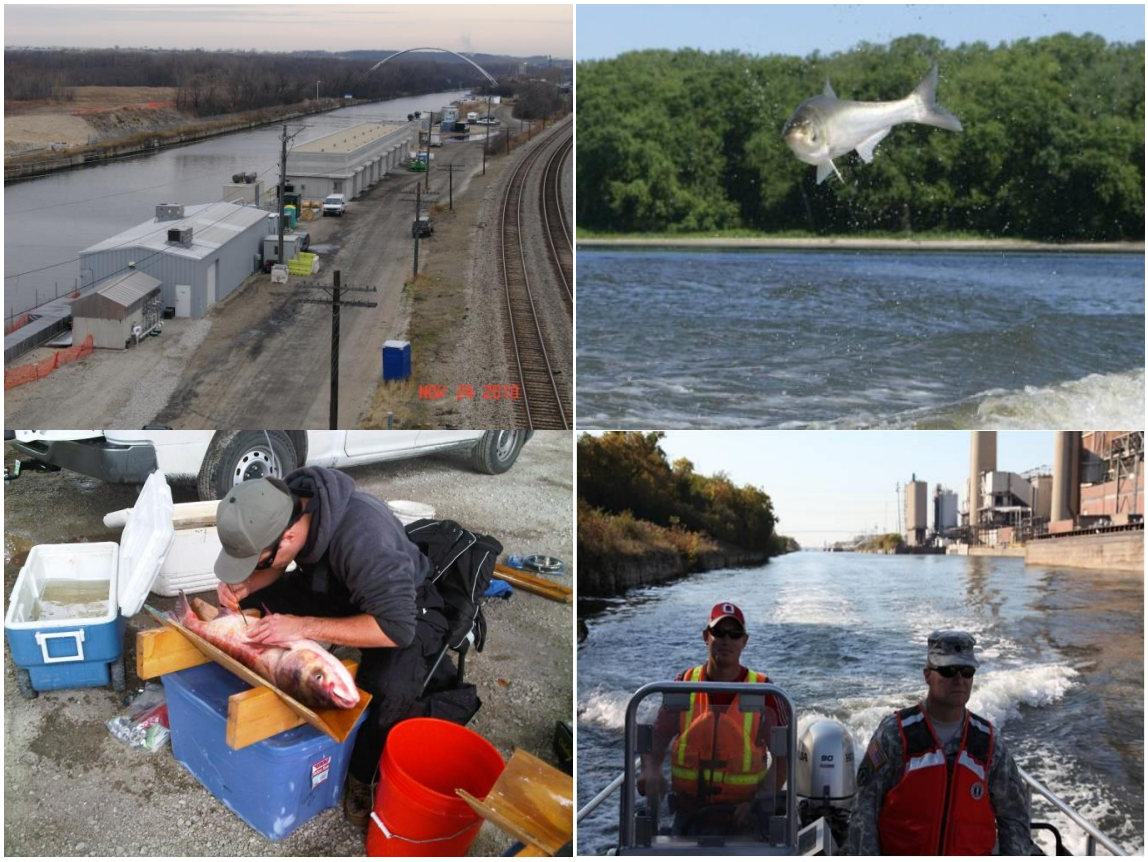
Dispersal Barrier Efficacy Study

Comprehensive Efficacy Study, Chicago Sanitary and Ship Canal Dispersal Barriers Risk Reduction Study and Integrated Environmental Assessment

Appendix B, Planning Information and Risk Register



June 2019

US Army Corps of Engineers
Chicago District

Information Tables

Table 1 – Waterway Impairments from 2008 Final Draft Illinois 303(d) List

	Impairment	Potential Cause of Impairment
General Use		
N. Shore Channel (N. Side Sewage Treatment Works to Lake Michigan)	• Fish Consumption	PCBs
	• Aquatic Life	Nickel, phosphorus (total), zinc
	• Primary Contact Recreation	Fecal coliform
Chicago River	• Aquatic Life	Phosphorus (total), silver
	• Fish Consumption	Mercury, PCBs
	• Primary Contact Recreation	Fecal coliform
Des Plaines River (CSSC confluence to Du Page River confluence)	• Fish Consumption	Mercury, PCBs
	• Aquatic Life	Chloride, DDT, hexachlorobenzene, iron, nickel, pH, phosphorus (total), PCBs, sedimentation/siltation, TSS
	• Primary Contact Recreation	Fecal coliform
Little Calumet River (from IL-IN State Line to Cal-Sag)	• Aquatic Life	Fluoride, hexachlorobenzene, oil & grease, pH, phosphorus (total), sedimentation/siltation, TSS, cyanide
	• Primary Contact Recreation	Fecal coliform
Secondary Contact		
N. Shore Channel	• Fish Consumption	Mercury, PCBs
N. Branch Chicago River	• Fish Consumption	PCBs
	• Indigenous Aquatic Life	Iron, oil & grease, phosphorus (total)
S. Branch Chicago River	• Fish Consumption	PCBs
S. Fork S. Branch CR	• Indigenous Aquatic Life	pH, phosphorus (total)
Chicago Sanitary and Ship Canal	• Fish Consumption	Mercury, PCBs
	• Indigenous Aquatic Life	Iron, oil & grease, ammonia (un-ionized), phosphorus (total)
Cal-Sag Channel	• Fish Consumption	Mercury, PCBs
	• Indigenous Aquatic Life	Iron, phosphorus (total), TSS
Little Calumet River (from Grand Cal to Cal-Sag)	• Fish Consumption	Mercury, PCBs
	• Indigenous Aquatic Life	Aldrin, iron, phosphorus (total), silver
Grand Calumet River	• Indigenous Aquatic Life	Ammonia (un-ionized), arsenic, barium, cadmium, chromium (total), copper, DDT, iron, lead, nickel, phosphorus (total), PCBs, sedimentation/siltation, silver, zinc

Table 2 - Fishes occupying listed reaches of the Chicago River, Calumet River, Cal-Sag Channel, CSSC, and Des Plaines River. Data were collected by the Field Museum of Natural History, Illinois Department of Natural Resources, and Illinois Natural History Survey from 1975-2004.

