby into southern Lake Michigan, depending on whether the environment becomes more or less favorable to this species.

3. P(passage) T_0-T_{50}: LOW-HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The tubenose goby is a small fish. Little is known about the species in the Great Lakes because of its low abundance (Dopazo et al. 2008). The invasion of the species into the Laurentian Great Lakes presumably occurred via ballast water from transoceanic cargo ships (Jude et al. 1992). Eggs are laid on the undersides of fixed objects like rocks

(Kocovsky et al. 2011), making transport by currents unlikely; it has also been reported that tubenose lay their eggs in eel grass (Dopazo et al. 2008) and that eggs attached to vegetation can be transported when the vegetation is uprooted. In its invasion of the River Rhine Basin, this species exhibited active upstream migration across large dam and lock systems (Von Landwust 2006).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the tubenose goby through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the tubenose goby as it passes through the CAWS.

b. *Human-Mediated Transport through Aquatic Pathways*

The distance from Calumet Harbor to the Brandon Road Lock and Dam is approximately 64 km (40 mi). The tubenose goby can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992), and there is commercial vessel traffic from the Brandon Road Lock and Dam to the T.J. O'Brien Lock and Dam, which is just south of Calumet Harbor (USACE 2011a,b). However, the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). In addition, water from Lake Michigan is periodically diverted into the CAWS, and this diversion could transport the tubenose goby into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

The Nonstructural Alternative is not expected to address the human-mediated transport of the tubenose goby through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: This species prefers waters less than 5 m (16.4 ft) in depth (Fuller et al. 2012). The water depth in the Chicago River and the CSSC is less than 9.1 m (30 ft), and less than 4.6 m (15 ft) in many areas. The Electric Dispersal Barrier System, located north of the Lockport Lock and Dam, may act as a barrier to some degree by repelling adult fish. However, the barrier may not be effective in shocking small fish like the tubenose goby, and adults that are shocked and early life stages could float downstream through the barrier. Tubenose goby eggs are benthic, but they could move through the barrier if resuspended in the water column. So there is a high potential that adults and early life stages may pass the barrier at the current setting. In its invasion of the River Rhine Basin, this species exhibited active upstream migration across large dam and lock systems (Von Landwust 2006). Therefore, the Lockport Lock and Dam and the Brandon Road Lock and Dam are not expected to be barriers to passage.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0. No changes in human or natural barriers are expected.

T_{25}: See T_{10}.

T_{50}: See T_{10}.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: Tubenose goby is found along rocky and/or vegetated shallow waters, as well as on sandy sediment. All these habitats are present in the CAWS (LimnoTech 2010). After entering Calumet Harbor, the tubenose goby would enter the Calumet River. In the Calumet River, there is in-stream habitat for aquatic life in the form of boulders, logs, brush debris jams, overhanging terrestrial vegetation, and aquatic vegetation in some reaches. Urban industrial and commercial riparian land use is also present. Sediments in the Little Calumet River are primarily inorganic silt, but areas of sand and gravel are also present (LimnoTech 2010). The banks of the CSSC are composed of vertical walls, rock, and some vegetative debris. Sediments in the CSSC vary but are primarily silt, sludge, bedrock, and sand with scattered cobble (LimnoTech 2010). Submerged aquatic vegetation is also present in portions of the CSSC (LimnoTech 2010). Tubenose goby prefer still or slow-flowing water (Dopazo et al. 2008), which is typical of the CAWS except during high flows (LimnoTech 2010). The tubenose goby is considered a cool-water species, preferring waters within the temperature range of 10 to 20°C (50 to 68°F) (Rasmussen 2002), although the western basin of Lake Erie, where this species has become successfully established, regularly exceeds this temperature range in summer (20–25°C [68–77 °F]) (EPA Great Lakes National Program Office, unpublished data). Therefore, water temperatures in the CAWS may not be suitable during the warmest months of the year.

The Nonstructural Alternative is not expected to affect habitat suitability for the tubenose goby in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: It is more than 64 km (40 mi) from Calumet Harbor to the Brandon Road Lock and Dam. Suitable adult and reproductive habitat is present throughout the CAWS (section 3e). It is unlikely that the tubenose goby would be transported through the CAWS by ballast water (section 3b); therefore, natural dispersion would be the most likely means of spreading from Calumet Harbor to the Brandon Road Lock and Dam. The Electric Dispersal Barrier System is not likely to reduce downstream movement (section 3c).

The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the tubenose goby to the Brandon Road Lock and Dam by natural dispersion. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Over time, the tubenose goby has a higher probability of spreading through the CAWS by natural dispersion. There do not appear to be any significant barriers to downstream movement.
T_{25}: See T_{10}. The tubenose goby has a higher probability of spreading through the CAWS by natural dispersion over a 25-year time frame.
T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: The tubenose goby may be able to pass through the Brandon Road Lock and Dam during this time step, but this species' potential speed of natural dispersion through the CAWS is uncertain, as is the potential for passive transport of adults and early life stages through the electric barrier system.

The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.
T_{10}: See T_0.
T_{25}: See T_0. The future rate of spread for this species is not well understood. However, habitat in the CAWS is suitable, and it is more certain that the tubenose goby would move through the CAWS to the Brandon Road Lock and Dam in 25 years compared to 10 years.

The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.
T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

PATHWAY 4

INDIANA HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Rating Summary[a]

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	U	P	U	P	U	P	U
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	***Low***	Medium	Medium	Medium	Medium	Medium
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[b]	***Low***	–	Medium	–	Medium	–

[a] The highlighted table cells indicate a rating change in the probability element.

[b] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Indiana Harbor and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW-MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The tubenose goby is a small, benthic fish. The tubenose goby has not spread widely in the Great Lakes Basin (Vanderploeg et al. 2002; Rasmussen 2002; Fuller et al. 2012). The species invaded the Laurentian Great Lakes in the 1990s, presumably via ballast water from transoceanic cargo ships (Jude et al. 1992). Dispersal by the tubenose goby from the lower Great Lakes to Lake Superior can be explained by ship transport (Dopazo et al. 2008). This species is less successful than the round goby, *Neogobius melanostomus,* in terms of spread and population growth (Dillon and Stepien 2001). The decline in wetland habitat may explain the low occurrence of tubenose gobies in the Great Lakes (Dopazo et al. 2008).

The Nonstructural Alternative is not expected to affect the arrival for the tubenose goby at the CAWS from natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Tubenose goby actively swim and do not require humans for dispersal; however, human-mediated transport is likely to be a faster mechanism than natural dispersion by swimming. The species can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992). There is cargo vessel traffic to Indiana Harbor from Duluth-Superior Harbor, where this species is located (USACE 2011a; NBIC 2012) that could transport this species closer to Indiana Harbor.

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting, which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular piscicides. The implementation of a ballast/bilge-water exchange program, education and outreach, and laws and regulations may reduce the human-mediated transport of the tubenose goby to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: The abundance of the tubenose goby is low in the Great Lakes Basin (Dopazo et al. 2008). The tubenose goby has spread throughout Lake St. Clair in Michigan and its tributaries (Jude et al. 1992), as well as the Detroit River system, and is commonly collected in the Duluth-Superior Harbor of Lake Superior (Kocovsky et al. 2011). A population of tubenose gobies has become established and self-sustaining in the western basin of Lake Erie (Kocovsky et al. 2011). Tubenose gobies reach maturity in

1–2 years (Freyhof and Kottelat 2008). The females of the species spawn more than once during a season (Freyhof and Kottelat 2008), and likely have a protracted spawning period (Leslie et al. 2002).

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting, which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular piscicides. However, the current distribution of the tubenose goby is too dispersed to be effectively controlled with occasional application of piscicides in localized areas.

If localized populations are found in shallow localized waters, desiccation (water drawdown) may be implemented to control isolated populations. Owing to the tubenose goby's small size and widespread distribution, controlled harvest and overfishing are not expected to be effective control measures to impact the arrival of the tubenose goby at the CAWS pathway.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Existing Physical Human/Natural Barriers*

T_0: There are no existing barriers. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. *Distance from Pathway*

T_0: Tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), Lake St. Clair (Jude et al. 1992), and the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). It is commonly collected in the Duluth-Superior Harbor of Lake Superior (Kocovsky et al. 2011). No records were found that indicated collection of this species in Lake Michigan.

The Nonstructural Alternative includes ballast/bilge-water exchange programs which may increase the time the tubenose goby takes to arrive at the CAWS pathway. The species invaded the Laurentian Great Lakes in the 1990s, presumably via ballast water from transoceanic cargo ships (Jude et al. 1992). Jump dispersal by the tubenose goby from the lower Great Lakes to Lake Superior can be explained by ship transport (Dopazo et al. 2008). Ballast/bilge water transport is thought to assist the tubenose goby's dispersion in the Great Lakes.

T_{10}: See T_0. Tubenose goby could move closer to Indiana Harbor by vessel transport or swimming to southern Lake Michigan. The species may be able to occupy shallow waters of all five Great Lakes (EPA 2008). Ballast/bilge water exchange programs may increase the time the tubenose goby takes to arrive at the CAWS pathway.

T_{25}: See T_{10}.

T_{50}: See T_{10}. In the future, the distance of the species from the CAWS could increase or decrease. Examples of future changes potentially affecting the distribution of tubenose goby in the Great Lakes include natural population growth, climate change, and new ANS.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The native range of tubenose goby includes slightly brackish to fresh waters of Eurasia, primarily in rivers and estuaries of the Black Sea Basin and rivers of the northern Aegean (Fuller et al. 2012; Neilson and Stepien 2009). The species is considered a cool-water species, preferring temperatures ranging from 10 to 0°C (50 to 68°F). Rasmussen (2002) and the U.S. Environmental Protection Agency (EPA 2008) suggested that southern Lake Michigan may be suitable, on the basis of temperature preferences. Tubenose goby prefer benthic habitats in low salinity estuaries, lakes, rivers, and wetlands (Dopazo et al. 2008); they typically dwell in shallow near-shore waters (Dopazo et al. 2008). Adults of this species inhabit waters less than 5 m (16.4 ft) in depth (Fuller et al. 2012), with maximum densities in western Lake Erie being reached in waters less than 1.5 m (4.9 ft) deep (Kocovsky et al. 2011). Densities of the species were significantly greater in riprap habitat than in sandy and macrophyte habitats (Jude and DeBoe 1996). Leslie et al. (2002) collected the species in water with no or slow flow. Tubenose goby spawn on the underside of fixed objects like rocks (Kocovsky et al. 2011); there is rocky habitat in the vicinity of the Indiana Harbor, as well as sandy habitat and Cladophora beds (MTRI 2012) that may be suitable. The EPA (2008) states that the species may be able to occupy all shallow waters of all five Great Lakes.

