Existing Infrastructure Retrofits for Risk Reduction of Aquatic Invasive Species Transfer between the Mississippi and Great Lakes Watershed Basins

A Briefing to the Restoring the Natural Divide Advisory Committee

By HDR Engineering and Greenleaf Advisors

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For the Great Lakes Commission and the Great Lakes and Saint Lawrence Seaway Cities Initiative

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Purpose and Background

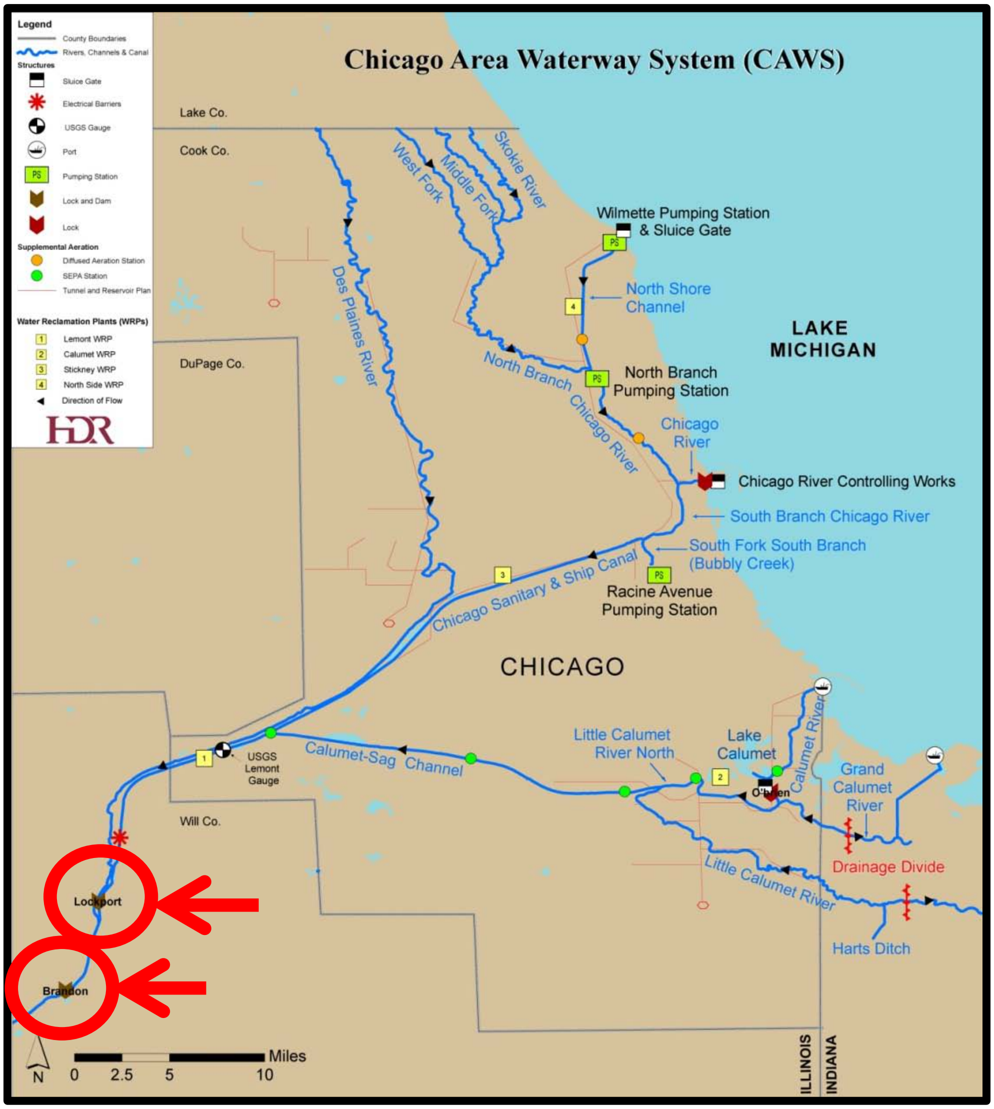
This memorandum was prepared as a summary reference document for the Advisory Committee of the *Restoring the Natural Divide* project regarding interim barrier concepts. As documented in the Technical Report prepared for the *Restoring the Natural Divide* project, alternatives involving permanent separation of the Mississippi River and Great Lakes basins in both directions require minimum timelines of 15 to 20 years for full completion. Consequently, some discussion among various Advisory Committee members has been focused on means for further reducing risk of AIS transfer, specifically Asian carp, in a more near term timeframe. This discussion prompted a reconnaissance level review of interim barrier concepts that may partially reduce the risk of AIS transfer until a permanent barrier is completed.