Species	Common Name	Sites					
		Chicago Lock	Chicago River at Throop Street	Calumet River at O'Brien Lock	Cal-Sag Channel at I&M Canal	CSSC at Lockport Lock	Des Plaines River at Brandon Lock
Lepisosteus osseus	Longnose Gar						X
Dorosoma cepdianum	Gizzard Shad			X	X		X
Carassius auratus	Goldfish				X	X	X
Ctenopharyngodon idella	Grass Carp	X					
Cyprinella spiloptera	Spotfin Shiner						X
Cyprinus carpio	Common Carp	X		X	X	X	X
Notemigonus crysoleucas	Golden Shiner	X					X
Notropis atherinoides	Emerald Shiner			X			X
Notropis hudsonius	Spottail Shiner	X					X
Notropis volucellus	Mimic Shiner	X					
Pimephales notatus	Bluntnose Minnow	X		X			
Pimephales promelas	Fathead Minnow				X		X
Semotilus atromaculatus	Creek Chub						X
Carpiodes carpio	River Carpsucker						X
Catostomus commersoni	White Sucker			X			X
Ictiobus bubalus	Smallmouth Buffalo						X
Moxostoma erythrurum	Golden Redhorse						X
Moxostoma macrolepidotum	Shorthead Redhorse						X
Ameiurus melas	Black Bullhead				X		X
Ictalurus punctatus	Channel Catfish						X
Noturus gyrinus	Tadpole Madtom						X
Esox americanus	Grass Pickerel						X
Umbra limi	Central Mudminnow				X		
Osmerus mordax	Rainbow Smelt	X					
Salmo trutta	Brown Trout	X					
Gambusia affinis	Western Mosquitofish						X
Labidesthes sicculus	Brook Silverside	X					
Cottus ricei	Spoonhead Sculpin	X					

Species	Common Name	Sites					
		Chicago Lock	Chicago River at Throop Street	Calumet River at O'Brien Lock	Cal-Sag Channel at I&M Canal	CSSC at Lockport Lock	Des Plaines River at Brandon Lock
Morone americana	White Perch		X	X			
Morone chrysops	White Bass					X	
Morone mississipiensis	Yellow Bass				X		
Ambloplites rupestris	Rock Bass	X		X			
Lepomis cyanellus	Green Sunfish	X		X	X		X
Lepomis gibbosus	Pumpkinseed	X		X	X		
Lepomis macrochirus	Bluegill	X	X	X	X		X
Micropterus dolomieu	Smallmouth Bass			X			X
Micropterus salmoides	Largemouth Bass	X		X	X		X
Pomoxis annularis	White Crappie						X
Pomoxis nigromaculatus	Black crappie	X		X			X
Perca flavescens	Yellow Perch	X					
Sander vitreum	Walleye						X
Aplodinotus grunniens	Freshwater Drum						X
Oncorhynchus kisutch	Coho Salmon	X					
Oncorhynchus tshawytscha	Chinook Salmon	X					
Gasterosteus aculeatus	Threespine Sticklebac	X					
Pungitius pungitius	Ninespine Stickleback	X					
Neogobius melanostomus	Round Boby			X			
Misgurnus anguillicaudatus	Weather Loach						X

Table 3 - Macroinvertebrates occupying listed reaches of the Chicago River, Calumet River, Cal-Sag Channel, CSSC, and Des Plaines River. Data were collected from 2001-2004 by the MWRD of Greater Chicago, via Hester-Dendy Artificial Substrate Samplers and Petite Ponar grabs.

Taxon	Sites					
	Chicago Lock	**Chicago River at Throop Street**	**Calumet River at O'Brien Lock**	**Cal-Sag Channel at I&M Canal**	**CSSC at Lockport Lock**	**Des Plaines River at Brandon Lock**
Ablabesmyia janta			X		X	
Ablabesmyia mallochi					X	X
Amnicola				X		X
Argia						X
Baetis intercalaris						X
Berosus					X	
Caecidotea				X	X	X
Caenis					X	X
Ceratopsyche morosa						X
Cheumatopsyche	X				X	X
Chironomidae			X	X	X	X
Cladopelma	X					
Cladotanytarsus vanderwulpi grp.						X
Corbicula fluminea					X	X
Corixidae						X
Cricotopus					X	
Cricotopus bicinctus grp.	X		X	X	X	X
Cricotopus sylvestric grp.	X		X	X	X	
Cricotopus trifascia grp.						X
Cryptochironomus	X			X	X	X
Cyranellus fraternus				X	X	
Dicrotenipes						X
Dicrotendipes neomodestus	X		X			X
Dicrotendipes simpsoni	X	X		X	X	
Dreissena polymorpha	X				X	X
Enallagma			X			
Erpobdella punctata punctata			X		X	X
Ferrissia					X	X

Taxon	Sites					
	Chicago Lock	Chicago River at Throop Street	Calumet River at O'Brien Lock	Cal-Sag Channel at I&M Canal	CSSC at Lockport Lock	Des Plaines River at Brandon Lock
Gammarus fasciatus	X			X	X	X
Glossiphoniidae					X	
Glyptotendipes	X	X		X	X	X
Helobdella					X	
Helobdella papillata					X	
Helobdella stagnalis			X		X	X
Helobdella triserialis		X			X	
Hemerodromia						X
Heterotrissocladius	X					
Hydra	X	X		X	X	X
Hydropsyche					X	X
Hydropsyche betteni						X
Hydropsyche bidens						X
Hydropsyche orris						X
Hydropsyche simulans						X
Hydroptila	X					
Macronychus glabratus						X
Menetus dilatatus					X	X
Mooreobdella microstoma			X	X	X	
Musculium					X	X
Musculium transversum						X
Nanocladius crassicornus/rectinervis						X
Nanocladius distinctus	X			X	X	X
Natarsia sp.						X
Nematoda						X
Oligochaeta	X	X	X	X	X	X
Orconectes virilis						X
Orthocladius						X
Palmacorixa						X
Parachironomus	X	X	X	X		
Paratanytarsus				X		
Pericoma					X	

Taxon	Sites					
	Chicago Lock	Chicago River at Throop Street	Calumet River at O'Brien Lock	Cal-Sag Channel at I&M Canal	CSSC at Lockport Lock	Des Plaines River at Brandon Lock
Petrophila						X
Physa				X	X	X
Physella		X				
Pleurocerida						X
Plumatella	X			X	X	X
Polypedilum flavum					X	X
Polypedilum halterale grp.	X					X
Polypedilum illinoense				X	X	X
Polypedilum scalaenum grp.					X	X
Procladius (Holotanypus)				X	X	X
Rheotanytarsus						X
Simulium						X
Stenacron					X	X
Stenelmis						X
Stenelmis crenata grp.						X
Stenochironomus					X	X
Stenonema integrum					X	
Tanypus			X		X	
Tanytarsus				X		X
Tanytarsus guerlus grp.						X
Thienemanniella similis						X
Thienemanniella xena						X
Thienemannimyia grp.		X				X
Trepobates						X
Tribelos fuscicorne						X
Tricorythodes						X
Turbellaria		X		X	X	X
Tventenia discoloripes grp.						X
Xenochironomus xenolabis					X	