The Nonstructural Alternative is not expected to reduce the habitat suitability for the tubenose goby in southern Lake Michigan.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Low	***Low***	Medium	Medium

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Probability Rating (Considering All Life Stages)

T_0: This species is not currently in Lake Michigan and is reported to have a slow rate of spread and low abundance (Fuller et al. 2012; Vanderploeg et al. 2002). Tubenose goby can be transported via ballast water (sections 2a, 2b), and there is cargo vessel traffic to Indiana Harbor that could transport this species (section 2b). Natural dispersion for this species is not well characterized in the Great Lakes, but this species is unlikely to spread from its current locations during the current time step, given that it has not yet been detected in southern Lake Michigan despite being in the Great Lakes since the 1990s (section 2a).

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway.

The Nonstructural Alternative reduces the likelihood of the tubenose goby arriving at the CAWS aquatic pathway. However, the Nonstructural Alternative's low probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. The tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), Lake St. Clair (Jude et al. 1992), and the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). The species can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992), which likely provides a faster mechanism than natural dispersion for the spread of the species.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the probability of arrival is reduced to low.

T_{25}: See T_{10}. There is commercial vessel transport to Indiana Harbor from ports where the tubenose goby is located (section 2b). The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. However, over time, the probability increases that the species would have time to spread by human-mediated transport to ports in southern Lake Michigan coupled with natural dispersion to Indiana Harbor. Therefore, its probability of arrival remains medium.

T_{50}: See T_{25}.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating	Low	Medium	Medium	Medium

Evidence for Uncertainty Rating

T_0: There is commercial vessel traffic between areas where the tubenose goby is located and Indiana Harbor, so the potential for ballast-water transport could be high. However, despite being present in the Great Lakes since the 1990s, the tubenose goby has not been documented in Lake Michigan, and the natural dispersion speed of the tubenose goby is not well characterized. The tubenose goby is documented to have low abundance where established and has been slow to spread in the Great Lakes compared to other invasive gobies.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the uncertainty is low.

T_{10}: See T_0. The tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), Lake St. Clair (Jude et al. 1992), and the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). The species can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992), which likely provides a faster mechanism than natural dispersion in the spread of the species.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby through aquatic pathways at the CAWS. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the uncertainty is medium.

T_{25}: See T_{10}. With the heavy vessel traffic to Indiana Harbor, the tubenose goby may be able to reach Indiana Harbor within 10 years. However, this species is documented to be relatively uncommon in the Great Lakes Basin. Therefore, over time, trends in future populations and spread rates become less certain. In addition, this species has been established in the Great Lakes Basin since the 1990s, and it is uncertain why it has not been detected in southern Lake Michigan despite the presence of suitable habitat.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. However, over time, trends in future populations and spread rates become less certain. Therefore, the uncertainty remains medium.

T_{50}: See T_{25}. The tubenose goby may be more certain to reach Indiana Harbor over 50 years. However, on the basis of its native distribution, tubenose goby appears to be more of a cool-water species, and temperature increases related to future climate change may affect its distribution (section 2f). Thus, future climate change could affect the movement of tubenose goby into southern Lake Michigan, depending on whether the environment becomes more or less favorable to this species.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. However, over time, trends in future populations and spread rates become less certain. Therefore, the uncertainty remains medium.

3. P(passage) T_0-T_{50}: LOW-HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The tubenose goby is a small fish. Little is known about the species in the Great Lakes because of its low abundance (Dopazo et al. 2008). The invasion of the species into the Laurentian Great Lakes presumably occurred via ballast water from transoceanic cargo ships (Jude et al. 1992). Eggs are laid on the undersides of fixed objects like rocks (Kocovsky et al. 2011), making transport by currents unlikely; it has also been reported that tubenose lay their eggs in eel grass (Dopazo et al. 2008) and that eggs attached to vegetation can be transported when the vegetation is uprooted. In its invasion of the

River Rhine Basin, this species exhibited active upstream migration across large dam and lock systems (Von Landwust 2006).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the tubenose goby through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the tubenose goby as it passes through the CAWS.

b. *Human-Mediated Transport through Aquatic Pathways*

The distance from Indiana Harbor to the Brandon Road Lock and Dam is approximately 64 km (40 mi). The tubenose goby can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992), but there is only lake-wide vessel traffic to Indiana Harbor (USACE 2011a,b), and the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012).

The Nonstructural Alternative is not expected to address the human-mediated transport of the tubenose goby through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: This species prefers waters less than 5 m (16.4 ft) in depth (Fuller et al. 2012). The water depth in the Chicago River and CSSC is less than 9.1 m (30 ft), and less than 4.6 m (15 ft) in many areas, suggesting that the depth is suitable in the CAWS. The Electric Dispersal Barrier System, located north of the Lockport Lock and Dam, may act as a barrier to some degree by repelling adult fish. However, the barrier may not be effective in shocking small fish like the tubenose goby, and adults that are shocked and early life stages could float downstream through the barrier. Tubenose goby eggs are benthic, but they could move through the barrier if resuspended in the water column. So there is a high potential that adults and early life stages may pass the barrier at the current setting. In its invasion of the River Rhine Basin, this species exhibited active upstream migration across large dam and lock systems (Von Landwust 2006). Therefore, the Lockport Lock and Dam and the Brandon Road Lock and Dam are not expected to be barriers to passage.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: Tubenose goby is found along rocky and/or vegetated shallow waters as well as on sandy sediment. All these habitats are present in the CAWS (LimnoTech 2010). After entering Indiana Harbor and passing through the Indiana Harbor Ship Canal, tubenose goby would enter the Grand Calumet River. Sediments in the Grand Calumet consist of primarily cobble, bedrock or concrete, but silt, sludge, and plant debris are also present (Gallagher et al. 2011). Water can flow east or west, depending on the water level in Lake Michigan. Sediments in the Little Calumet River are primarily inorganic silt, but areas of sand and gravel are also present (LimnoTech 2010). The banks of the CSSC are composed of vertical walls, rock, and some vegetative debris. Sediments in the CSSC vary, but are primarily silt, sludge, bedrock, and sand with scattered cobble (LimnoTech 2010). Submerged aquatic vegetation is also present in portions of the CSSC (LimnoTech 2010). Tubenose goby prefer still or slow-flowing water (Dopazo et al. 2008), which is typical of the CAWS except during high flows (LimnoTech 2010). The tubenose goby is considered a cool-water species, preferring waters within the temperature range of 10 to 20°C (50 to 68°F) (Rasmussen 2002), although the western basin of Lake Erie, where this species has become successfully established, regularly exceeds this temperature range in summer (20–25°C [68–77°F]) (EPA Great Lakes National Program Office, unpublished data). Therefore, water temperatures in the CAWS may be suitable during the warmest months of the year.

The Nonstructural Alternative is not expected to affect habitat suitability for the tubenose goby in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: It is more than 64 km (40 mi) from Indiana Harbor to the Brandon Road Lock and Dam. Suitable adult and reproductive habitat is present throughout the CAWS (section 3e). It is unlikely that the tubenose goby would be transported through the CAWS by ballast water (section 3b). The Electric Dispersal Barrier System is not likely to reduce downstream movement (section 3c).

The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the tubenose goby to the Brandon Road Lock and Dam by natural dispersion. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Over time, the tubenose goby has a higher probability of spreading through the CAWS by natural dispersion. There do not appear to be any significant barriers to downstream movement.

T_{25}: See T_{10}. The tubenose goby has a higher probability of spreading through the CAWS by natural dispersion over a 25-year time frame.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: The tubenose goby may be able to pass through the Brandon Road Lock and Dam during this time step, but this species' potential speed of natural dispersion through the CAWS is uncertain, as is the potential for passive transport of adults and early life stages through the electric barrier system.

The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.

T_{10}: See T_0.

T_{25}: See T_0. The future rate of spread for this species is not well understood. However, habitat in the CAWS is suitable, and it is more certain that the tubenose goby could move through the CAWS to the Brandon Road Lock and Dam in 25 years compared to 10 years.

The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.

T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

PATHWAY 5

BURNS SMALL BOAT HARBOR (BSBH) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Ballast/Bilge-water Exchange, Monitoring, Laws and Regulations, and ANS Control Methods

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Rating Summary [a]

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	Low	Low	***Low***	Medium	Medium	Medium	Medium	Medium
P(passage)	High	Medium	High	Medium	High	Low	High	Low
P(colonizes)	Medium	High	Medium	High	Medium	High	Medium	High
P(spreads)	Medium	High	Medium	High	Medium	High	Medium	High
P(establishment)	Low	–[b]	***Low***	–	Medium	–	Medium	–

[a] The highlighted table cells indicate a rating change in the probability element.

[b] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the Burns Small Boat Harbor (BSBH) and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not impact the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: LOW-MEDIUM

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

The tubenose goby is a small, benthic fish. It exhibits a slow invasion speed and has not spread rapidly in the Great Lakes Basin (Vanderploeg et al. 2002; Rasmussen 2002; Fuller et al. 2012). The species invaded the Laurentian Great Lakes in the 1990s, presumably via ballast water from transoceanic cargo ships (Jude et al. 1992). Jump dispersal by the tubenose goby from the lower Great Lakes to Lake Superior can be explained by ship transport (Dopazo et al. 2008). This species is less successful than the round goby, *Neogobius melanostomus*, in terms of spread and population growth (Dillon and Stepien 2001). The decline in wetland habitat may explain the low occurrence of tubenose gobies in the Great Lakes (Dopazo et al. 2008).

The Nonstructural Alternative is not expected to affect the arrival of the tubenose goby at the CAWS via natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Tubenose goby actively swim and do not require humans for dispersal; however, human-mediated transport is likely to be a faster mechanism for the spread of this species than natural dispersion. The species can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992). There is recreational but no commercial vessel traffic to the BSBH from the Great Lakes (USACE 2011a,b). However, there is commercial vessel traffic to the adjacent Burns Harbor from Duluth-Superior Harbor, where this species is located (USACE 2011a; NBIC 2012), which could transport this species closer to the BSBH.