To conceptualize a near-term interim barrier, the following assumptions and objectives were established:

- Existing services, including flood management, transportation, and water quality, will be maintained
- Barrier would utilize existing infrastructure to the extent practicable
- Physical control is first priority as it is considered to have greatest opportunity for risk reduction
- Focus is on a 1-way barrier for Asian carp and other invasive species (reduce risk of transfer from Mississippi to Great Lakes)
- The review discussed in this memo is focused on hydraulic elements of an interim barrier concept. Treatment of water passing through lock structures is discussed in a separate evaluation report

Previous approaches to a near term physical control have focused on existing infrastructure at the Chicago and Calumet River systems' interface with Lake Michigan (i.e. closing gates/locks at Wilmette, Chicago River Controlling Works, and O'Brien); however, this approach would not maintain existing services, in particular transportation movements and flood management. Conversely, this review focused on the downstream end the Chicago Area Waterway System (CAWS) to take advantage of existing infrastructure and the decrease in topographical elevation that occurs in this area. As illustrated in Exhibit 1, the two primary facilities that exist in this area of the CAWS and are the focus of this interim barrier concept review are : 1) Lockport powerhouse/lock & controlling works and 2) Brandon Lock & Dam.

Exhibit 1. Location of Interim Barrier Concepts – Lockport and Brandon



Lockport Facilities

Background

The Lockport Facilities consists of the powerhouse/navigation lock (river mile 291.1) and the Lockport controlling works (river mile 293.2), as illustrated in Exhibit 2. The MWRD owns and manages the powerhouse, which is used to pass the flows of the Chicago Ship and Sanitary Canal (CSSC) to protect against flooding and generate hydropower. During dry weather, the MWRD operates the powerhouse to pass flows through the remaining functional turbines located in bays 1 and 2 of the 8 bays within the powerhouse. During wet weather, additional flow is passed as needed through bays 3, 4 and 7 to maintain the stage of approximately -2.5 CCD (CCD is the Chicago City Datum, zero CCD is defined by an historic average lake level) in the CSSC. If the powerhouse is unable to pass the current or anticipated flows, then the Lockport Controlling works are opened to increase the drainage of the CSSC.

Exhibit 2. Location of Lockport Facilities

The CSSC immediately upstream of the Lockport powerhouse/lock has the capacity to convey approximately 30,000 cfs. The Lockport powerhouse and controlling works have a combined capacity to move greater than 30,000 cfs and is not a hydraulic constraint. Prior to a storm, the canal is drawn down to create storage and flow within the channel. The draw down elevation scenario can be as much as -10.5 CCD at the powerhouse, resulting in stages of approximately -7 to -10 CCD at the Lockport controlling works and -4.5 CCD at the confluence of the CalSag and CSSC which, per intergovernmental agreement between MWRD and USACE, cannot go lower than -4.5 CCD.

It takes approximately four hours for drawdown actions at the powerhouse to influence water levels at Wilmette (river mile 341). Tailwater conditions (the Brandon pool) are maintained by the Brandon lock and dam (river mile 286) and are maintained in a limited range of stage that is +/- 0.5 foot of elevation -41 CCD.

The USACE operates a navigational lock as part of the Lockport facilities and measures for reducing risk of AIS transfer via the lock are addressed in documentation from others. A smaller, abandoned lock owned by MWRD has been bulkheaded closed and would appear not to present a measureable risk for AIS transfer.