Risk Level

Frequency of Event	Negligible	Low	Medium	High	Certain
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Unlikely	0	1	2	3	4
Very Unlikely	0	0	1	2	3

Opportunity for Passage Due to Event

Frequency of Event

Very Likely	will occur frequently
Likely	will occur sometimes
Unlikely	will occur rarely
Very Unlikely	will almost never occur

If Event Occurred, Opportunity for Passage ~~Due to Event~~

Negligible	Passage is highly unlikely
Low	Passage is unlikely
Medium	Passage could intermittently occur
High	Passage is likely
Certain	Passage will occur

Qualitative Risk Analysis
Final Efficacy Study

Failure Mode		Current Risk Characterization						Potential Mitigation		Remaining Risk After Further Mitigation			
Number	Event	Concerns	Existing Mitigation	Discussions, Investigations & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Frequency of Event	Opportunity for Passage Due to Event	Risk Level	Mitigation Measure	Implementing Agency	Projected Mitigation Results	Discussions, Investigations & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Frequency of Event	Opportunity for Passage Due to Event	Risk Level
Inter Basin Connections														
IB-1	Temporary Connection between the Des Plaines River & CSSC Upstream of the Barriers	The Des Plaines River is approximately parallel to the CSSC for approximately 13 miles upstream of the barriers. Connection of the CSSC and the Des Plaines River during an intensive rainfall event could allow fish in the Des Plaines River to enter the CSSC upstream of the electric barriers, thereby bypassing the barriers. Flood waters connecting the two have occasionally occurred.	The Des Plaines River Barrier was constructed in 2010 .It is a physical barrier consisting of concrete barriers and fine-mesh fencing. Fence height was set at the 1% storm plus 3 feet. Subsuquent to completion of the original barrier, approximately 7,300 feet of barrier was buried under a berm 30-60 feet high & 200-400 feet wide as way to manage fill from another project. This buried reach has even less risk of flood overflow. "Turtle gates" were installed in 2011 to minimize wildlife migration impacts. The operations plan for the gates utilizes forecasts and river levels at gaging stations to make decisions on gate openings and closings. This conservative approach should virtually eliminate the possibility that the gates would be left open during a high flow event.	The Des Plaines River Barrier reduces the risk of fish bypass during flood flow conditions. A minor risk exists that silver carp are able to jump over the fence when flood waters elevate to the 1% storm. This risk is still considered unlikely due to the shallow depths that would present and numerous obstructions submerged or overhanging such as trees. The modifications completed in 2011 to address migratory turtles and wildlife impacts shouldn't impact the effectiveness of the barrier. Gates remain in open position during migratory season. During high water events, the gates will need to be closed manually. Risks associated with mobilizing personnel within the available time window are de minimus. Gates are locked in both open and closed positions to deter vandalism. Vandalism, hydraulic scouring, or vehicle accidents may damage the barrier which would require repairs. Periodic inspection of the fence is conducted to identify any deficiencies. Repair materials are maintained on hand. The primary remaining risks associated with fish bypass under flood flow conditions are the passage of eggs or small fish through the fence mesh or the barrier becoming damaged during a high-water event in some way that compromises its integrity. A lesser risk would be an event that results in water levels that exceed the 1% storm plus 3 feet.	Unlikely	Medium	2	No additional mitigation required				Unlikely	Medium	2
IB-2	Breaching or overtopping of the rock plug in the I&M Canal	There are culverts that connect the I&M Canal to the CSSC upstream of the barriers.	A rock plug was constructed in the I&M Canal in 2010 at a high spot or watershed divide (see Interim I report). This plug is a barrier preventing fish downstream of the barriers in the I&M from getting to the culverts. The rock plug is periodically inspected to ensure its integrity.	The risk of bypass via the I&M has been rendered highly unlikely. It's very unlikely that early life stages of Asian carp would be able to transit the interstitial spaces in the rock plug. The current measure has reduced bypass risk at this location as much as is possible using an engineered solution. The only risk would be an extreme flood event that could completely overtop the plug. Even if the plug were breached or overtopped, it is unclear if fish would move from the I&M to the CSSC. There are two areas downstream of the plug and one upstream of the plug where the I&M is filled in by roads and only culverts connect the water from one side of the road to the other. There are two areas downstream of the plug and one upstream of the plug where the I&M is almost entirely full of aquatic vegetation such as cattails and phragmites.	Very Unlikely	Medium	1	No additional mitigation required				Very Unlikely	Medium	1
IB-3	Breaching or overtopping of the Lyons Levee	The Lyons Levee is located on the Des Plaines River near the historic basin divides. It is upstream of the Des Plaines River Barrier at a point where the Des Plaines is north-south (perpendicular to the CSSC). Water overtopping the Lyons Levee would flow to the CSSC and, depending on the duration and depth, could provide a pathway for fish, thereby bypassing the barriers. Interconnectivity of local sewers between the waterways is unknown, which might also provide an interconnection between the waterways.	The levee was constructed in the early 1900s and hadn't been maintained in accordance with levee standards for many years. Temporary improvements were completed In 2014 to provide protection for a 1% storm.	An overtopping event occurred in April 2013 with flood waters from the Des Plaines overtopping the Lyons Levee and Inundating the community of Forest View. Significant overbank flooding required the evacuation of the entire community. Water from the direction of Forest View was observed flowing into the CSSC, but it was unclear exactly what path it was taking & whether it could have provided a pathway for fish to move from the Des Plaines to the CSSC. The improvements completed in 2014 have reduced the risk of this occurring again, but are only considered temporary. If steps aren't take to improve the levee for the long-term, the risk level would likely increase over time. Even if the levee were overtopped, it is unclear if fish would move through or over the levee and into the CSSC. The fish would have to move over flooded land and/or through sewers to reach the CSSC.	Unlikely	Medium	2	A more permanent reconstruction of the levee to strengthen it and raise it to the elevation of the 1% storm plus freeboard is underway. USACE worked with MWRDGC as a non-federal sponsor to complete a flood risk management study and subsequently awarded a construction contract in September 2018.	USACE and MWRDGC	Rehabilitation and regular maintenance of the Lyons Levee would reduce risk of levee breach under high flow events that do not overtop the structure.	More permanent rehabilitation does not dramatically reduce the current risk level since the 2014 improvements, but does ensure the risk level remains similar for a longer period of time. However, even when rehabilitated, extreme events over the 1% storm event could overtop the levee resulting in possible breach and connection of the two waterways. Interconnectivity of local sewers between the waterways is unknown at this time. Additional evaluations may be conducted on the area's sewer network. Floodway & floodplain requirements were considered during design development & evaluation. Designs included an assessment of the drainage network and any interbasin connections. Flood risk management is the primary goal of the levee rehabilitation.	Unlikely	Medium	2
Movement/Release by People or Animals														