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting, which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular piscicides. The implementation of a ballast/bilge-water exchange program, education and outreach, and laws and regulations may reduce the human-mediated transport of the tubenose goby to the CAWS pathway.

c. Current Abundance and Reproductive Capacity

T_0: The abundance of the tubenose goby in the Great Lakes Basin is low (Dopazo et al. 2008). The tubenose goby has spread throughout Lake St. Clair in Michigan and its tributaries (Jude et al. 1992), as well as the Detroit River system, and is commonly collected in the Duluth-Superior Harbor of Lake Superior (Kocovsky et al. 2011). A population of tubenose gobies has become established and self-sustaining in the western basin of Lake Erie (Kocovsky et al. 2011). Tubenose gobies reach maturity in 1–2 years (Freyhof and Kottelat 2008). The females of the species spawn more than once during a season (Freyhof and Kottelat 2008), and likely have a protracted spawning period (Leslie et al. 2002).

The Nonstructural Alternative includes agency monitoring and voluntary occurrence reporting, which, in combination with education and outreach, may be used to determine where to target nonstructural control measures, in particular piscicides. However, the current distribution of the tubenose goby is too dispersed to be effectively controlled with occasional application of piscicides in localized areas.

If localized populations are found in shallow localized waters, desiccation (water drawdown) may be implemented to control isolated populations. Owing to the tubenose goby's small size and widespread distribution, controlled harvest and overfishing are not expected to be effective control measures to impact the arrival of the tubenose goby at the CAWS pathway.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Existing Physical Human/Natural Barriers*

T_0: There are no existing barriers. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. *Distance from Pathway*

T_0: Tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), in Lake St. Clair (Jude et al. 1992), and in the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). It is commonly collected in the Duluth-Superior harbor of Lake Superior (Kocovsky et al. 2011). No records were found that indicated collection of this species in Lake Michigan. The U.S. Environmental Protection Agency (EPA 2008) states that the species may be able to occupy all shallow waters of all five Great Lakes.

The Nonstructural Alternative includes ballast/bilge-water exchange programs, which may increase the time the tubenose goby takes to arrive at the CAWS pathway. The species invaded the Laurentian Great Lakes in the 1990s, presumably via ballast water from transoceanic cargo ships (Jude et al. 1992). Jump dispersal by the tubenose goby from the lower Great Lakes to Lake Superior can be explained by ship transport (Dopazo et al. 2008). Ballast/bilge water transport is thought to assist the tubenose goby's dispersion in the Great Lakes.

T_{10}: See T_0. Tubenose goby could move closer to the BSBH by vessel transport or natural dispersion to southern Lake Michigan. The species may be able to occupy shallow waters of all five Great Lakes (EPA 2008). Ballast/bilge-water exchange programs may increase the time the tubenose goby takes to arrive at the CAWS pathway.

T_{25}: See T_{10}.

T_{50}: See T_{10}. In the future, the distance of the species from the CAWS could increase or decrease. Examples of future changes potentially affecting the distribution of tubenose goby in the Great Lakes include natural population growth, climate change, or new ANS.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: The native range of tubenose goby includes slightly brackish to fresh waters of Eurasia, primarily in rivers and estuaries of the Black Sea Basin and rivers of the northern Aegean (Fuller et al. 2012; Neilson and Stepien 2009). The species is considered a cool-water species, preferring temperatures ranging from 10 to 20°C (50 to 68°F). Rasmussen (2002) and the EPA (2008) suggested that southern Lake Michigan may be suitable on the basis of temperature preferences. Tubenose goby prefers benthic habitats in low salinity estuaries, lakes, rivers and wetlands (Dopazo et al. 2008); it typically dwells in shallow near-shore waters (Dopazo et al. 2008). Adults of this species inhabit waters less than 5 m (16.4 ft) in depth (Fuller et al. 2012), with maximum densities in western Lake Erie being reached in waters less than 1.5 m (4.9 ft) deep (Kocovsky et al. 2011). Densities of the species were significantly greater in riprap habitat than in sandy and macrophyte habitats (Jude and DeBoe 1996). Leslie et al. (2002) collected the species in water with no or slow flow. Tubenose goby spawns on the underside of fixed objects like rocks (Kocovsky et al. 2011); there is rocky habitat in the vicinity of the BSBH, as well as sandy habitat and Cladophora beds (MTRI 2012) that may be suitable.

The Nonstructural Alternative is not expected to reduce the habitat suitability for the tubenose goby in southern Lake Michigan.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating[a]	Low	***Low***	Medium	Medium

[a] The highlighted table cell indicates a rating change in the probability element.

Evidence for Probability Rating (Considering All Life Stages)

T_0: This species is not currently in Lake Michigan, and is reported to have a slow rate of spread and low abundance (Fuller et al. 2012; Vanderploeg et al. 2002). Tubenose goby can be transported via ballast water (sections 2a, 2b), and there is cargo vessel traffic to Burns Harbor that could transport this species to the vicinity of the BSBH (section 2b). Natural dispersion for this species is not well characterized in the Great Lakes, but this species is unlikely to spread from its current locations during the current time step, given that it has not yet been detected in southern Lake Michigan despite being in the Great Lakes since the 1990s (section 2a).

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway.

The Nonstructural Alternative reduces the likelihood of the tubenose goby arriving at the CAWS aquatic pathway. However, the Nonstructural Alternative's low probability of arrival rating for this time step does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. The tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), Lake St. Clair (Jude et al. 1992), and the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). The species can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992), which likely provides a faster mechanism than natural dispersion for the spread of the species.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the probability of arrival is reduced to low.

T_{25}: See T_{10}. There is commercial vessel transport from ports where the tubenose goby is located to ports adjacent to the BSBH (section 2b). This species has not spread rapidly in the Great Lakes (section 2a).

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. However, over time, the probability increases that that the species would have time to spread by human-mediated transport to ports in southern Lake Michigan, coupled with natural dispersion to the BSBH. Therefore, its probability of arrival remains medium.

T_{50}: See T_{25}.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Medium	Medium	Medium
Nonstructural Alternative Rating	Low	Medium	Medium	Medium

Evidence for Uncertainty Rating

T_0: There is commercial vessel traffic between areas where the tubenose goby is located and the vicinity of the BSBH, so the potential for ballast-water transport could be high. However, despite being present in the Great Lakes since the 1990s, the tubenose goby has not been documented in Lake Michigan, and the natural dispersion speed of the tubenose goby is not well characterized. The tubenose goby is documented to have low abundance where established, and has been slow to spread in the Great Lakes compared to other invasive gobies.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the uncertainty is low.

T_{10}: See T_0. The tubenose goby is established in the western basin of Lake Erie (Kocovsky et al. 2011), Lake St. Clair (Jude et al. 1992), and the St. Louis River, which empties into Lake Superior (Fuller et al. 2012). The species can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992), which likely provides a faster mechanism than natural dispersion for the spread of the species.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby at the CAWS through aquatic pathways. The implementation of a ballast/bilge-water exchange program is expected to increase the time it takes for the tubenose goby to arrive at the pathway. Therefore, the uncertainty is medium.

T_{25}: See T_{10}. With the heavy vessel traffic to Burns Harbor, the tubenose goby may be able to reach the BSBH within 10 years. However, this species is documented to be relatively uncommon in the Great Lakes Basin. This species has been established in the Great Lakes Basin since the 1990s, and it is uncertain why it has not been detected in southern Lake Michigan despite the presence of suitable habitat.

The Nonstructural Alternative is expected to affect the arrival of the tubenose goby through aquatic pathways at the CAWS. However, over time, trends in future populations and spread rates become less certain. Therefore, the uncertainty remains medium.

T_{50}: See T_{25}. The tubenose goby may be more certain to reach the BSBH over 50 years. However, on the basis of its native distribution, tubenose goby appears to be more of a cool-water species, and temperature increases related to future climate change may affect its distribution (section 2f). Thus, future climate change could affect the movement of tubenose goby into southern Lake Michigan, depending on whether the environment becomes more or less favorable to this species.

3. P(passage) T_0-T_{50}: LOW-HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

The tubenose goby is a small fish. Little is known about the species in the Great Lakes because of its low abundance (Dopazo et al. 2008). The invasion of the species into the Laurentian Great Lakes presumably occurred via ballast water from transoceanic cargo ships (Jude et al. 1992). Eggs are laid on the undersides of fixed objects like rocks (Kocovsky et al. 2011), making transport by currents unlikely; it has also been reported that tubenose lays eggs in eel grass (Dopazo et al. 2008) and that eggs attached to vegetation can be transported when the vegetation is uprooted. In its invasion of the River Rhine Basin, this species exhibited active upstream migration across large dam and lock systems (Von Landwust 2006).

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., swimming and passive drift) of the tubenose goby through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of the tubenose goby as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

The distance from the BSBH to the Brandon Road Lock and Dam is greater than 64 km (40 mi). The tubenose goby can be transported in ballast water (Dopazo et al. 2008; Jude et al. 1992), but there is generally only lake-wide vessel traffic to the BSBH and the adjacent Burns Harbor, and the discharge of ballast water does not typically occur at inland ports within the CAWS (USACE 2011a,b; NBIC 2012).

The Nonstructural Alternative is not expected to address the human-mediated transport of the tubenose goby through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: This species prefers waters less than 5 m (16.4 ft) in depth (Fuller et al. 2012). The water depth in the Chicago River and the CSSC is less than 9.1 m (30 ft), and less than 4.6 m (15 ft) in many areas. The Electric Dispersal Barrier System, located north of the Lockport Lock and Dam, may act as a barrier to some degree by repelling adult fish. However, the barrier may not be effective in shocking small fish like the tubenose goby, and adults that are shocked and early life stages could flow downstream through the barrier. Tubenose goby eggs are benthic, but they could move through the barrier if resuspended in the water column. So there is a high potential that adults and early life stages may pass the barrier at the current setting. In its invasion of the River Rhine Basin, this species exhibited active upstream migration across large dam and lock systems (Von Landwust 2006). Therefore, the Lockport Lock and Dam and the Brandon Road Lock and Dam are not expected to be a barrier to passage.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: Tubenose goby are found along rocky and/or vegetated shallow waters as well as on sandy sediment. All these habitats are present in the CAWS (LimnoTech 2010). After entering the BSBH and passing through Burns Ditch, the tubenose goby would enter the south branch of the Little Calumet River. The banks of the south leg of the Little Calumet River are vegetated, and sediments are composed of plant debris, silt, sand, cobble, gravel, and boulder (Gallagher et al. 2011). Sediments in the Little Calumet River are primarily inorganic silt, but areas of sand and gravel are also present

(LimnoTech 2010). The banks of the CSSC are composed of vertical walls, rock, and some vegetative debris. Sediments in the CSSC vary, but are primarily silt, sludge, bedrock, and sand, with scattered cobble (LimnoTech 2010). Submerged aquatic vegetation is also present in portions of the CSSC (LimnoTech 2010). Tubenose goby prefers still or slow-flowing water (Dopazo et al. 2008), which is typical of the CAWS except during high flows (LimnoTech 2010). The tubenose goby is considered a cool-water species, preferring waters within the temperature range of 10 to 20°C (50 to 68°F) (Rasmussen 2002), although the western basin of Lake Erie, where this species has become successfully established, regularly exceeds this temperature range in summer (20 to 25°C [68 to 77°F]) (EPA Great Lakes National Program Office, unpublished data). Therefore, water temperatures in the CAWS may not be suitable during the warmest months of the year.