Lockport Powerhouse

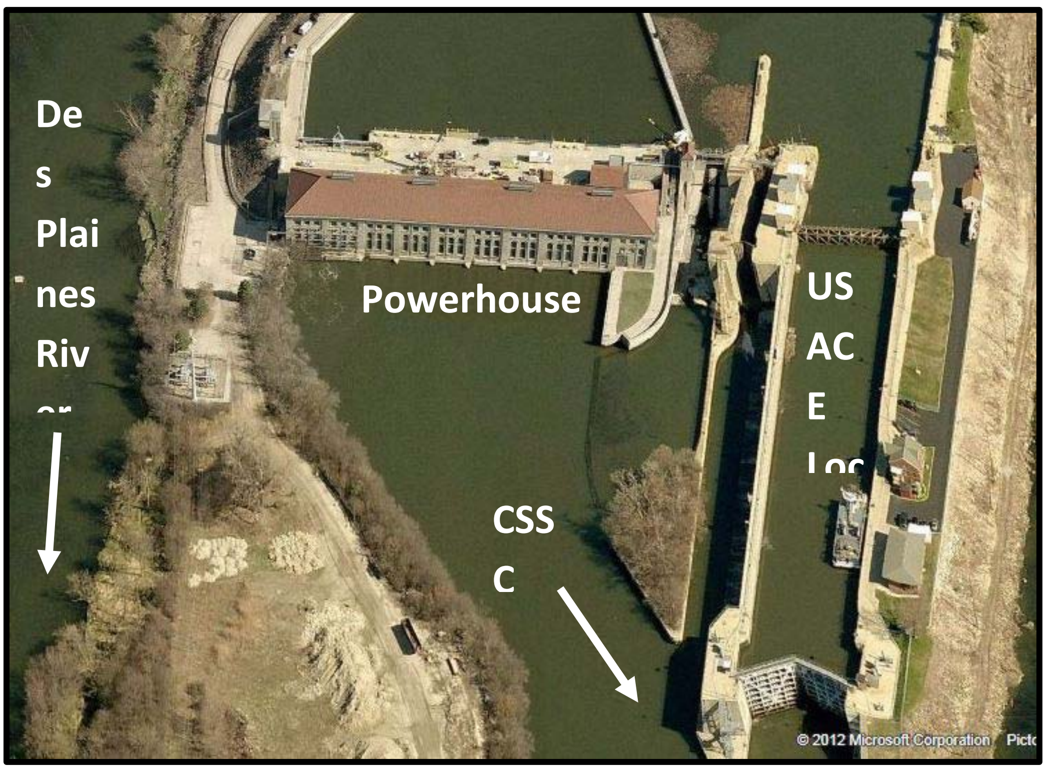
The Lockport Powerhouse & Navigation lock are illustrated in Exhibit 3 and described below and in Figures 1 and 2:

- Powerhouse facility consists of 8 total bays
- Bays 1 and 2 are used for turbines, and likely represent a minimal risk pathway for upstream transfer of invasive species. Each of the two turbine units has a capacity of 6,750 kW at 37.5 feet of head and 2,500 cfcs, meaning Bays 1 and 2 have a combined flow capacity of 5,000 cfs at 37.5 feet of head (headwater elevation -2.5 CCD). Aquatic Invasive Species (AIS) barriers include the turbines which have wicket gates that are closed when the turbine is not spinning, as well as stop log gates which are used if the turbine is in need of repairs. While additional investigation is needed for verification of velocities, the physical elements of the turbines along with the

flow/velocities produced during operation would likely inhibit the upstream movement of species through the turbines.

- Bays 3, 4 and 7 have had the original horizontal turbines removed, and are now used to manage CSSC elevations via gates that control the flow into chambers that once held turbines. A series of three gates exists within each bay providing a total of 9 gates, with each 9-ft x 14-ft gate having a flow capacity of 2,500 cfs for a headwater elevation of -2.5 CCD. The floors of these chambers have openings that drop into draft tubes (conveyance pipes out of building). When the bay is not passing flows, it is dry, with the floor of the bay approximately 10 to 11 feet above the water elevation. The floor of these bays are at -29 and the water level below the floor is maintained at -41 CCD by the Brandon Locks. Critical elevations are indicated in Figures 1 and 2.
- When bays 3, 4, and 7 are being used to pass flows, the water is extremely turbulent and at a high velocity. As the bays were not designed for this purpose, they do not create a smooth laminar flow typically expected from a bypass or chute. Bay 7 has been bulkheaded for repairs for several years, and is now back in operation, this will increase the capacity of the powerhouse to move water for draw down purposes.
- Bays 5 and 6 are bulkheaded. Water does not pass though these bays. The outer structure of an eighth bay was constructed but was never fully completed or operational.
- The powerhouse also has an abandoned lock structure that is bulkheaded and sealed.
- The larger lock structure is owned and operated by USACE. Measures for reducing risk of AIS transfer via the lock are addressed in documentation from others.

Exhibit 3. Lockport Powerhouse and Navigation Lock



Lockport Powerhouse Findings

Although it appears unlikely that a fish can pass upstream through the powerhouse, a hydraulic study should be conducted before relying on the existing infrastructure to prevent the upstream passage of AIS. To better understand the movement of fish through a turbine (studies show the survival of fish in the downstream direction through a turbine is higher with low head, Kaplan turbines) calculation of the flow velocities through the turbine to see if the flows exceed fish burst speeds should be considered. In addition, the chamber bays should be studied to determine flow rates through the orifices in the floor. If necessary, the hydraulics of the chamber may be improved to increase velocities of the flow, and the capacity of the chambers.