Qualitative Risk Analysis
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Failure Mode		Current Risk Characterization						Potential Mitigation		Remaining Risk After Further Mitigation				
Number	Event	Concerns	Existing Mitigation	Discussions, Investigations & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Frequency of Event	Opportunity for Passage Due to Event	Risk Level	Mitigation Measure	Implementing Agency	Projected Mitigation Results	Discussions, Investigations & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Frequency of Event	Opportunity for Passage Due to Event	Risk Level
MR-1	Direct Release of Fish on the Wrong Side of the Barriers	Risks include: 1) Captured or purchased live fish released due to cultural practices. 2) Release of fish previously held in aquaria. 3) Other deliberate movement of fish followed by deliberate or accidental release Sources: Shiu, H. and L. Stokes. 2008. Buddhist animal release practices: historic, environmental, public health and economic concerns. Contemporary Buddhism, Vol 9, pp. 181-196. Padilla, D.K. and S.L. Williams. 2004. Beyond ballast water: aquarium and ornamental trades as a source of invasive species in aquatic ecosystems. Frontiers in Ecology, vol. 2(3), pp. 131-138. Meyerson, L.A. and J.K. Reaser. 2003. Bioinvasions, bioterrorism, and biosecurity. Frontiers in Ecology, vol. 1(6)	The State of Illinois and City of Chicago have banned sale of live Asian carp. Asian carp have been added to the Lacey Act, making it illegal to transport live Asian carp, including viable eggs, across state lines. Increased law enforcement makes it less likely that individuals could capture live fish and transport them unnoticed.	Reducing the opportunity for people to acquire live Asian carp through laws and regulations reduces the likelihood that intentional or inadvertent releases would happen. However, even with reduced availability of live fish, motivated individuals could still acquire fish and do harm by intentionally or inadvertently releasing fish into uninfested waters.	Very Unlikely	Certain	3	Increased enforcement. Increased education.	USFWS, Illinois DNR	Further reduction in likelihood of deliberate releases.	Although further reduction in the likelihood of releases may be possible and would of course be desirable, the frequency rating for this risk analysis can't be decreased further.	Very Unlikely	Certain	3
MR-2	Use of Bait Releases Fish on the Wrong Side of the Barriers	Risks include: 1) Live fish in wild-captured bait (i.e. using a cast net) could be transported from an infested water body and introduced into an uninfested water body by fishermen or boaters. 2) Fish could be inadvertently mixed with commercially purchased bait from wholesalers and sold to fishermen that subsequently release bait in uninfested waters. Sources: Ludwig. H.R. and J.A. Leitch. 1996. Interbasin transfer of aquatic biota via anglers' bait buckets, Fisheries, vol. 21(7), pp. 14-18. Litvek, M.K. and N.E. Madrak. 1993. Ecology of freshwater baitfish use in Canada and the United States. Fisheries, vol. 18(12), pp. 6-13. Williamson, C.J. and J.E. Garvey. 2005. Growth, fecundity, and diets of newly	USFWS is enforcing the Lacey Act and is working with state natural resource agencies to undertake carp inspections at bait shops, fish processors, fish markets and retail food establishments. The Illinois DNR investigated the bait sale industry in the Chicago area to determine the likelihood of movement of Asian carp via this pathway and how it may be reduced or eliminated. Source: USFWS. 2011. Bighead carp added to Federal list of injurious wildlife. USFWS News Release. Accessed July 16, 2012 at http://www.fws.gov/midwest/News/release.cfm?rid=369 Illinois DNR. 2011. IDNR announces results of Chicago area bait shops inspections for Asian carp. Press Release, February 23, 2011, Illinois Department of Natural Resources.	Regardless of education efforts and laws, this pathway remains as long as fishermen use live bait that may have originated in a place where Asian carp are present. Bighead and silver carps are fast growing do not remain bait size (i.e. 1-6 inches) for very long, therefore there is only a short time during their life cycle that they may be mistaken for common bait species. The Illinois DNR survey of bait shop owners and employees indicated that minnows were purchased from local wholesalers and not captured from the wild which reduces the risk somewhat.	Unlikely	Certain	4	Increased enforcement. Increased education.	USFWS, Illinois DNR	Further reduction in likelihood of unintentional releases due to bait use.	Although further reduction in the likelihood of releases may be possible and would of course be desirable, it is difficult to evaluate how much it may impact the risk. Therefore, the risk level hasn't been changed.	Unlikely	Certain	4