The Nonstructural Alternative is not expected to affect habitat suitability for the tubenose goby in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: It is more than 64 km (40 mi) from the BSBH to the Brandon Road Lock and Dam. Suitable adult and reproductive habitat is present throughout the CAWS (section 3e). It is unlikely that the tubenose goby would be transported through the CAWS by ballast water (section 3b). The Electric Dispersal Barrier System is not likely to reduce downstream movement (section 3c).

The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of the tubenose goby to the Brandon Road Lock and Dam by natural dispersion. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0. Over time, the tubenose goby has a higher probability of spreading through the CAWS by natural dispersion. There do not appear to be any significant barriers to downstream movement.

T_{25}: See T_{10}. The tubenose goby has a higher probability of spreading through the CAWS by natural dispersion over a 25-year time frame.

T_{50}: See T_{25}.

Uncertainty of Passage

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Medium	Medium	Low	Low
Nonstructural Alternative Rating	Medium	Medium	Low	Low

Evidence for Uncertainty Rating

T_0: The tubenose goby may be able to pass through the Brandon Road Lock and Dam during this time step, but this species' potential speed of natural dispersion through the CAWS is uncertain, as is the potential for passive transport of adults and early life stages through the electric barrier system. The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains medium.
T_{10}: See T_0.
T_{25}: See T_0. The future rate of spread for this species is not well understood. However, habitat in the CAWS is suitable, and it is more certain that the tubenose goby would move through the CAWS to the Brandon Road Lock and Dam in 25 years compared to 10 years.

The Nonstructural Alternative is not expected to affect the passage of the tubenose goby through the aquatic pathway by natural dispersion or human-mediated transport. Overall, the uncertainty remains low.
T_{50}: See T_{25}.

4. P(colonizes) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from the No New Federal Action Risk Assessment.

Uncertainty: HIGH

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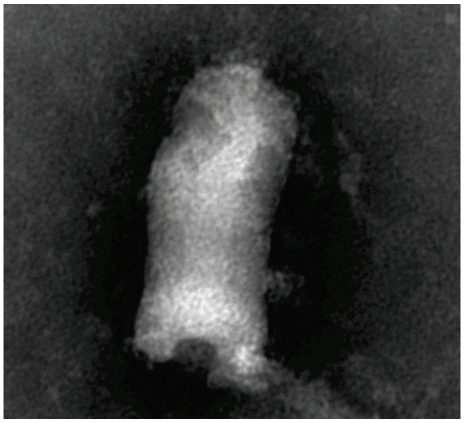
E.2.2.5 Virus

E.2.2.5.1 Viral Hemorrhagic Septicemia (Novirhabdovirus sp.)



NONSTRUCTURAL ALTERNATIVE

This alternative would potentially include the implementation of a combination of the following measures that can be implemented at time step 0 (T_0, in units of years) by local, state, and federal agencies and the public. The Nonstructural Alternative would include the development of a monitoring and response program.

Nonstructural Alternative Measures for Viral Hemorrhagic Septicemia

Option or Technology	Description
Education and Outreach	• Signage, pamphlets, brochures on how to identify ANS and control the spread of ANS; promote national campaigns (i.e., "Stop Aquatic Hitchhikers") • Education of recreational waterway users
Anti-Fouling Hull Paints	• Education of vessel owners and operators to promote use of antifouling paints
Ballast/Bilge-water Exchange	• Ballast/bilge-water exchange
Monitoring	• Agency monitoring • Voluntary occurrence reporting
Laws and Regulations	• USFWS Lacey Act listing • Mandatory watercraft inspection and decontamination

PATHWAY 1

WILMETTE PUMPING STATION (WPS) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**P**	**U**	**P**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between WPS and the Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

Viral hemorrhagic septicemia (VHSv) is a viral disease of freshwater and marine fish. Until the 1980s, VHSv was believed to be isolated to freshwaters of Europe (Wolf 1988). Since that time, four genotypes of the virus have been found in various marine and freshwater habitats, including water bodies in Europe, North America, Korea, and Japan (Nishizawa et al. 2002; Skall et al. 2005). It was first reported in the Great Lakes in 2003 from Lake St. Clair (Elsayed et al. 2006), and by 2010 it had spread to all five Great Lakes (MNDR 2010). VHSv genotype IVb has now been confirmed in five coldwater species and 19 coolwater species in the Great Lakes (Whelan 2009); 28 species of fish from the Great Lakes Basin are considered at risk from the virus, including smallmouth bass, walleye, and bluegill (Dudis 2011). Susceptible fish contract the virus by being in close proximity to other infected individuals, or by ingesting infected material. Affected fish shed the virus into the surrounding environment through urine and reproductive fluids (Meyers and Winton 1995); the virus can enter the body through the gills or open wounds (Whelan 2009). Survivors of viral infection are carriers and continue to shed virus particles for extended periods of time (Kim and Faisal 2012). Ingesting infected prey fish or invertebrates that are harboring the virus can also lead to infection (Ahne 1980; Skall et al. 2005; Faisal and Winters 2011). VHSv can exist for extended periods of time in freshwater without a host, depending on temperature (Whelan 2009; Hawley and Garver 2008); contact with water containing the virus is also a means of spread (Castric and de Kinkelin 1980; Muroga et al. 2004). Infected females can also shed the virus during egg deposition; the virus can persist for a period long enough to infect progeny (Tuttle-Lau et al. 2010). Blood-sucking leeches are also potential transmitters of the virus to fish (Faisal and Schulz 2009).

The Nonstructural Alternative is not expected to affect VHSv's arrival at the Chicago Area Waterway System (CAWS) as a result of natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Potential spread mechanisms include the movement of infected fish (baitfish or gamefish) to new water bodies; the transport of contaminated waters, fish, or fish parts in ballast water or in bilges of recreational boats, or; the movement of contaminated fishing equipment (Whelan 2009; Warren 1983). Ship ballast has been shown to be a transport mechanism of non-native bacteria and viruses (Drake et al. 2007); however, the current distribution of the virus does not suggest shipping-related transport (Bain et al. 2010) as a mechanism of spread. There is no commercial vessel traffic from the Great Lakes to the WPS, but there is recreational boat traffic (USACE 2011a,b).

Anti-fouling hull paints are a possible measure for controlling the VHSv on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS as a result of human-mediated transport through aquatic pathways.

c. *Current Abundance and Reproductive Capacity*

T_0: The North American strain of the virus has established populations in all five Great Lakes since its discovery in 2003, and has been found in several inland waters of New York, Ohio, Michigan, and Wisconsin (Kipp et al. 2013). Once the virus is established in a region, it will become widespread, hosted by fish without disease symptoms, and capable of persistence at low but detectable levels (Bain et al. 2010). Benthic macroinvertebrates sampled in Lake Michigan have tested positive for the virus (Faisal et al. 2012). No documented fish kills in Lake Michigan resulting from VHSv were found.

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of VHSv.

T_{10}: See T_0.

T_{25}: See T_{10}.

T_{50}: See T_{25}. Changes in water temperature related to future climate change (Wuebbles et al. 2010) could affect the spread or virulence of this species.

d. *Existing Physical Human/Natural Barriers*

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: VHSv was reported in Lake Michigan near Waukegan in Illinois, and at Green Bay, Little Sturgeon Bay, Algoma, and Milwaukee in Wisconsin (Kipp et al. 2013; Whelan 2009).

The Nonstructural Alternative is not expected to limit VHSv's movement outside of its current distribution.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: VHSv has been detected in southwestern Lake Michigan at Waukegan and Winthrop harbors (Dudis 2011), suggesting climate is suitable. The pathogen replicates at temperatures of 2–15°C (35.6–59°F) (Wolf 1988; McAllister 1990; Meyers and Winton 1995); peak viral activity in the Great Lakes corresponds to spring spawning periods and winter when temperatures are suitable (Eckerlin et al. 2011). Optimum replication temperature is 14–15°C (57.2–59°F), and VHSv can last a few weeks in freshwater at moderate temperatures (10–15°C; 50–59°F) without a host (Hawley and Garver 2008; Whelan 2009). Replication is low at 6°C (42.8°F) and almost nonexistent at 20°C (68°F) (de Kinkelin et al. 1980; Bernard et al. 1983; McAllister 1990). The virus is adapted to colder waters and becomes inactive after 24 hours in water temperatures above 20°C (68°F) (CFSPH 2003; Hawley and Garver 2008). The Great Lakes genotype IVb has been confirmed in five coldwater and 19 coolwater species (Whelan 2009), and 28 species of fish from the Great Lakes Basin are considered at risk (Dudis 2011). Fish are most susceptible to the virus during times of stress, in crowded conditions, during early life stages, and in cold temperatures (9–15°C; 48.2–59°F [Smail 1999]).

The Nonstructural Alternative is not expected to reduce habitat suitability for VHSv in southern Lake Michigan.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: VHSv is sensitive to climatological conditions. Future climate change and/or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for VHSv. Future climate change is projected to increase water temperature in the Great Lakes (Wuebbles et al. 2010), which could reduce the productivity of VHSv.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: VHSv has spread throughout the Great Lakes in less than a decade. It has been documented in Lake Michigan as far south as Waukegan. There are no barriers to the movement of this species by boat, current, or host fish. Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by VHSv. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of VHSv at the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: VHSv is considered to be established in Lake Michigan and was documented offshore of the Waukegan and Winthrop harbors in Illinois (section 2e). Its ability to spread rapidly in the Great Lakes has been documented. Therefore, the uncertainty of the probability of arrival is considered to be low.