Lockport Controlling Works

The controlling works consists of 7 active bays shown in Exhibit 4, as well as 8 additional bulkheaded bays that were never put into operation. The MWRD operates the gates, and owns the operational components of the gates, whereas the USACE owns the structures that hold the gates (bays). The USACE has recently completed some re-investment in the 7 active bays.

Exhibit 4. Lockport Controlling Works

Each of the 7 gates is 16-ft (H) X 30-ft (W) with a flow capacity of 2,500 cfs for a headwater elevation of -2.5 CCD. When the gates are opened, they are lifted completely out of the water, and although each gate can be opened independently, typical operations open all gates to maximize flood control. Typically, the gates are opened only after the drawdown process has begun. In other words, the drawdown process is first managed through the Powerhouse, and then, if needed, the Controlling Works gates are opened; typically the CSSC elevation at Controlling Works is near -8.0 when they are opened to provide flood relief. Refer to Figures 3 and 4 for a schematic of the drawdown and equalization process.

The gates discharge to a pool which flows overland towards the Des Plaines River. The tail water to these controlling Works gates tends to rise quickly, to a near equal elevation. It appears that the rapid tailwater rise is due in part to the limited capacity of the downstream tailrace channel to drain into the Des Plaines River.

Lockport Controlling Works Findings

The Lockport Controlling Works represent an AIS risk through the gates, as the tailwater and headwater reach a near equal elevation, allowing a fish in the tailwater with the ability to overcome the water velocity of the gates, access to the CSSC. It is suggested to take measurements at appropriate places that allow the calibration of models to determine the high and low velocities through the gates, and inform changes to the Lockport Controlling Works tail water pool drainage to the Des Plaines.

Several options are available to reduce the risk of transfer through the controlling works.

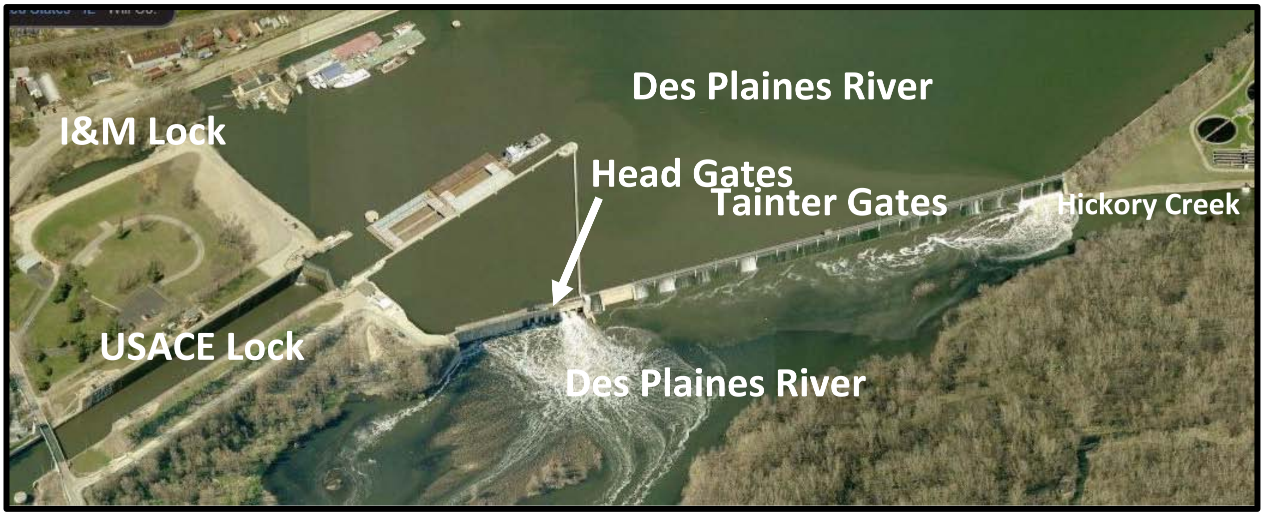
1. Increasing the capacity of the tailrace channel would likely lower the tailwater elevation. The improved hydraulics could enhance other modifications to the gates to make them less susceptible to transfer AIS.
2. Changing the current gate arrangement to be an overflow would require a longer sill, but there is likely room to develop this capacity. The sill elevation would need to be managed to adjust for draw down. Further, it is unlikely that the elevation difference between the sill and the tailwater is preventative to a jumping carp (min 10 foot elevation difference is often quoted). Therefore, the sill would need to have a means to stop leaping fish. This could be a net, or a hydraulic design, to reduce the risk of species jumping the sill of the weir.
3. Construction of new gates perpendicular to the existing gates, and facing the tailwater raceway, offers the opportunity to build gates designed for the additional intention of AIS protection, i.e. gates that create high velocities. The existing gates could then be abandoned, or left in the open position.
4. Incorporating other deterrents to the system such as rotenone, CO_2, bubblers etc., to keep fish out of the area can be applied to the tailrace channel.