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MR-3	Unintentional Stocking of Fish on the Wrong Side of the Barriers	Chicago's Columbus Park, Garfield Park, Humboldt Park, Lincoln Park South, and McKinley Park Lagoons, Flatfoot Lake, and Schiller Pond all have had either bighead carp captured or reportedly captured in them. All bighead carp obtained from Chicago area ponds to date have been very large fish of similar size and age which points towards stocking as a potential source. These ponds are located on the upstream side of the barrier, some with direct links to Lake Michigan. Source: Illinois DNR. 2011. Bighead carp in Illinois urban fishing ponds. Division of Fisheries, Aquatic Nuisance Species Program. 8 Pages.	21 Fishing ponds identified within the IDNR Urban Fishing Program have been sampled for Asian carp with 7 returning verified captures and 1 with observed carp but no captures (McKinley Park). An additional 8 ponds were sampled where eDNA positive results were found resulting in captures of Asian carp at 2 of those ponds.	Asian carp in Chicago Parks have not reproduced (no small fish), and the Illinois DNR has actively removed fish from contaminated lakes through draining the lake and targeted fishing with commercial nets and electrofishing. There is now increased awareness of the need to avoid contaminated stocking. Regardless of the increased awareness and ongoing efforts by the Illinois DNR, any stocked fish (non-Asian carp) that originated in a watershed where Asian carp are present has the potential to be contaminated with Asian carp, its eggs or larvae. Sources of risk include federal and state hatcheries, private hatcheries, and wild-caught fish from commercial fisheries.	Very Unlikely	Certain	3	Increased education. Increased inspection of stocked fish sources.	USFWS, Illinois DNR	Further reduction in the likelihood of unintentional stocking.	Although further reduction in the likelihood of unintentional stocking may be possible and would of course be desirable, the frequency rating for this risk analysis can't be lowered further.	Very Unlikely	Certain	3
MR-4	Bird or other Animal Transport of Fish to the Wrong Side of the Barriers	Foraging birds at the barriers such as cormorant, seagull, heron, egret, osprey or eagle may grab a fish near or within the barrier and accidentally release the fish upstream of the barrier with little to no injury.	None.	Birds have learned that the barriers are a source for food. Each of the listed birds have been observed at the barriers. Birds have been observed carrying fish over a barrier and then dropping the fish; however, the fish did not recover. Fish survival rates for this type of transport are uncertain, but are estimated to be low.	Unlikely	Low	1	Bird repellant techniques	USACE/USFWS	Scare cannons, noise makers, bird spikes on the roofing and other bird repellant techniques could reduce or eliminate bird presence at the barriers decreasing the risk for breach of barriers.	Waterfowl management has had some success at other locations including confined disposal facilities and airports. The frequency of occurrence should be reduced if the number of birds in the vicinity is reduced. However, given the already low risk level for this mode, there are no current plans to implement bird repellant techniques.	Very Unlikely	Low	0
Inadvertent Movement by Vessels														
IMV-1	Fish Transport in Ballast or Bilge Water	Fish or eggs may be able to become entrained within ballast tanks or bilge water on one side of the canal and be returned to the water on the other side.	USCG has promulgated ballasting restrictions as part of the Regulated Navigation Area at the Barriers. This should eliminate ballasting on one side of the barrier and discharging on the other side. Maintenance of tanks to address cracks through which fish could enter would reduce possibility of carp in tanks.	USCG has published a report titled "Survivability of Asian Carp in Barge Tanks in the Illinois River". The report concluded that Asian carp larvae were able to survive in ballast water tanks, but only a very small percentage were able to survive entrainment from ballast pumping. Results of this study indicate that while it may be possible for early life stages to be transported in a barge ballast tank for long periods, there is a low probability that those life stages will survive passage through the pump when the tanks are deballasted. Additional risk is introduced if tanks are not well maintained and have holes through which fish could enter and/or leave.	Unlikely	Low	1	No additional mitigation anticipated.			USCG will continue enforcement of ballasting restrictions.	Unlikely	Low	1

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Number	Event	Concerns	Existing Mitigation	Discussions, Investigations & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Frequency of Event	Opportunity for Passage Due to Event	Risk Level	Mitigation Measure	Implementing Agency	Projected Mitigation Results	Discussions, Investigations & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Frequency of Event	Opportunity for Passage Due to Event	Risk Level
IMV-2	Fish Transport by Vessel Movements	Fish may become entrained by water movements generated by vessel passage (e.g., return velocity, bow wave, propeller jets, etc.) or impinged on the vessel itself and be transported across a barrier.	None.	Frequency is very likely because barge tows regularly move over the barriers. An entrainment study using flume modeling of water motions was completed by ERDC-CHL to better characterize the risk and potential solutions. USFWS has done field experiments at the barriers with fish and barge tows. Both the lab and field testing results indicate that fish can become trapped by moving vessels and transported distances longer than the widths of the barriers. All of the fish moved across the barriers in the USFWS testing survived.	Very Likely	High	5	Design of additional barrier features and Engineering Controls to disrupt transport mechanisms (for example, potentially water jets). Recommendations on barge configurations or tow speeds for both up and downstream directions to reduce entrainment opportunities. Management of ambient canal velocities may be used in conjunction with restricted speed limits in the canal to reduce the reverse flows associated with south-bound vessel traffic to reduce the upstream passage of small fishes.	USACE, USCG	Reduced entrainment	Entrainment by southbound vessels can be reduced by moving as slowly as possible with a raked barge at the leading edge and management of downstream canal discharge over the required levels sufficient to overcome return flow of displaced water. Entrainment by northbound tows can be reduced by using a box bow barge at the leading edge to reduce entrainment. However, a box bow barge at the leading edge is apparently not practical. Other potential studies may consider in-canal velocity measurements, fish swim speed testing, and fish mortality testing to better define the risks. The opportunity for passage might be able to be reduced to medium or low if practices or features to disrupt transport mechanisms can be identified. However, this is uncertain at this time. Furthermore, constraints on the amount of water that may be released downstream to maintain elevated discharge rates exist. It is unlikely that fish entrainment by vessel-generated water movements can ever be reduced to a negligible level.	Very Likely	High	5
IMV-3	Fish Jumping on Vessels	Fish may jump onto barges, be carried over a barrier, and then be dislodged back into the water. If the time out of water is short enough, the fish may survive.	A program has been initiated to bag fish found on barge decks and turn them in at locks. Jointly USACE, USEPA, and ILDNR have implemented guidelines for vessel users to clear their decks at locks below the barrier (to eliminate the transfer of carcasses). USACE has installed signage and Lockmasters have implemented protocols to document these events and also dispose of the fish properly.	Vessels regularly pass over the barriers. The likelihood of a fish jumping and landing on a vessel is difficult to define, but certainly possible. Silver carp in particular are active jumpers. Silver carp carcasses have been observed on decks of barges making their way into the CAWS from downstream where populations are abundant. Asian carp are tolerable to out of water experiences. If they were to jump onto barge decking in the immediate vicinity of the barrier and return to the water shortly after passage over the barriers, they may survive. How long they would remain out of the water during any occurrence is uncertain.	Likely	Medium	3	Posting signage to all boat traffic to clear all fish that have jumped onto the decking prior to passing over the barriers and to ensure that no live fish are returned to the water after passage. Other educational outreach to commercial and recreational boaters.	USACE, USCG	Reduced probability of a live fish being returned to the water upstream of the barriers.	Potential risk would still be present because of boat operators who choose to ignore instructions or for those live fish that may move themselves off of the boat above the barrier before they can be removed. Sign erection and other outreach aren't currently underway, but can be implemented if Asian carp population front moves closer to the barriers.	Likely	Low	2
Barrier Performance Issues														
BP-1	Extended Loss of Power to the Pulse Generating Equipment	If electrical power from the utility is lost, each barrier has a diesel-powered backup generator system that will automatically activate. If the backup system doesn't operate properly, power to the water may be lost. Fish staging below the barriers may be able to sense that the electric field is off and could pass unaffected during a power outage.	More frequent testing and regular exercising of back-up generators has been initiated to reduce the risk of backup generator failures. Barrier IIA and the Demo Barrier are on the same utility power feed. Barrier IIB is on a different power feed. Permanent Barrier I will be fed by two power feeds that are different from each other and from all of the existing barriers.	Telemetry data have observed fish in the vicinity of barrier (non AC species) repeatedly testing/challenging barrier over the course of several hours a day during certain conditions. Lab study has also observed small AC consistently challenging a barrier (Holliman). Independence of the electric feeds minimizes the possibility that all of the barriers will lose power simultaneously.	Very Unlikely	High	2	No additional mitigation anticipated.				Very Unlikely	High	2
BP-2	Short Duration Loss of Power to the Pulse Generating Equipment	Currently when power transitions between the utility and backup generators or vice versa, there is a brief loss of power in the water (30 seconds or less) even if all systems operate as designed. Fish staging below the barriers may be able to sense that the electric field is off and could pass unaffected during a power outage.	An uninterrupted power supply (UPS) has been installed at Barrier IIA which is capable of operating the barrier for up to 8 minutes without either utility power or the backup generator.	Generator use doesn't occur only in emergencies. Gensets must periodically be tested under load to clear wet stack build up that could result in hydraulic lock-up. Testing under load results in a power loss in water of approximately 30 seconds. Fishes challenging the barrier may utilize these brief outages to cross upstream. It is hard to predict how quickly fish might recognize there is no power in the water and attempt to move through the barrier area.	Likely	Medium	3	Use of uninterrupted power supplies at all barriers.	USACE	An uninterrupted power supply (UPS) system can provide full power during the time gap between transition of power. The power gap can be reduced to zero or only a few seconds.		Very Unlikely	Medium	1

