

Princeton Dam Evaluation Study DFD Project Number 13K1I



Prepared by



For

**State of Wisconsin
Wisconsin Department of Administration
Division of Facilities Development**

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1.0 INTRODUCTION

The Princeton Lock and Dam Project (Project) is located in Green County, Wisconsin on the Upper Fox River at river mile 97.5 from the head of the Fox River at Green Bay. The Project consists of the following features:

- A concrete capped stone-filled timber crib dam (dam) with dry stone masonry abutment retaining walls built in 1898 employing a seasonal flashboard system;
- A decommissioned lock with dry stone masonry walls built in 1878 and upstream gate structure with five electric-motor-driven screw-drive operated slide gates;
- Upstream electric fish barrier; and
- An upstream safety cable system for the placement and removal of the dam flashboards.

The flashboard system consists of a series of 1-inch- and 1.5-inch-diameter 30-in- and 36-in-high steel pins, four feet on centers, inserted into pockets in the dam's concrete cap to support the placement of three rows of 2-in by 6-in wooden flashboards. The 16.5-in-high flashboard system serves to increase the normal summer levels in Lake Puckaway by approximately 6-inches. The flashboards are removed in the autumn to lower the lake levels to reduce the potential for ice damage to lake association member boat docks during the winter.

The manual placement and removal of the flashboards requires that the volunteers from the Lake Puckaway Association work in water flowing over the dam. While water levels are somewhat controlled and reduced by diverting Fox River flows through the lock gate structure, working in water flowing over the dam is not uncommon. The gradual rise in upstream water levels during the placement of the flashboards is controlled by sequencing the installation of the flashboards across the dam horizontally one row at a time.

Under these conditions a "hydraulic" (back roller) can occur downstream of the dam which can entrain the volunteers placing and removing the flashboards. Some reduction of this safety hazard to the volunteers has been achieved by using safety harnesses connected to an upstream safety cable system spanning across the dam, and having responders from the Princeton Fire Department present in boats downstream of the dam in case of emergency. The safety cable system provides adequate protection during flashboard installation, but employs an anchorage to a tree on the southern abutment which must be replaced with an engineered anchorage.

The five 3-HP slide gate motors located at the lock are operated with drum switches located at each individual gate. The gates have screw drives but do not have limit switches. The gates can be easily accessed from either lock abutment via a wooden plank-decked walkway located on

steel supports approximately 3.3-foot to 3.5-foot on centers. The deck supports are welded to the vertical slide gate support columns. The gated structure does not have a gross trashrack to prevent floating and submerged material from becoming lodged in the gate opening when the gates are raised. Access to the lock gate walkway and gate operators raise safety and security concerns.

Trees and brush are growing through the interstices of the dam and lock dry stone masonry walls which, if not removed, will eventually cause a heaving of the masonry blocks.

A functional electric fish barrier upstream of the dam is activated in the summer months to prevent the upstream migration of carp when the water temperatures in the Fox River rise. The fish barrier is deactivated to allow game fish to freely migrate over the dam during periods when the water temperatures are low.

2.0 UNDERSTANDING OF THE ASSIGNMENT

MWH was retained by the Wisconsin Department of Administration, Division of Facilities Development (DFD) to perform a Dam Evaluation Study for Princeton Dam.

The primary objective of the evaluation study is to:

- Improve operator and public safety at the dam by significantly reducing or eliminating the downstream hydraulic.

Secondary objectives of the evaluation study include:

- Stabilization of the upstream water levels and downstream flows;
- Provide continued Lake Puckaway drawdown capability; and
- Controlled fish passage.

The evaluation study also included a site visit to observe that condition of the primary water retaining structures. The observation included the dam, intermediate embankment, and lock gate system located at the entrance to the lock.

The evaluation study scope initially identified the following three (3) conceptual layouts involving modifications to the existing Project to achieve the objectives of the assignment:

- Conceptual Layout 1 – Raised fixed crest to replace the existing wooden flashboard system;
- Conceptual Layout 2 – A pneumatic bladder flashboard system to regulate Lake Puckaway level adjustments; and

- Conceptual Layout 3 – An improved flashboard system for seasonal adjustments to Lake Puckaway levels.

Each of the three conceptual layouts included modifications to improve operator and public safety by significantly reducing the potential for a “hydraulic”, and included provisions for a step/pool type bypass fishway.

Two (2) additional conceptual layouts were identified in the evaluation study scope for DFD budgetary purposes. The conceptual layouts included:

- Conceptual Layout 4 - Reconstruction of the dam; and
- Conceptual Layout 5 – Removal of the dam and restoration of the river channel.

While not identified in the study scope, a sixth conceptual layout was developed to provide a “base case” for comparison with the five layouts identified in the DFD RFP:

- Conceptual Layout 0 – Maintain current wooden flashboard system.

Following discussions with the DFD, there were some concerns expressed regarding the ability of fish to safely pass over the Conceptual Layout 1 – Raised Fixed Crest. Consequently, an additional Conceptual Layout 1a was selected which combined the Conceptual Layout 1 raised fixed crest with a shortened 60-foot-long, 20-foot-wide, two (2) step pool bypass fishway located within the northern end of the existing dam.

Based on the condition assessment of the water retaining structures, improvements to prolong the operational life of these structures have been identified and recommended.