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

VHSv can be transported by the movement of infected fish or eggs, or through the movement of contaminated water (Meyers and Winton 1995; Whelan 2009; Hawley and Garver 2008). The virus has a history of quickly invading through waterways, rivers, and lakes (Fisheries Technical Committee 2009). From the WPS, VHSv must move more than 64 km (40 mi) downstream to reach the Brandon Road Lock and Dam. The downstream flow of water would facilitate the transport of this species downstream of the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e. infected host and passive drift) of VHSv through the aquatic pathway; therefore, this alternative is not expected to affect the mobility/invasion speed of VHSv as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

VHSv can potentially be transported via ballast water (Whelan 2009; Elsayed et al. 2006), although the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). In addition, a sluice gate at the WPS controls the entry of vessel traffic from Lake Michigan into the North Shore Channel. Water from Lake Michigan is periodically pumped into the North Shore Channel, which could transport the virus into the CAWS. There is no commercial vessel traffic in the North Shore Channel. Therefore, some natural downstream movement would likely be required for VHSv to reach the Brandon Road Lock and Dam. In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport VHSv into the CAWS. The Nonstructural Alternative would not address the passage of VHSv by the Lake Michigan diversion through the aquatic pathway.

Anti-fouling hull paints are a possible measure for controlling VHSv on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of VHSv through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: None. Surface water is present year-round, and water depth is adequate throughout the CAWS (LimnoTech 2010). There is a sluice gate separating the CAWS from Lake

Michigan that is periodically opened and closed. Water from Lake Michigan is periodically pumped into the North Shore Channel, which could transport VHSv into the CAWS.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0. No changes in human or natural barriers are expected. The sluice gate is expected to continue to operate under current procedures.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: VHSv has been reported from both freshwater and marine environments (Kipp et al. 2013). The virus can exist in freshwater for extended periods of time without a host, particularly at cool water temperatures (Hawley and Garver 2008). At high water temperatures (30°C; 86°F), the virus becomes inactivated within 1 day (Hawley and Garver 2008). Within the Great Lakes Basin, 28 fish species are at risk from the virus (Dudis 2011), and many of these species are found in the CAWS.

The Nonstructural Alternative is not expected to affect habitat suitability for VHSv in the CAWS.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: VHSv could be transported through the WPS and move downstream to the Brandon Road Lock and Dam through gravity flow or fish hosts. The Nonstructural Alternative is not expected to affect the passage of VHSv through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address the passage of VHSv by the Lake Michigan diversion, transport by contaminated water, or transport by contaminated fish to Brandon Road Lock and Dam.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by VHSv. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of VHSv through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of VHSv through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the

Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: **T_0:** VHSv's movement through waterways has been documented. There are fish species in the CAWS that could serve as hosts for VHSv and transport VHSv downstream. The Nonstructural Alternative is not expected to affect the passage of VHSv through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains low.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Project Risk Assessment.

Uncertainty: LOW

5. **P(spreads) T_0-T_{50}: MEDIUM**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Project Risk Assessment.

Uncertainty: MEDIUM

PATHWAY 2

CHICAGO RIVER CONTROLLING WORKS (CRCW) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between the CRCW and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative does not affect the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

VHSv is a viral disease of freshwater and marine fish. Until the 1980s, VHSv was believed to be isolated to freshwaters of Europe (Wolf 1988). Since that time, four genotypes of the virus have been found in various marine and freshwater habitats, including water bodies in Europe, North America, Korea, and Japan (Nishizawa et al. 2002; Skall et al. 2005). It was first reported in the Great Lakes in 2003 from Lake St. Clair (Elsayed et al. 2006), and by 2010 it had spread to all five Great Lakes (MNDR 2010). VHSv genotype IVb has now been confirmed in five coldwater species and 19 coolwater species in the Great Lakes (Whelan 2009); 28 species of fish from the Great Lakes Basin are considered at risk from the virus, including smallmouth bass, walleye, and bluegill (Dudis 2011). Susceptible fish contract the virus by being in close proximity to other infected individuals, or by ingesting infected material. Affected fish shed the virus into the surrounding environment through urine and reproductive fluids (Meyers and Winton 1995); the virus can enter the body through the gills or open wounds (Whelan 2009). Survivors of viral infection are carriers and continue to shed virus particles for extended periods of time (Kim and Faisal 2012). Ingesting infected prey fish or invertebrates harboring the virus can also lead to infection (Ahne 1980; Skall et al. 2005; Faisal and Winters 2011). VHSv can exist for extended periods of time in freshwater without a host, depending on temperature (Whelan 2009; Hawley and Garver 2008); contact with water containing the virus is also a means of spread (Castric and de Kinkelin 1980; Muroga et al. 2004). Infected females can also shed the virus during egg deposition; the virus can persist for a period long enough to infect progeny (Tuttle-Lau et al. 2010). Blood-sucking leeches are also potential transmitters of the virus to fish (Faisal and Schulz 2009).

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS as a result of natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Potential spread mechanisms include the movement of infected fish (baitfish or gamefish) to new water bodies; the transport of contaminated waters, fish, or fish parts in ballast water or in bilges of recreational boats, or; the movement of contaminated fishing equipment (Whelan 2009; Warren 1983). Ship ballast has been shown to be a transport mechanism of non-native bacteria and viruses (Drake et al. 2007); however, the current distribution of the virus does not suggest shipping-related transport (Bain

et al. 2010) as a mechanism of spread. There is commercial and recreational vessel traffic from the Great Lakes to the CRCW (USACE 2011a,b).

Anti-fouling hull paints are a possible measure for controlling VHSv on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS as a result of human-mediated transport through aquatic pathways.

c. *Current Abundance and Reproductive Capacity*

T_0: The North American strain of the virus has established populations in all five Great Lakes since its discovery in 2003, and has been found in several inland waters of New York, Ohio, Michigan, and Wisconsin (Kipp et al. 2013). Once the virus is established in a region, it will become widespread, hosted by fish without disease symptoms, and capable of persistence at low but detectable levels (Bain et al. 2010). Benthic macroinvertebrates sampled in Lake Michigan have tested positive for the virus (Faisal et al. 2012). No documented fish kills in Lake Michigan resulting from VHSv were found.

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of VHSv.

T_{10}: See T_0.

T_{25}: See T_{10}.

T_{50}: See T_{25}. Changes in water temperature related to future climate change (Wuebbles et al. 2010) could affect the spread or virulence of this species in Lake Michigan.

d. *Existing Physical Human/Natural Barriers*

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. *Distance from Pathway*

T_0: VHSv was reported in Lake Michigan near Waukegan in Illinois, and at Green Bay, Little Sturgeon Bay, Algoma, and Milwaukee in Wisconsin (Kipp et al. 2013; Whelan 2009).

The Nonstructural Alternative is not expected to limit the movement of VHSv outside of its current distribution.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: VHSv has been detected in southwestern Lake Michigan at Waukegan and Winthrop harbors (Dudis 2011), suggesting climate is suitable. The pathogen replicates at temperatures of 2–15°C (35.6–59°F) (Wolf 1988; McAllister 1990; Meyers and Winton 1995); peak viral activity in the Great Lakes corresponds to spring spawning periods and winter when temperatures are suitable (Eckerlin et al. 2011). Optimum replication temperature is 14–15°C (57.2–59°F), and VHSv can last a few weeks in freshwater at moderate temperatures (10–15°C; (50–59°F) without a host (Hawley and Garver 2008; Whelan 2009). Replication is low at 6°C (42.8°F) and almost nonexistent at 20°C (68°F) (de Kinkelin et al. 1980; Bernard et al. 1983; McAllister 1990). The virus is adapted to colder waters and becomes inactive after 24 hours in water temperatures above 20°C (68°F) (CFSPH 2003; Hawley and Garver 2008). The Great Lakes genotype IVb has been confirmed in five coldwater and 19 coolwater species (Whelan 2009), and 28 species of fish from the Great Lakes Basin are considered at risk (Dudis 2011). Fish are most susceptible to the virus during times of stress, in crowded conditions, during early life stages, and in cold temperatures (9–15°C; 48.2–59°F [Smail 1999]).

The Nonstructural Alternative is not expected to reduce habitat suitability for VHSv in southern Lake Michigan.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0. VHSv is sensitive to climatological conditions. Future climate change and/or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for VHSv. Future climate change is projected to increase water temperature in the Great Lakes (Wuebbles et al. 2010), which could reduce the productivity of VHSv.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: VHSv has spread throughout the Great Lakes in less than a decade. It has been documented in Lake Michigan as far south as Waukegan. There are no barriers to the movement of this species by boat, current, or host fish.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required.

Additional study is needed to assess the effectiveness of these paints to control fouling by VHSv. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of VHSv at the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: VHSv is considered to be established in Lake Michigan and was documented offshore of the Waukegan and Winthrop harbors in Illinois (section 2e). Its ability to spread rapidly in the Great Lakes has been documented.

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

3. P(passage) T_0-T_{50} : HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

VHSv has a history of rapid spread through waterways by movement of infected fish, virus-containing waters, or human-mediated mechanisms (Meyers and Winton 1995; Whelan 2009; Hawley and Garver 2008). The virus has a history of quickly invading through waterways, rivers, and lakes (Fisheries Technical Committee 2009). From the CRCW, VHSv must move more than 80 km (50 mi) downstream to reach the Brandon Road Lock and Dam. The downstream flow of water would facilitate the transport of this species downstream of the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., infected host and passive drift) of VHSv through the aquatic pathway; therefore, this alternative is not expected to affect VHSv's mobility/invasion speed as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

VHSv may be transported in ballast water (Whelan 2009; Elsayed et al. 2006), and there is some commercial vessel traffic between the CRCW and the Brandon Road Lock and Dam (USACE 2011a; NBIC 2012). However, the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport VHSv into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Anti-fouling hull paints are a possible measure for controlling VHSv on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of VHSv through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: None. Surface water is present year-round. There are no barriers to this species moving to Brandon Road Lock and Dam from the CRCW.

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0. No changes in human or natural barriers are expected.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: VHSv has been reported from both freshwater and marine environments (Kipp et al. 2013). The virus can exist in freshwater for extended periods of time without a host, particularly at cool water temperatures (Hawley and Garver 2008). At high water temperatures (30°C; 86°F), the virus becomes inactivated within 1 day (Hawley and Garver 2008). Within the Great Lakes Basin, 28 fish species are at risk from the virus (Dudis 2011), and many of these species are found in the CAWS.

The Nonstructural Alternative is not expected to affect habitat suitability for VHSv in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: VHSv could be transported through the CRCW and move downstream to the Brandon Road Lock and Dam through gravity flow or fish hosts. The Nonstructural Alternative is not expected to affect the passage of VHSv through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address VHSv's passage to Brandon Road Lock and Dam via the Lake Michigan diversion or transport in infected fish.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by VHSv. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of VHSv through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of VHSv through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: VHSv's movement through waterways has been documented. There are fish species in the CAWS that could serve as hosts for VHSv and transport VHSv downstream. The Nonstructural Alternative is not expected to control the passage of VHSv through the

aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains low.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

4. **P(colonizes) T_0-T_{50}: HIGH**

   The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Project Risk Assessment.