Brandon Lock and Dam

Background

The Brandon Lock and Dam, located 286 miles above the confluence of the Illinois River and the Mississippi River, is owned and operated by the USACE and has four elements with the potential for passing water (main lock, I&M Lock, Headgates, Tainter Gates). These primary elements are illustrated in Exhibit 5 and described below. The operation of the Brandon dam and (associated structures) is driven by the flows of Lockport with the objective of maintaining an upstream pool elevation of -41 CCD for navigation. The dam and its associated storage is designed and operated for navigational control (run of the river operation), that is, no storage is allocated for flood control and flood discharges are passed directly downstream (inflow = outflow).

Exhibit 5. Brandon Lock & Dam



Abandoned Lock from I&M Canal

An abandoned lock exists to the west side of the structure, and appears to have some leakage (unconfirmed). This potential pathway should be confirmed, and possibly bulkheaded to prevent any flow of water.

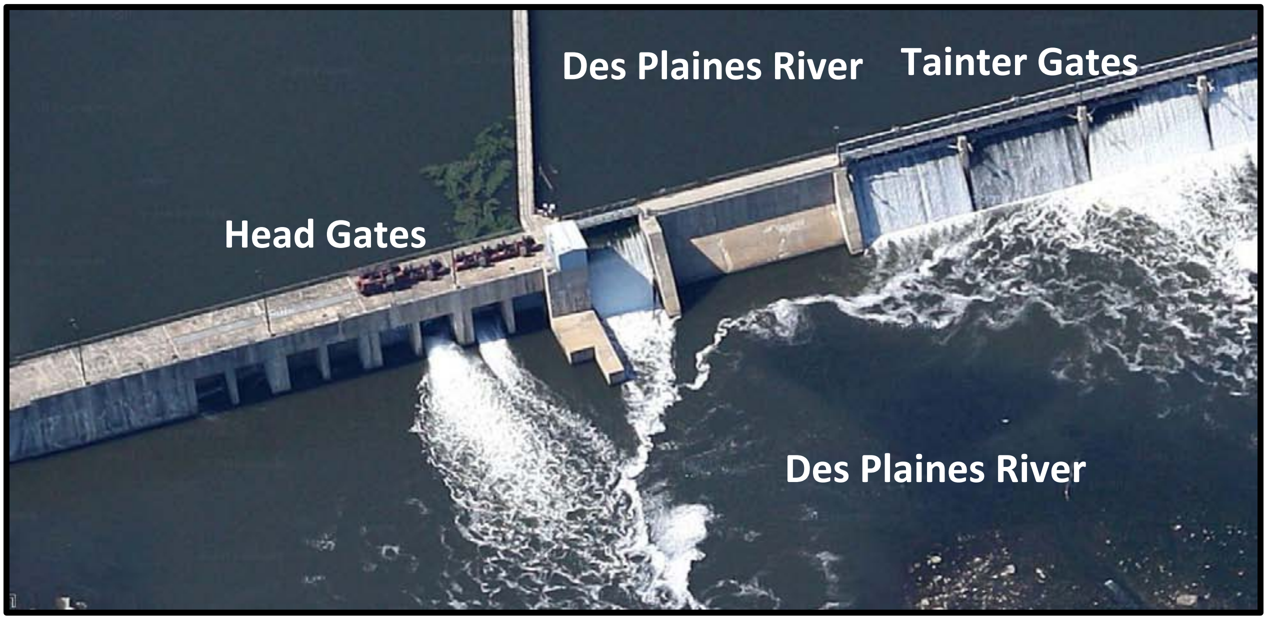
Main Lock

Measures for reducing risk of AIS transfer via the active USACE lock are addressed in documentation from others.

Head Gates and Tainter Gates

Exhibit 6 provides a closer look at the Brandon Dam head and Tainter gates. The pier dam contains sixteen 15-ft (W) x 15-ft (H) single-leaf, vertical lift headgates. Eight of the sixteen headgates have been concreted in the closed position. The critical elevations of the 8 functional headgates are described in Figure 5 and each headgate has a maximum discharge capacity of approximately 7,000 cfs at a maximum headwater elevation of -36.0 CCD (total capacity of 56,000 cfs). These headgates are utilized to pass high flows. There is a drop of approximately five feet from the sill of the head gates to the tailwater. Occasionally the tailwater rises above the sill elevation of -68 CCD indicating a direct path if the gates were opened, and the velocities were not exceeding the burst speeds of the species of interest; however, it should be noted a considerable head of at least 20 feet would be providing the energy for discharges through the head gates at all times.