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BP-3	On-Land Equipment Failure Causing Loss of Power in the Water	Equipment such as pulsers, DC rectifiers, heating and cooling equipment, etc. could fail, making it impossible to provide power to the water. In worst-case scenarios, the equipment failure could lead to fire or explosion, damaging other equipment. Fish staging below the barriers may be able to sense that the electric field is off and could pass unaffected during a power outage.	Periodic inspections and regular maintenance of the barriers are completed to make the system as reliable as possible. Maintaining a full inventory of critical spare parts may reduce downtime if a failure does occur. Single barrier outages allow for fish to be entrained between barriers when they are back on line and those fish could pass upstream at the next barrier outage. Communication to the MRWG will help to eliminate Asian carp that could be entrained between barriers and prevent upstream passage.	Maintenance of the barriers requires consistent funding. The operation of multiple barriers provides redundancy. It is unlikely all barriers will have equipment failures at overlapping times. MRWG clearing operations may not be 100% effective due to limited technologies for clearing and constraints of the environment for implementing certain capture methods (electrofishing only takes care of surface and deep nets are a safety issue).	Unlikely	High	3	No additional mitigation anticipated..				Unlikely	High	3
BP-4	Accidents Causing In-Water Damage that Results in Loss of Power in the Water	Physical damage to the underwater electrodes, caused by debris striking or moving them, could result in inability to transmit the electrical pulses to the water or an in-water electric field of reduced strength or distorted shape. Debris may also sit across multiple electrodes causing a short circuit on the system.	No mitigation has been identified. Shielding around the electrodes would interfere with the electric field in the water.	The electrodes sit approximately 15 feet below the depth of deepest draft of passing vessels. The electrodes for Barriers IIA & IIB, and the planned electrodes for Permanent Barrier I, are made of solid steel billets that span the approximate width of the canal. Therefore, they are dense and very heavy and are likely very difficult to move or dent, notch, or otherwise damage. However, the Demonstration Barrier was once having operational problems and it was found that an empty tank used for welding gas was resting across an electrode. Also, one of the parasitic frames for Barriers II was once discovered to have moved off of the support on which it was supposed to be resting. The cause hasn't been determined. Consequence could range from low to high depending on exact impact on electric field. The operation of multiple barriers provides redundancy. It is unlikely all barriers will have electrode damage at overlapping times.	Very Unlikely	High	2	No feasible mitigation yet identified.			Regular measurement of the surface voltage gradients should provide quick notification of potential problems. Response times to a solution may still allow for long outages of power in the water at the affected barrier, but maintenance and planned outages for upstream barriers could be delayed to maintain power to the water as a system. However, there is likely no way to fully protect the electrodes.	Very Unlikely	High	2
BP-5	Operation at Less than Optimal Operating Parameters due to Inadequate Knowledge	Operating parameters are set based on laboratory and field research. If factors that aren't fully evaluated in the research have a significant effect on barrier effectiveness, parameters of the barriers may not be able to deter fish passage. Environmental conditions, such as conductivity and water temperature, could reduce the effectiveness of a given set of operating parameters. This is of particular concern for smaller fish because deterring them is more sensitive to the operating parameters and environmental conditions. Recent measurements have shown the voltage at the canal surface is less than expected for a given voltage setting for the on-land pulse generating equipment. This may be due to corrosion of the electrodes, layering of canal conductivity, or some other cause.	Operating parameters have been periodically adjusted as new research information became available. Operating parameters are currently at levels research indicates are effective for fish as small as 2 to 4 inches in total length. Research on optimal operating parameters is ongoing and adjustments will be made if new results indicate a need. The frequency of monitoring of voltage at the canal surface is being increased to better determine if unexpected variations may occur.	The operating parameters currently in use are likely conservative because they will induce immobility, which should be more than what is needed for deterrence. Research on operating parameters has been ongoing for years, but new information may come to light. An example would be the DIDSON monitoring in 2013 that recorded groups of smaller fish crossing over the Barrier IIB narrow array. This led to testing of the impacts of high water temperature on barrier effectiveness. That research is ongoing, but indicates that water temperature may have a greater influence than previously thought. It is possible that there are still some other influences that aren't fully understood. The opportunity for passage could range from low to high depending on the exact impact on the electric field and the size of the fish. The opportunity for passage is ranked high here assuming that smaller fish are a concern. Larger fish are readily deterred over a wider range of parameters and water conditions than smaller fish. The operating voltage can be adjusted if monitoring of voltage at the canal surface indicates an unexpected reduction in field strength.	Likely	High	4	Permanent Barrier I is designed for a greater power capacity. Adjust operating parameters. Install conductivity probes at different elevations at the fish barriers to better evaluate the influence of conductivity layering at the site on voltage in the water.	USACE	Ongoing adjustments to operating parameters. Use Barriers IIA and IIB together for redundancy; Permanent Barrier I will be capable of operating over a wider range of operating parameters.	Barrier I will have greater capacity and range of operating parameters. Redundancy with IIA and IIB can be incorporated in operating parameters as well. Increasing voltage to incapacitate fish-may make them more susceptible to transport by barge entrainment. Ongoing research will gradually reduce the uncertainty related to optimal operating parameters.	Unlikely	High	3