   Uncertainty: LOW

5. **P(spreads) T_0-T_{50}: MEDIUM**

   The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Project Risk Assessment.

   Uncertainty: MEDIUM

PATHWAY 3
CALUMET HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Calumet Harbor and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not affect the existence of the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

VHSv is a viral disease of freshwater and marine fish. Until the 1980s, VHSv was believed to be isolated to freshwaters of Europe (Wolf 1988). Since that time, four genotypes of the virus have been found in various marine and freshwater habitats, including water bodies in Europe, North America, Korea, and Japan (Nishizawa et al. 2002; Skall et al. 2005). It was first reported in the Great Lakes in 2003 from Lake St. Clair (Elsayed et al. 2006), and by 2010 it had spread to all five Great Lakes (MNDR 2010). VHSv genotype IVb has now been confirmed in five coldwater species and 19 coolwater species in the Great Lakes (Whelan 2009); 28 species of fish from the Great Lakes Basin are considered at risk from the virus, including smallmouth bass, walleye, and bluegill (Dudis 2011). Susceptible fish contract the virus by being in close proximity to other infected individuals, or by ingesting infected material. Affected fish shed the virus into the surrounding environment through urine and reproductive fluids (Meyers and Winton 1995); the virus can enter the body through the gills or open wounds (Whelan 2009). Survivors of viral infection are carriers and continue to shed virus particles for extended periods of time (Kim and Faisal 2012). Ingesting infected prey fish or invertebrates harboring the virus can also lead to infection (Ahne 1980; Skall et al. 2005; Faisal and Winters 2011). VHSv can exist for extended periods of time in freshwater without a host, depending on temperature (Whelan 2009; Hawley and Garver 2008); contact with water containing the virus is also a means of spread (Castric and de Kinkelin 1980; Muroga et al. 2004). Infected females can also shed the virus during egg deposition; the virus can persist for a period long enough to infect progeny (Tuttle-Lau et al. 2010). Blood-sucking leeches are also potential transmitters of the virus to fish (Faisal and Schulz 2009).

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS as a result of natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Potential spread mechanisms include the movement of infected fish (baitfish or gamefish) to new water bodies; the transport of contaminated waters, fish, or fish parts in ballast water or in bilges of recreational boats, or; the movement of contaminated fishing equipment (Whelan 2009; Warren 1983). Ship ballast has been shown to be a transport mechanism of non-native bacteria and viruses (Drake et al. 2007); however, the current distribution of the virus does not suggest shipping-related transport (Bain

et al. 2010) as a mechanism of spread. There is commercial and recreational vessel traffic from the Great Lakes to Calumet Harbor (USACE 2011a,b).

Anti-fouling hull paints are a possible measure for controlling VHSv on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS as a result of human-mediated transport through aquatic pathways.

c. Current Abundance and Reproductive Capacity

T_0: The North American strain of the virus has established populations in all five Great Lakes since its discovery in 2003, and has been found in several inland waters of New York, Ohio, Michigan, and Wisconsin (Kipp et al. 2013). Once the virus is established in a region, it will become widespread, hosted by fish without disease symptoms, and capable of persistence at low but detectable levels (Bain et al. 2010). Benthic macroinvertebrates sampled in Lake Michigan have tested positive for the virus (Faisal et al. 2012). No documented fish kills in Lake Michigan resulting from VHSv were found.

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of VHSv.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Changes in water temperature related to future climate change (Wuebbles et al. 2010) could affect the spread or virulence of this species in Lake Michigan.

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: As of 2009, VHSv was reported in Lake Michigan near Waukegan and Winthrop harbors in Illinois, and at Green Bay, Little Sturgeon Bay, Algoma, and Milwaukee in Wisconsin (Kipp et al. 2013; Whelan 2009).

The Nonstructural Alternative is not expected to limit VHSv's movement outside of its current distribution.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: VHSv has been detected in southwestern Lake Michigan at Waukegan and Winthrop harbors (Dudis 2011), suggesting climate is suitable. The pathogen replicates at temperatures of 2–15°C (35.6–59°F) (Wolf 1988; McAllister 1990; Meyers & Winton 1995); peak viral activity in the Great Lakes corresponds to spring spawning periods and winter when temperatures are suitable (Eckerlin et al. 2011). Optimum replication temperature is 14–15°C (57.2–59°F), and VHSv can last a few weeks in freshwater at moderate temperatures (10–15°C; 50–59°F) without a host (Hawley and Garver 2008; Whelan 2009). Replication is low at 6°C and almost nonexistent at 20°C (68°F) (de Kinkelin et al. 1980; Bernard et al. 1983; McAllister 1990). The virus is adapted to colder waters and becomes inactive after 24 hours in water temperatures above 20°C (68°F) (CFSPH 2003; Hawley and Garver 2008). The Great Lakes genotype IVb has been confirmed in five coldwater and 19 coolwater species (Whelan 2009), and 28 species of fish from the Great Lakes Basin are considered at risk (Dudis 2011). Fish are most susceptible to the virus during times of stress, in crowded conditions, during early life stages, and in cold temperatures (9–15°C; 48.2–59°F [Smail 1999]).

The Nonstructural Alternative is not expected to reduce habitat suitability for VHSv in southern Lake Michigan.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0. VHSv is sensitive to climatological conditions. Future climate change and/or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for VHSv. Future climate change is projected to increase water temperature in the Great Lakes (Wuebbles et al. 2010), which could reduce VHSv's productivity.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: VHSv has spread throughout the Great Lakes in less than a decade. It has been documented in Lake Michigan as far south as Waukegan. There are no barriers to the movement of this species by boat, current, or host fish.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required.

Additional study is needed to assess the effectiveness of these paints to control fouling by VHSv. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of VHSv at the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect the arrival of VHSv through aquatic pathways to the CAWS. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: VHSv is considered to be established in Lake Michigan and was documented offshore of the Waukegan and Winthrop harbors in Illinois (section 2e). Its ability to spread rapidly in the Great Lakes has been documented.

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

VHSv can be transported by the movement of infected fish or eggs, or through the movement of contaminated water (Meyers and Winton 1995; Whelan 2009; Hawley and Garver 2008). The virus has a history of quickly invading through waterways, rivers, and lakes (Fisheries Technical Committee 2009). From Calumet Harbor, VHSv must move approximately 64 km (40 mi) downstream to reach the Brandon Road Lock and Dam. The downstream flow of water would facilitate the transport of this species downstream of the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., infected host and passive drift) of VHSv through the aquatic pathway; therefore, this alternative is not expected to affect VHSv's mobility/invasion speed as it passes through the CAWS.

b. *Human-Mediated Transport through Aquatic Pathways*

Although there is little commercial river traffic to Calumet Harbor (NBIC 2012), there is heavy commercial vessel traffic between the Brandon Road Lock and Dam and the T.J. O'Brien Lock and Dam, which is approximately 8 km (5 mi) south of Calumet Harbor (USACE 2011a; NBIC 2012). VHSv may be transported in ballast water (Whelan 2009; Elsayed et al. 2006), although the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). In addition, water from Lake Michigan is periodically diverted into the CAWS, which could transport VHSv into the CAWS. The water is directed through the North Shore Channel, the Chicago River, and the Calumet River.

Anti-fouling hull paints are a possible measure for controlling VHSv on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of VHSv through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: None. Surface water is present year-round, and water depth is adequate throughout the CAWS (LimnoTech 2010).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: VHSv has been reported from both freshwater and marine environments (Kipp et al. 2013). The virus can exist in freshwater for extended periods of time without a host, particularly at cool water temperatures (Hawley and Garver 2008). At high water temperatures (30°C; 86°F), the virus becomes inactivated within 1 day (Hawley and Garver 2008). Within the Great Lakes Basin, 28 fish species are at risk from the virus (Dudis 2011).

The Nonstructural Alternative is not expected to affect habitat suitability for VHSv in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: VHSv could be transported through Calumet Harbor and move downstream to the Brandon Road Lock and Dam via gravity flow or fish hosts. The Nonstructural Alternative is not expected to control the passage of VHSv through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address VHSv's passage to Brandon Road Lock and Dam via the Lake Michigan diversion, downstream passive transport in contaminated water, or infected fish.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by VHSv. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of VHSv through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of VHSv through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: VHSv's movement through waterways has been documented. There are fish species in the CAWS that could serve as hosts for VHSv and transport VHSv downstream.

The Nonstructural Alternative is not expected to control the passage of VHSv through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains low.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

4. P(colonizes) T_0-T_{50}: HIGH

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Project Risk Assessment.

Uncertainty: LOW

5. P(spreads) T_0-T_{50}: MEDIUM

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Project Risk Assessment.

Uncertainty: MEDIUM

PATHWAY 4

INDIANA HARBOR TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	**T_0**		**T_{10}**		**T_{25}**		**T_{50}**	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between Indiana Harbor and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not affect the existence of the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

VHSv is a viral disease of freshwater and marine fish. Until the 1980s, VHSv was believed to be isolated to freshwaters of Europe (Wolf 1988). Since that time, four genotypes of the virus have been found in various marine and freshwater habitats, including water bodies in Europe, North America, Korea, and Japan (Nishizawa et al. 2002; Skall et al. 2005), with the first known report in the Great Lakes in 2003 from Lake St. Clair (Elsayed et al. 2006). The virus has now reached all five Great Lakes after being reported in Lake Superior in 2010 (MNDR 2010). VHSv genotype IVb has now been confirmed in five coldwater species and 19 coolwater species in the Great Lakes (Whelan 2009); 28 species of fish from the Great Lakes Basin are considered at risk from the virus, including smallmouth bass, walleye, and bluegill (Dudis 2011). VHSv can be transmitted horizontally and vertically amongst fish populations (Whelan 2009). Chronically infected fish shed the virus through urine and reproductive fluids (Meyers and Winton 1995); ingesting infected prey fish or invertebrates harboring the virus can also lead to infection (Ahne 1980; Skall et al. 2005; Faisal and Winters 2011). VHSv can exist for extended periods of time in freshwater without a host, depending on temperature (Whelan 2009; Hawley and Garver 2008); contact with water containing the virus is also a means of spread (Castric and de Kinkelin 1980; Muroga et al. 2004). Infected females can also shed the virus during egg deposition; the virus can persist for a period long enough to infect progeny (Tuttle-Lau et al. 2010). Blood-sucking leeches are also potential transmitters of the virus to fish (Faisal and Schulz 2009).