Exhibit 6. Brandon Dam Head & Tainter Gates



Within the 1,100 foot long concrete pier dam there are 21 Tainter gates each 2.25-ft (H) x 50-ft (W) Tainter gates. The key elevations to the existing Tainter gates are described in Figure 6. These gates have a vertical drop from the sill to the maximum tailwater of approximately 23 feet. The Tainter Gates are utilized to control the Brandon Pool water elevation for navigation purposes.

Head Gates and Tainter Gates Findings

There are several approaches to reducing the risk of AIS transfer through the Brandon Dam.

1. The most effective option would likely be to take advantage of the large vertical drop of the dam by closing the Headgates and compensating for the loss of hydraulic capacity by lowering the sill elevation and enlarging the Tainter gates. It is possible to lower the Tainter gates approximately 6 to 9 feet to accommodate the existing hydraulic capacity of the headgates and create a minimum 14- to 17-foot vertical drop between high tail water and Tainter gate sill elevation as an AIS barrier (see Figure 7). This vertical drop would still exceed the maximum jump height for Asian carp species estimated at 10 to 12 feet.
2. Alter the Head gates so that they have a “flip bucket”. This would create an arching flow out of the gates, and reduce the likely hood of a fish entering the gate. Detailed hydraulics would need to be completed to determine the extent of the “flip”, and the corresponding reduction of AIS transfer. See Figure 8 for example “flip bucket” effect.
3. Alter the Head Gates hydraulics to remove stagnation points and/or increase velocities. One potential concept would be adding a channel to the bottom of the sill extending out so that the outflow structure is extended beyond the ability of AIS to swim through. Essentially add a culvert to the exit of the gate.

Before any of these potential approaches is pursued, a hydraulic study should be conducted to better understand the outlet velocities and stagnation areas of the headgates during various gate openings relative to specific Asian carp species burst speeds. In particular, areas around the perimeter of the outer most gate openings would likely be the areas with the highest potential for areas of flow stagnation (lower velocities) that may provide a potential pathway for AIS transfer if fish can maintain burst speeds long enough to overcome these lower velocities. If sufficient hydraulic and fish biology information is evaluated, it is possible the existing hydraulics of the headgates may be determined to provide limited risk for AIS transfer in the upstream direction.

Conclusions

Key elements and findings of this initial review of a near-term, interim barrier concept include:

- Barrier would utilize existing infrastructure to the extent practicable and maintain existing services, including flood management, transportation, and water quality.
- Interim barrier intended to provide enhanced risk reduction of AIS transfer from Mississippi to Great Lakes (1-way barrier only) until permanent bi-directional solution is implemented.
- Brandon Dam is the most suitable location to retrofit as it would further reduce risk of AIS transfer for the CAWS and the Des Plaines River via a single location.
- Prior to pursuing modifications to Brandon Dam, a risk evaluation involving headgate hydraulic conditions relative to fish swim speeds should be conducted to assess the probability of AIS transfer and, therefore, the need for Brandon Dam modifications.
- An interim 1-way barrier that maintains existing services is feasible only when combined with measures for reducing risk of AIS transfer via the active Brandon navigation lock (addressed in separate report).

Overall, this initial review indicates that the Brandon Dam is more suitable to retrofit for risk reduction of AIS transfer than the Lockport powerhouse, dam, and controlling works. In addition to providing a greater elevation drop between headwater and tailwater elevations, the Brandon location is downstream of the Des Plaines River confluence. A barrier at Brandon would reduce the risk of AIS transfer in the Des Plaines watershed as well as the CAWS. Furthermore, the Brandon location would further reduce the risk of AIS transfer between the Des Plaines River and the CSSC that a barrier in the Lockport location does not address.

Retrofitting the Brandon dam would be a significant project and would require much more detailed evaluation, feasibility review, and, if warranted, design. However, the retrofits of Brandon mentioned are within the reasonable range of dam retrofit and modification projects, as numerous examples of gate changes, upgrades, and even sill elevation changes exist within USACE dams and controlling works. Furthermore, the opportunity to maximize potential funds would occur by combining potential dam modifications with already planned major rehabilitation and maintenance items at Brandon Dam. Currently, USACE has approximately $48.5 million of maintenance items at Brandon Dam identified.