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BP-6	Operation at Less than Optimal Operating Parameters due to Inadequate Power	High water conductivities can cause the power demand required to maintain operating parameters to exceed the power capacity of a barrier. When this occurs, the operating parameters must be reduced (referred to as a foldback). This can lead to operating parameters not at sufficient level versus operating at levels that testing efforts have determined to be optimal parameters.	The power foldback algorithm has been reprogrammed to minimize impact of foldbacks.	This is a seasonal problem. High water conductivities usually occur in the winter after thaws send large quantities of road salt into the CSSC. The existing barriers have experienced at least short duration foldbacks each winter. Power foldbacks are very unlikely in the warmer months. Risk characterization is based on the winter months. Consequences could range from low to high depending on the extent the parameters fold back from the desired levels Water temperature is a mitigating factor because fish are less active in the colder water that is typically present when power foldbacks occur.	Likely	Medium	3	Permanent Barrier I has almost 3 times the power capacity of Barriers IIA and IIB.	USACE	Permanent Barrier I will be unlikely to have to foldback parameters even at high water conductivities.	When Permanent Barrier I is operational at least one barrier is expected to be able to maintain optimal operating parameters in extreme conditions.	Unlikely	Medium	2
BP-7	Operation at Less than Optimal Operating Parameters due to Stray Voltage Concerns	Underground stray voltage from the barriers can impact neighboring properties. If the impacts create significant safety issues the operating parameters may have to be reduced to alleviate concerns. In the winter of 2015 operating voltages had to be substantially reduced to avoid railroad crossing signal interference.	Actions have been taken that have minimized stray voltage concerns at the three residences close to the site. Installation of a site-wide grounding system has reduced the spread of underground stray voltage.	Interference with a nearby railroad crossing signal was an issue in the past and has limited some options for operational parameters. Possible impacts on a nearby underground petroleum pipeline are still being investigated.	Unlikely	High	3	Installation of further improvments to the grounding system and installation of non-conductive fencing are scheduled to be completed in 2019.	USACE	Reduction in touch potential safety risks for people, but the impacts on reducing risks to neighboring infrastructure are hard to predict.	Effectiveness of further mitigation techniques is unknown at this time.	Unlikely	High	3
BP-8	Operation at Less than Optimal Operating Parameters due to EMF Concerns	If potential health risks are created by EMF fields generated by barrier operation, the operating parameters may have to be reduced.	Areas of high EMF have been restricted from access. All are located on site where they could only be accessed by Corps staff.	The most recent EMF study indicated that barrier operation is creating EMF concerns only in a few limited areas where the Corps can control access.	Very Unlikely	High	2	No additional mitigation is planned.				Very Unlikely	High	2
BP-9	Fish Moving Near the Irregular Canal Sidewalls	Testing to collect electrical field strength measurements along the walls and notches showed reduced field strength deeper in the notches. Fish may be able to utilize crevices, notches, etc. as refuge from higher field intensities and stage there before continuing through the barrier.	Some of the notches have been filled with concrete.	Preliminary minnow trap assessment indicated that small fish were able to remain within the wide array of Barrier IIA inside the crevices, but no fish were observed within the narrow array. It is very likely that some fish do move near the canal walls. It is uncertain how much this increases the ability of fish to traverse the entire barrier. That may depend on the spacing of the notches relative to one another and the level of reduced voltage within the notches.	Very Likely	Medium	4	Fill in all notches in the proximity of the active electrodes.	USACE	Reduces refuge and resting area for fish challenging the barriers thus reducing the risk.	Filling in the notches and/or lining the walls would eliminate this area of risk and is an ongoing effort during the construction of PB1 where site conditions allow the opportunity.	Very Likely	Negligible	2
BP-10	Variations in the Electric Field in the Immediate Vicinity of Metal Vessel Hulls	Some studies of fish towed in cages next to metal boat hulls have shown that the fish may be less likely to be incapacitated by the electric field. This raised concerns that a fish could get close to a barge and potentially move with it through the electric field. Study of barge tows indicates that the in-water field strength is at negligible levels in the open space below where a rake bow is against a square stern.	None.	Frequency is very likely because barge tows regularly move over the barriers. Recent testing measured the electric field strength within 1-2 feet of barge hulls and found that it was not reduced in absolute magnitude. However, the primary direction of the electric field was changed from upstream-downstream to top-bottom. All fish near the hulls in that study were incapacitated. Fish where not incapacitated in the open space below where a rake bow is against a square stern. However, even if they were, the flow regime in that area would pull the incapacitated fish along with the barge movement. Therefore, the risk in that area is due to inadvertent movement (IMV-2) rather than the electric field strength.	Very Likely	Low	3	Supplemental barrier systems, biological deterrents physical deterrents, or alterations to electrode design.	USACE	Supplemental barriers, biological deterrents, or physical deterrents would reduce the number of fish present near a passing vessel. Alterations to the electrode design might result in an electric field that is less distorted in the immediate vicinity of metal hulls.	Effectiveness of any of these potential mitigation techniques is unknown at this time.	Very Likely	Low	3