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS as a result of natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Potential spread mechanisms include the movement of infected fish (baitfish or gamefish) to new water bodies; the transport of contaminated waters, fish, or fish parts in ballast water or in bilges of recreational boats, or; the movement of contaminated fishing equipment (Whelan 2009; Warren 1983). Ship ballast has been shown to be a transport mechanism of non-native bacteria and viruses (Drake et al. 2007); however, the current distribution of the virus does not suggest shipping-related transport (Bain et al. 2010) as a mechanism of spread. There is heavy commercial vessel traffic from the Great Lakes to Indiana Harbor (USACE 2011a).

Anti-fouling hull paints are a possible measure for controlling VHSv on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS as a result of human-mediated transport through aquatic pathways.

c. Current Abundance and Reproductive Capacity

T_0: The North American strain of the virus has established populations in all five Great Lakes since its discovery in 2003, and has been found in several inland waters of New York, Ohio, Michigan, and Wisconsin (Kipp et al. 2013). Once the virus is established in a region, it will become widespread, hosted by fish without disease symptoms, and capable of persistence at low but detectable levels (Bain et al. 2010). Benthic macroinvertebrates sampled in Lake Michigan have tested positive for the virus (Faisal et al. 2012). No documented fish kills in Lake Michigan resulting from VHSv were found.

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of VHSv.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

e. Distance from Pathway

T_0: VHSv was reported in Lake Michigan near Waukegan in Illinois, and at Green Bay, Little Sturgeon Bay, Algoma, and Milwaukee in Wisconsin (Kipp et al. 2013; Whelan 2009).

The Nonstructural Alternative is not expected to limit VHSv's movement outside of its current distribution.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: VHSv has been detected in southwestern Lake Michigan at Waukegan and Winthrop harbors (Dudis 2011), suggesting climate is suitable. The pathogen replicates at temperatures of 2–15°C (35.6–59°F) (Wolf 1988; McAllister 1990; Meyers and Winton 1995); peak viral activity in the Great Lakes corresponds to spring spawning periods and winter when temperatures are suitable (Eckerlin et al. 2011). Optimum replication temperature is 14–15°C (57.2–59°F), and VHSv can last a few weeks in freshwater at moderate temperatures (10–15°C; 50–59°F) without a host (Hawley and Garver 2008; Whelan 2009). Replication is low at 6°C (42.8°F) and almost nonexistent at 20°C (68°F) (de Kinkelin et al. 1980; Bernard et al. 1983; McAllister 1990). The virus is adapted to colder waters and becomes inactive after 24 hours in water temperatures above 20°C (68°F) (CFSPH 2003; Hawley and Garver 2008). The Great Lakes genotype IVb has been confirmed in five coldwater and 19 coolwater species (Whelan 2009), and 28 species of fish from the Great Lakes Basin are considered at risk (Dudis 2011). Fish are most susceptible to the virus during times of stress, in crowded conditions, during early life stages, and in cold temperatures (9–15°C; 48.2–59°F [Smail 1999]).

The Nonstructural Alternative is not expected to reduce habitat suitability for VHSv in southern Lake Michigan.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. VHSv is sensitive to climatological conditions. Future climate change and/or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for VHSv. Future climate change is projected to increase water temperature in the Great Lakes (Wuebbles et al. 2010), which could reduce the productivity of VHSv.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: VHSv has spread throughout the Great Lakes in less than a decade. It has been documented in Lake Michigan as far south as Waukegan. There are no barriers to the movement of this species by boat, current, or host fish.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by VHSv. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of VHSv at the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	T_0	T_{10}	T_{25}	T_{50}
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: VHSv is considered to be established in Lake Michigan and was documented offshore of the Waukegan and Winthrop harbors in Illinois, but has not yet been reported from southern Lake Michigan (section 2e). The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

VHSv has a history of rapid spread through waterways by movement of infected fish or virus-containing waters, or human-mediated mechanisms (Meyers and Winton 1995; Whelan 2009; Hawley and Garver 2008). The virus has a history of quickly invading through waterways, rivers, and lakes (Fisheries Technical Committee 2009). From Indiana Harbor, VHSv must move to reach the Brandon Road Lock and Dam. The downstream flow of water and fish hosts would facilitate the transport of this species downstream of the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., infected host and passive drift) of VHSv through the aquatic pathway; therefore, this alternative is not expected to affect VHSv's mobility/invasion speed as it passes through the CAWS.

b. Human-Mediated Transport through Aquatic Pathways

Vessel traffic to Indiana Harbor is primarily lake-wide (USACE 2011a). VHSv may be transported in ballast water (Whelan 2009; Elsayed et al. 2006), although the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). There is no vessel traffic in the Grand Calumet River east of Indiana Harbor. Consequently, some natural downstream dispersal would likely be necessary to reach the Brandon Road Lock and Dam.

Anti-fouling hull paints are a possible measure for controlling VHSv on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of VHSv through the aquatic pathway.

c. Existing Physical Human/Natural Barriers

T_0: None. Surface water is present year-round, and water depth is adequate throughout the CAWS (LimnoTech 2010).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: VHSv has been reported from both freshwater and marine environments (Kipp et al. 2013). The virus can exist in freshwater for extended periods of time without a host, particularly at cool water temperatures (Hawley and Garver 2008). At high water temperatures (30°C; 86°F), the virus becomes inactivated within 1 day (Hawley and Garver 2008). Within the Great Lakes Basin, 28 fish species are at risk from the virus (Dudis 2011). Survivors of the virus continually shed the virus in urine and reproductive fluids throughout their lifetime (Whelan 2009). Water flows out of Indiana Harbor into Lake Michigan. West of the Indiana Harbor Canal, the easternmost sections of the Grand Calumet River also generally flow toward Lake Michigan, and other sections can flow east or west depending on location (Weiss et al. 1997). Thus, the virus would have to move upstream via infected fish to enter the CAWS and move to the Calumet Sag Channel.

The Nonstructural Alternative is not expected to affect habitat suitability for VHSv in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: VHSv could be transported through the Indiana Harbor and move downstream to the Brandon Road Lock and Dam by gravity flow or fish hosts. The Nonstructural Alternative is not expected to control the passage of VHSv through the aquatic pathway by natural dispersion or human-mediated transport. The alternative does not include measures to address VHSv's passage to Brandon Road Lock and Dam by passive transport of contaminated water or infected fish.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by VHSv. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of VHSv through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to affect the passage of VHSv through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: VHSv's movement through waterways has been documented. There are fish species in the CAWS that could serve as hosts for VHSv and transport VHSv downstream.

The Nonstructural Alternative is not expected to control the passage of VHSv through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains low.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Project Risk Assessment.

Uncertainty: LOW

5. **P(spreads) T_0-T_{50}: MEDIUM**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Project Risk Assessment.

Uncertainty: MEDIUM

PATHWAY 5

BURNS SMALL BOAT HARBOR (BSBH) TO BRANDON ROAD LOCK AND DAM

NONSTRUCTURAL: Education and Outreach, Anti-Fouling Hull Paints, Ballast/Bilge-water Exchange, Monitoring, and Laws and Regulations

PROBABILITY OF ESTABLISHMENT SUMMARY

No New Federal Action Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

Nonstructural Alternative Rating Summary

Probability Element	T_0		T_{10}		T_{25}		T_{50}	
	P	**U**	**P**	**U**	**P**	**U**	**P**	**U**
P(pathway)	High	None	High	None	High	None	High	None
P(arrival)	High	Low	High	Low	High	Low	High	Low
P(passage)	High	Low	High	Low	High	Low	High	Low
P(colonizes)	High	Low	High	Low	High	Low	High	Low
P(spreads)	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
P(establishment)	Medium	–[a]	Medium	–	Medium	–	Medium	–

[a] "–" Indicates an uncertainty rating was not assigned to *P(establishment)* because there is no objective way to characterize overall uncertainty for an aggregate rating.

EVIDENCE FOR ESTIMATING THE RISK OF ESTABLISHMENT/UNCERTAINTY

1. P(pathway) T_0-T_{50}: HIGH

Evidence for Probability Rating:

Pathway is visible, confirmed, and present year-round. No activities or events are expected to reduce or eliminate the hydrologic connection between BSBH and Brandon Road Lock and Dam over the next 50 years.

The Nonstructural Alternative would not affect the existence of the pathway.

Uncertainty: NONE

Evidence for Uncertainty Rating

The existence of the pathway has been confirmed with certainty.

2. P(arrival) T_0-T_{50}: HIGH

In determining the probability of arrival, the pathway is assumed to exist.

Factors That Influence Arrival of Species

a. Type of Mobility/Invasion Speed

VHSv is a viral disease of freshwater and marine fish. Until the 1980s, VHSv was believed to be isolated to freshwaters of Europe (Wolf 1988). Since that time, four genotypes of the virus have been found in various marine and freshwater habitats, including water bodies in Europe, North America, Korea, and Japan (Nishizawa et al. 2002; Skall et al. 2005). It was first reported in the Great Lakes in 2003 from Lake St. Clair (Elsayed et al. 2006), and by 2010 it had spread to all five Great Lakes (MNDR 2010). VHSv genotype IVb has now been confirmed in five coldwater species and 19 coolwater species in the Great Lakes (Whelan 2009); 28 species of fish from the Great Lakes Basin are considered at risk from the virus, including smallmouth bass, walleye, and bluegill (Dudis 2011). Susceptible fish contract the virus by being in close proximity to other infected individuals, or by ingesting infected material. Affected fish shed the virus into the surrounding environment through urine and reproductive fluids (Meyers and Winton 1995); the virus can enter the body through the gills or open wounds (Whelan 2009). Survivors of viral infection are carriers and continue to shed virus particles for extended periods of time (Kim and Faisal 2012). Ingesting infected prey fish or invertebrates harboring the virus can also lead to infection (Ahne 1980; Skall et al. 2005; Faisal and Winters 2011). VHSv can exist for extended periods of time in freshwater without a host, depending on temperature (Whelan 2009; Hawley and Garver 2008); contact with water containing the virus is also a means of spread (Castric and de Kinkelin 1980; Muroga et al. 2004). Infected females can also shed the virus during egg deposition; the virus can persist for a period long enough to infect progeny (Tuttle-Lau et al. 2010). Blood-sucking leeches are also potential transmitters of the virus to fish (Faisal and Schulz 2009).