Additional Figures

Figure 1 – Lockport Powerhouse Gates 3, 4, 7

Green numbers are elevation in CCD.
The gates are used as needed to pass flows from the CCSC. When not in use, the gate is closed and an "airgap" is created which is a strong AIS prevention. When gates are open, the room is flooded, but with high turbidity and water velocity as the flows make their way into the draft tube.

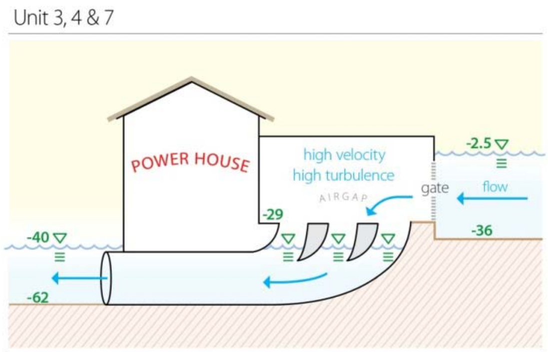


Figure 2 – Lockport Powerhouse Gates 1, 2

Gates 1 and 2 are used for hydropower generation. Vertical axis Kaplan with wicket gates are a significant AIS barrier, yet studies have shown survival rates of fish passing on the downstream direction of other low head Kaplan turbines. This indicates a slight chance that a fish could pass through the turbine in the upstream direction Nonetheless, evaluating the dimension of the wicket gates, and flow velocities could definitively indicate the risk of AIS transfer in the upstream direction.

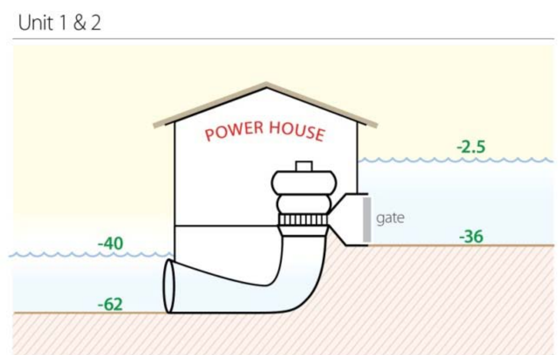


Figure 3 – Lockport Controlling Works

This cross section indicates the process of a draw down, with CCD elevation data. Typical water elevation at the LCW is around -2.5 CCD. As the CSSC is drawn down this elevation decreases. As needed, the gates are opened to pass additional water.