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BP-11	Variations in the Electric Field Farther from Metal Vessel Hulls	Electric field strength farther than a few feet from a barge appears to be diminished during the passage of barges. Testing done in 2013 showed up to a 40% drop in field strength at the center of the Barrier IIB narrow array, near the water surface, close to a passing metal hulled barge.	None.	When measured near one canal wall, the effect is relatively small when a barge tow passes by close to the opposite wall or down the center of the canal. However, the 40% was seen when the barge passed close to the wall where the metering was located. Frequency is very likely because barge tows regularly move over the barriers. Opportunity varies depending on proximity to the barge.	Very Likely	Medium	4	Supplemental barrier systems, biological deterrents physical deterrents, or alterations to electrode design.	USACE	Supplemental barriers, biological deterrents, or physical deterrents would reduce the number of fish present near a passing vessel. Alterations to the electrode design might result in an electric field that is less distorted in the immediate vicinity of metal hulls.	Effectiveness of any of these potential mitigation techniques is unknown at this time.	Very Likely	Medium	4
Other Risks														
OR-1	Person in Water	USACE is committed to shutting down the barriers if a person is in the water near them. Fish staging below the barriers may be able to sense that the electrical field is off as they continually test the barrier and could pass unaffected during a power outage.	Ongoing efforts to enforce the RNA will increase awareness of this risk and therefore reduce the likelihood of incidence.	The length of the shutdown would depend on the length of rescue operations. Telemetry data have observed fish in vicinity of barrier (non AC species) repeatedly testing/challenging barrier over the course of several hours a day during certain conditions.	Very Unlikely	High	2	No additional mitigation required.				Very Unlikely	High	2
OR-2	Flow Reversal	Water flow in the CSSC occasionally reverses direction. This can be caused by an abrupt shutdown or throttle down of the turbines at the power station located downstream at Lockport Lock & Dam or by wind driving surface flows. Fish could be swept through the barriers during flow reversals. If a fish is rendered unconscious by a barrier and remains afloat, a relatively low reverse flow at the surface could move it across the barrier.	None.	The CSSC is a man-made waterway and current flow within it is managed. Current driven flow reversals have been analyzed over the past 5-year time frame by MWRD and USGS with results indicating that durations long enough to transport a fish far enough to pass the barriers are rare. Wind driven surface flow reversals are more common and on-site personnel have observed fish pushed across an active barrier before swimming away. The presence of a low-powered array is important because it reduces the likelihood that fish will be stunned.	Likely	High	4	Actively managing the discharge rates in the canal to increase the ambient downstream velocity at periods of increased southerly winds may help reduce or overcome wind driven surface currents.	MWRDGC	A 2017 field study of mitigation actions to reduce return flow (flow reversal) associated with the passage of downstream barges identified increased downstream ambient flow velocities as a potential mitigation measure. Results from that study indicated that flow reversals due to displaced water of a south-bound vessel could be mitigated but did not specifically investigate surface currents driven by wind events. Further study may be required to fully understand the efficacy of this mitigation technique.	A monitoring station that will record reverse flows at the barriershas been installed. This will provide information on the frequency of reverse flows so that this risk can be better understood. However, more information will not mitigate the risk directly. Reverse flow events caused by wind at the canal surface may be analyzed in conjunction with ambient canal velocity and discharge. A break-even analysis may be conducted to determine if an ambient canal velocity is possible to counteract the effects of southerly wind speeds at the surface of the canal. Flow in the CSSC is regulated by the MWRD to support various water quality and naviation goals. Diversion of water into the CSSC from Lake Michigan is limited by U.S. Supreme Court decree to an average annual flow of 90.61 m3/s (3,200 cfs), and minimum and maximum water levels are governed by the Code of Federal Regulations. These regulations place constraints on the options for this mitigation technique to be employeed. While the frequency of this event may be lowered by the identified mitigation action, the likelihood that MWRD has the ability to do so needs further evaluation. Until further study is completed, this risk level must be maintained.	Likely	High	4
OR-3	Fish Jumping Over the Electrified Water	Silver carp are known to jump from the water when startled by noise or electric fields.	None.	Silver carp are not able to jump over the 40 ft necessary to clear the electrode arrays. When electrofishing, they are observed to jump initially, but then become incapacitated when returning to the electrified water. Therefore, they are not able to cross the barriers in a series of jumps.	Very Unlikely	Negligible	0	No mitigation required.				Very Unlikely	Negligible	0
Population Pressure														

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PP-1	Population Pressure	Population pressure isn't itself a failure mode for the barriers. However, it essentially acts as a multiplier. The risk associated with any of the above failure modes is higher if there is a larger population of fish in the immediate vicinity of the event. On the other hand, the risk associated with any of the above failure modes is lower if there is a lower population of fish in the immediate vicinity of the event.	Harvesting by the Illinois DNR using commercial fishermen has been successful in removing significant quantities of Asian carp downstream of the barriers. This barrier defense program is ongoing.	The commercial fishing barrier defense program is likely playing a significant role in reducing the potential population pressure at the barriers. However, analysis completed by Dr. Garvey (SIU) indicates that harvesting needs to include a range of sizes of Asian carps in order to maximize effectiveness at reducing population pressure.				Fish detection system near the barriers. Biological deterrents. Physical deterrents. Improved monitoring of fish locations.			A fish detection system would provide warning of increases in fish in the vicinity . This information could be used to initiate a clearing action. Biological deterrents, such as introduction pheromones, or physical deterrents, such as water guns or sound, could be used to keep fish from staging in the vicinity of the barriers. Improved identification of areas with large populations would increase the effectiveness of harvesting for population control.			

Risk Summary

Risk Area			Current Risk	Projected Risk
Interbasin Connections	IB-1	Permanent bypass - Des Plaines River	2	2
	IB-2	Permanent bypass - I&M Canal	1	1
	IB-3	Breaching or overtopping of the Lyons Levee	2	2
Movement/Release by People or Animals	MR-1	Direct Release of Fish on the Wrong Side of the Barriers	3	3
	MR-2	Use of Bait Releases Fish on the Wrong Side of the Barriers	4	4
	MR-3	Unintentional Stocking of Fish on the Wrong Side of the Barriers	3	3
	MR-4	Bird or other Animal Transport of Fish to the Wrong Side of the Barriers	1	0
Inadvertent Movement by Vessels	IMV-1	Fish Transport in Ballast or Bilge Water	1	1
	IMV-2	Fish Transport by Vessel Movements	5	5
	IMV-3	Fish Jumping on Vessels	3	2
Barrier Performance Issues	BP-1	Extended Loss of Power to the Pulse Generating Equipment	2	2
	BP-2	Short Duration Loss of Power to the Pulse Generating Equipment	3	1
	BP-3	On-Land Equipment Failure Causing Loss of Power in the Water	3	3
	BP-4	Accidents Causing In-Water Damage that Results in Loss of Power in the Water	2	2
	BP-5	Operation at Less than Optimal Operating Parameters due to Inadequate Knowledge	4	3
	BP-6	Operation at Less than Optimal Operating Parameters due to Inadequate Power	3	2
	BP-7	Operation at Less than Optimal Operating Parameters due to Stray Voltage Concerns	3	3
	BP-8	Operation at Less than Optimal Operating Parameters due to EMF Concerns	2	2
	BP-9	Fish Moving Near the Irregular Canal Sidewalls	4	2
	BP-10	Variations in the Electric Field in the Immediate Vicinity of Metal Vessel Hulls	3	3
	BP-11	Variations in the Electric Field Farther from Metal Vessel Hulls	4	4
Other Risks	OR-1	Person in Water	2	2
	OR-2	Flow Reversal	4	4
	OR-3	Fish Jumping Over the Electrified Water	0	0
Propulation Pressure	PP-1	Population Pressure		

Population pressure is not counted as a risk itself but may elevate risk levels as popluation varies in proximity to the barriers.
Current Risk = risk at time of report
Projected Risk = risk if final mitigation measures are implemented