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS as a result of natural dispersion through aquatic pathways.

b. Human-Mediated Transport through Aquatic Pathways

Potential spread mechanisms include the movement of infected fish (baitfish or gamefish) to new water bodies; the transport of contaminated waters, fish, or fish parts in ballast water or in bilges of recreational boats, or; the movement of contaminated fishing equipment (Whelan 2009; Warren 1983). Ship ballast has been shown to be a transport mechanism of non-native bacteria and viruses (Drake et al. 2007); however, the current distribution of the virus does not suggest shipping-related transport (Bain

et al. 2010) as a mechanism of spread. There is recreational but no commercial vessel traffic from the Great Lakes to the BSBH (USACE 2011a). However, there is heavy commercial traffic to Burns Harbor, which is adjacent to the BSBH.

Anti-fouling hull paints are a possible measure for controlling VHSv on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS as a result of human-mediated transport through aquatic pathways.

c. Current Abundance and Reproductive Capacity

T_0: The North American strain of the virus has established populations in all five Great Lakes since its discovery in 2003, and has been found in several inland waters of New York, Ohio, Michigan, and Wisconsin (Kipp et al. 2013). Once the virus is established in a region, it will become widespread, hosted by fish without disease symptoms, and capable of persistence at low but detectable levels (Bain et al. 2010). Benthic macroinvertebrates sampled in Lake Michigan have tested positive for the virus (Faisal et al. 2012). No documented fish kills in Lake Michigan resulting from VHSv were found.

The Nonstructural Alternative is not expected to affect the current abundance or reproductive capacity of VHSv.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. Changes in water temperature related to future climate change (Wuebbles et al. 2010) could affect the spread or virulence of this species in Lake Michigan.

d. Existing Physical Human/Natural Barriers

T_0: None. The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

e. Distance from Pathway

T_0: As of 2009, VHSv had been reported in Lake Michigan near Waukegan and Winthrop harbors in Illinois, and at Green Bay, Little Sturgeon Bay, Algoma, and Milwaukee in Wisconsin (Kipp et al. 2013; Whelan 2009).

The Nonstructural Alternative is not expected to limit VHSv's movement outside of its current distribution.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

f. Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)

T_0: VHSv has been detected in southwestern Lake Michigan at Waukegan and Winthrop harbors (Dudis 2011), suggesting climate is suitable. The pathogen replicates at temperatures of 2–15°C (35.6–59°F) (Wolf 1988; McAllister 1990; Meyers and Winton 1995); peak viral activity in the Great Lakes corresponds to spring spawning periods and winter when temperatures are suitable (Eckerlin et al. 2011). Optimum replication temperature is 14–15°C (57.2–59°F), and VHSv can last a few weeks in freshwater at moderate temperatures (10–15°C; 50–59°F) without a host (Hawley and Garver 2008; Whelan 2009). Replication is low at 6°C (42.8°F) and almost nonexistent at 20°C (68°F) (de Kinkelin et al. 1980; Bernard et al. 1983; McAllister 1990). The virus is adapted to colder waters and becomes inactive after 24 hours in water temperatures above 20°C (68°F) (CFSPH 2003; Hawley and Garver 2008). The Great Lakes genotype IVb has been confirmed in five coldwater and 19 coolwater species (Whelan 2009), and 28 species of fish from the Great Lakes Basin are considered at risk (Dudis 2011). Fish are most susceptible to the virus during times of stress, in crowded conditions, during early life stages, and in cold temperatures (9–15°C; 48.2–59°F [Smail 1999]).

The Nonstructural Alternative is not expected to reduce habitat suitability for VHSv in southern Lake Michigan.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0. VHSv is sensitive to climatological conditions. Future climate change and/or new environmental regulations may alter the physical, chemical, and climatological suitability of the Great Lakes for VHSv. Future climate change is projected to increase water temperature in the Great Lakes (Wuebbles et al. 2010), and this could affect the virulence, spread, or abundance of VHSv.

Probability of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: VHSv has spread throughout the Great Lakes in less than a decade. It has been documented in Lake Michigan as far south as Waukegan. There are no barriers to the movement of this species by boat, current, or host fish.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by VHSv. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the arrival of VHSv at the CAWS due to fouled vessels.

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS through aquatic pathways. Therefore, the Nonstructural Alternative's high probability of arrival rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Arrival

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: VHSv is considered to be established in Lake Michigan and was documented offshore of the Waukegan and Winthrop harbors in Illinois, but has not been reported from southern Lake Michigan (section 2e). Therefore, the uncertainty of the probability of arrival is considered to be low.

The Nonstructural Alternative is not expected to affect VHSv's arrival at the CAWS through aquatic pathways. Therefore, the uncertainty remains low.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

3. P(passage) T_0-T_{50}: HIGH

In determining the probability of passage, the species is assumed to have arrived at the pathway.

Factors That Influence Passage of Species (Considering All Life Stages)

a. Type of Mobility/Invasion Speed

VHSv has a history of rapid spread through waterways by movement of infected fish, virus-containing waters, or human-mediated mechanisms (Meyers and Winton 1995; Whelan 2009; Hawley and Garver 2008). The virus has a history of quickly invading through waterways, rivers, and lakes (Fisheries Technical Committee 2009). From the BSBH, VHSv must move more than 64 km (40 mi) downstream to reach the Brandon

Road Lock and Dam. The downstream flow of water and fish hosts would facilitate the transport of this species downstream of the Brandon Road Lock and Dam.

The Nonstructural Alternative is not expected to address the natural dispersion (i.e., infected host and passive drift) or VHSv through the aquatic pathway; therefore, this alternative is not expected to affect VHSv's mobility/invasion speed as it passes through the CAWS.

b. *Human-Mediated Transport through Aquatic Pathways*

Vessel traffic to the BSBH is primarily lake-wide (USACE 2011a,b). VHSv may be transported in ballast water (Whelan 2009; Elsayed et al. 2006), although the discharge of ballast water does not typically occur at inland ports within the CAWS (NBIC 2012). Consequently, some natural downstream dispersal would likely be necessary to reach the Brandon Road Lock and Dam.

Anti-fouling hull paints are a possible measure for controlling VHSv on vessels. However, these paints are only considered temporarily effective at controlling the attachment of fouling ANS due to wear from normal vessel operation (i.e., chipping, scraping, punctures, and abrasion) which exposes unprotected surfaces. Other factors that influence effectiveness include: the type of anti-fouling hull paint (toxic [with biocide] or non-toxic); frequency and method of application; frequency of hull cleaning compared to manufacturer-recommended cleaning schedule (e.g., possible dry-docking schedule for cleaning), and; development and compliance with future regulatory schemes that would require anti-fouling hull paints on commercial and recreational vessels. Currently, environmental communities and regulators are discouraging the use of biocide-based hull paints due to their impact on biodiversity due to leaching.

The Nonstructural Alternative is not expected to address the human-mediated transport of VHSv through the aquatic pathway.

c. *Existing Physical Human/Natural Barriers*

T_0: None. Surface water is present year-round, and water depth is adequate throughout the CAWS (LimnoTech 2010).

The Nonstructural Alternative does not include physical human/natural barriers.

T_{10}: See T_0.

T_{25}: See T_0.

T_{50}: See T_0.

d. *Suitable Habitat (Physical, Structural, Hydrologic, Hydraulic, Chemical, and Climatological)*

T_0: VHSv has been reported from both freshwater and marine environments (Kipp et al. 2013). The virus can exist in freshwater for extended periods of time without a host, particularly at cool water temperatures (Hawley and Garver 2008). At high water temperatures (30°C; 86°F), the virus becomes inactivated within 1 day (Hawley and Garver 2008). Within the Great Lakes Basin, 28 fish species are at risk from the virus (Dudis 2011), and many of these species are found in the CAWS. Water flows out of the BSBH into Lake Michigan. The eastern segment of the south branch of the Little

Calumet River also generally flows toward Lake Michigan, depending on location and water level in Lake Michigan (GSWMD 2008). To enter and pass through the BSBH, this species would have to move upstream through Burns Ditch and portions of the south branch of the Little Calumet River, where flow direction is toward Lake Michigan.

The Nonstructural Alternative is not expected to affect habitat suitability for VHSv in the CAWS.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Probability of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	High	High	High	High
Nonstructural Alternative Rating	High	High	High	High

Evidence for Probability Rating (Considering All Life Stages)

T_0: Water flow in the BSBH and portions of the Little Calumet River is toward Lake Michigan. Because of the lack of vessel traffic (section 3b), natural spread via fish hosts through the south branch of the Little Calumet River would likely be required for VHSv to move from Lake Michigan to the Calumet Sag Channel. After reaching the Calumet Sag Channel, VHSv could move to Brandon Road Lock and Dam by gravity flow or fish hosts.

Before anti-fouling hull paints could be considered an effective measure in the CAWS and the Great Lakes, changes in vessel maintenance and operation would be required. Additional study is needed to assess the effectiveness of these paints to control fouling by VHSv. Until additional study is completed and these issues are addressed, anti-fouling hull paints are considered ineffective at controlling the passage of VHSv through the aquatic pathway due to fouled vessels.

The Nonstructural Alternative is not expected to control the passage of VHSv through the aquatic pathway by natural dispersion or human-mediated transport. Therefore, the Nonstructural Alternative's high probability of passage rating does not differ from that in the No New Federal Action Risk Assessment.

T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

Uncertainty of Passage

Time Step	**T_0**	**T_{10}**	**T_{25}**	**T_{50}**
No New Federal Action Rating	Low	Low	Low	Low
Nonstructural Alternative Rating	Low	Low	Low	Low

Evidence for Uncertainty Rating

T_0: VHSv's movement through waterways has been documented. There are fish species in the CAWS that could serve as hosts for VHSv and transport VHSv downstream.

The Nonstructural Alternative is not expected to control the passage of VHSv through the aquatic pathway by natural dispersion or human-mediated transport; therefore, the uncertainty remains low.
T_{10}: See T_0.
T_{25}: See T_0.
T_{50}: See T_0.

4. **P(colonizes) T_0-T_{50}: HIGH**

The probability and uncertainty ratings for *P(colonizes)* are assumed to remain unchanged from those in the No New Federal Action Project Risk Assessment.

Uncertainty: LOW

5. **P(spreads) T_0-T_{50}: MEDIUM**

The probability and uncertainty ratings for *P(spreads)* are assumed to remain unchanged from those in the No New Federal Action Project Risk Assessment.

Uncertainty: MEDIUM

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