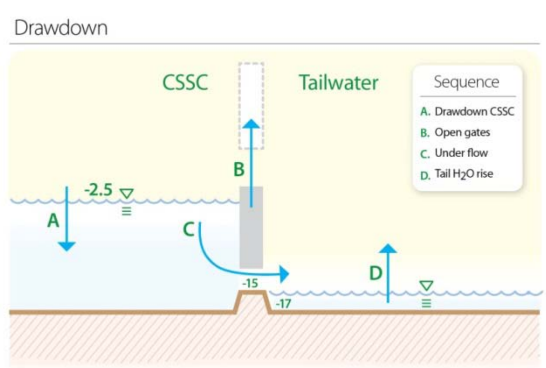


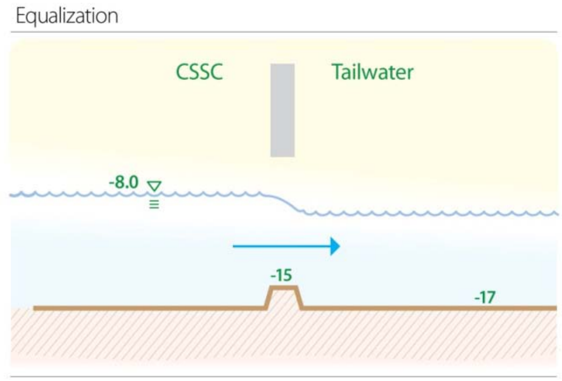
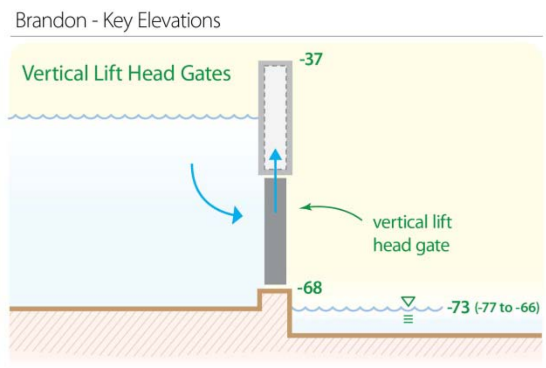
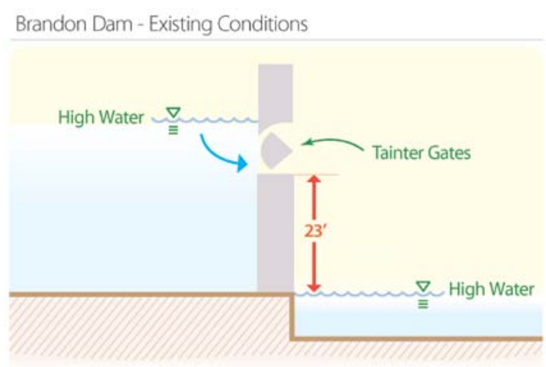
Figure 4 – Lockport Controlling Works As the tailwater rises, the CSSC and the tailwater start to equalize and create potential pathway for AIS.	
Figure 5 - Brandon Head Gates The head gates are vertical lift gates. The elevation of the sill is only a few feet above average tailwater elevation and represents a possible pathway for AIS. Changes to this sill elevation can be offset by changes to the Tainter gates.	
Figure 6 – Brandon Tainter Gates - Existing There are 21 Tainter gates at Brandon, each 50 feet long, and about 2 feet high. When open, they are lifted upwards, and the flow passes under the arc. These Tainter gates have a sill approximately 23 feet above the tailwater and do not represent an AIS pathway. One proposal is to lower the sill of these Tainter gates by 6 to 9 feet and utilize only Tainter gates to manage the Brandon pool elevation, thereby eliminating the need to open the headgates.	

Figure 7 – Brandon Tainter Gates - Proposed

One proposal is to lower the sill of these Tainter gates by 6 to 9 feet and utilize only Tainter gates to manage the Brandon pool elevation, thereby eliminating the need to open the headgates. This proposed modification would still provide a vertical separation of 14 to 17 feet between the Tainter gate sill elevation and maximum tailwater elevation. This vertical drop would still exceed the maximum jump height for Asian carp species estimated at 10 to 12 feet.

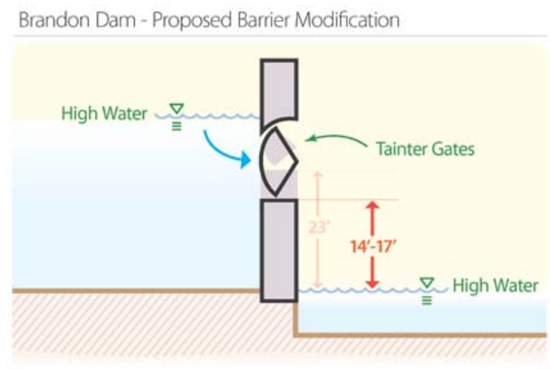


Figure 8 - Example Effect from "Flip Bucket"

Although this is more dramatic than could be created at Brandon or Lockport, it represents the idea that the flow itself can be modified to reduce the risk of AIS transfer. The flip bucket refers to the ramp that angles the flow form the chute in an upward arch.

References

In addition to documented reports, this investigation has been informed by personal interviews and information from MWRDGC, USACE, and USGS which provided valuable insight into the features, operations, and issues associated with the Lockport and Brandon facilities.

Reports:

- Upper Mississippi River Basin – Illinois Waterway Master Water Control Manual Appendix 1, Lockport Lock and O'Brien Lock & Controlling Works. USACE, 1986.

- Upper Mississippi River Basin – Illinois Waterway Master Water Control Manual Appendix 2, Brandon Road Lock & Dam. USACE, 1996.

- Control Structure Ratings on the Chicago Sanitary and Ship Canal near Lockport, IL, SIR 2012-5131. USGS, 2012.

- CHICAGO SANITARY AND SHIP CANAL, LOCKPORT CONTROLLING WORKS, WRITTEN HISTORICAL AND DESCRIPTIVE DATA, HISTORIC AMERICAN ENGINEERING RECORD, National Park Service, U.S. Department of the Interior, 1849 C Street NW, Washington, DC 20240-0001

- ILLINOIS WATERWAY, BRANDON ROAD LOCK AND DAM, WRITTEN HISTORICAL AND DESCRIPTIVE DATA, HISTORIC AMERICAN ENGINEERING RECORD, National Park Service, U.S. Department of the Interior, 1849 C Street NW, Washington, DC 20240-0001

- Research and Development Office, Report #08-15R, Description of the Chicago Area Waterway System for the UAA, March, 2008