Conceptual-level comparative construction cost estimates were developed to allow the DFD to select the alternative and proceed to feasibility-level design. The feasibility-level design of the selected alternative will be at the Class 5 (ACEI Cost Estimate Classification System) construction cost estimate.

3.0 APPROACH AND ASSUMPTIONS

Operator and Public Safety. The formation of a “hydraulic” downstream of the Princeton Dam poses a significant hazard to both dam operator and public safety. The hydraulic can not only trap a person in the back roller associated with the hydraulic due to the recirculation of plunging flow, but due to the entrainment of air the ability to float and swim is reduced. The formation of a hydraulic downstream of a low head dam can be potentially reduced or eliminated in by raising the downstream channel configuration to prevent flow leaving the crest to plunge into the tailwater and cause a back roller. This can be achieved at Princeton Dam by placing:

- Fabricast moulded grout-filled blocks in a step fashion; or
- Gently sloping rip rap which can be contoured to potentially provide step pools for enhanced fish passage.

Due to fish passage considerations, the rip rap solution was selected for reducing the hazards associated with a hydraulic.

Stabilization of Upstream Water Levels and Downstream Flows. Each of the conceptual layouts, with the exception of the complete dam removal, would provide very nearly the same Project discharge capacity as the dam with the current 16.5-in-high flashboards in their installed position. Two of the conceptual layouts would provide the same operational flexibility as the current flashboard system. With the exception of the complete dam removal concept, each of the remaining concepts would essentially provide the stabilization of upstream water levels and downstream flows as with the existing Project with the flashboards raised. However, the raised fixed crest concept would increase upstream water levels during flood events. The complete removal of the dam would cause, over time, a decrease of water levels in Lake Puckaway as the Fox River gradually stabilizes to its pre-Project profile.

Provide Lake Puckaway Drawdown Capability. Each of the concepts, including the complete dam removal concept, would provide improvements to the lock gate structure to allow the diversion of flows to lower Lake Puckaway levels for environmental improvements similar to those performed at Lake Delton and Buffalo Lake, if necessary.

Controlled Fish Passage. Controlled fish passage includes a layout of a bypass fishway employing step pools. Gaining from experience at other DNR fish ladders, the initial bypass fishway concept featured a series of five (5) 6-in-high steps and 30-ft-long by 20-ft-wide step pools to pass fish completely around the dam's north abutment. Although not shown on the raised fixed crest sketch, the downstream rip rap can be contoured to provide step pools for fish passage. In addition, this initial bypass fishway would provide stop log structures at the upstream and downstream ends to prevent access to the fishway and work with the upstream electric fish barrier to prevent upstream carp migration.

Following discussions with the DFD, a shortened 60-foot-long by 20-foot-wide bypass fishway concept was developed and located within the north end of the dam. This shortened fishway featured two (2) 12-in-high steps. This bypass fishway was selected to work with the 16.5-in fixed raised crest developed as Conceptual Layout 1. The shortened bypass fishway provides stop logs to work with the electric fish barrier to prevent upstream carp migration.

Site Improvements. Site improvements included an assessment of the condition of the water retaining structures. The assessment included the detriments to the structural integrity of the

dam, embankment and lock; operator and public safety; site security; and operational improvements.

Conceptual-level Construction Cost Comparison. Conceptual-level construction cost estimates were developed to provide a direct comparison of the potential costs associated with each of the conceptual layouts. The cost estimates were based on a conceptual-level quantity take-off of the primary components of each concept and unit prices taken from generally accepted references applying our experience on similar projects. A 50% contingency was applied to each estimate, with the exception of applying a 15% contingency to the budgetary quote provided by Obermeyer for the pneumatic bladder flashboard system.

4.0 EVALUATION STUDY RESULTS

4.1 Conceptual Layout -1a: Raised Fixed Crest and Bypass Fishway

Raised Fixed Crest and Bypass Fishway Description. The conceptual layout combines the 16.5-in-thick concrete slab over the crest of the existing dam with a 20-foot-wide bypass fishway located on the northern end of the timber crib dam. The 160-foot-long raised fixed crest slab will be placed in the dry during low flow conditions behind a portadam system which will be arranged to isolate the four 40-foot-wide sections in a checkerboard fashion. The northernmost slab section will include a 3-foot-wide intermediate wall featuring stop log slots to isolate the bypass fishway from the raised fixed crest slab. The slab overlay will be doweled into the existing 6-in-thick slab and wooden plank surface.

During the raising of the crest, and 40-foot-long sheetpile cutoff will be driven along the northern most face of the existing dam to prevent the river from flowing through the bypass fishway construction area. The installation of the downstream 15-foot-long by 20-foot-wide by two-foot-thick base of the bypass fishway will require the removal of a 20-foot-wide section of the existing timber crib dam by approximately seven feet. After the timber crib has been removed, base formwork and reinforcement will be lowered into the removed section and filled underwater with tremmie concrete. This initial section will include formwork for an endsill weir two-foot-lower than the 16.5-in-thick fixed raised crest.

After the placement of the fixed crest slab overlay and the installation of the downstream bypass fishway section, a 15-foot-long by 20-foot-wide sheetpile “box” will be driven to form the perimeter of the upstream section of the bypass fishway. After the sheeting has been driven, it will be burned to the height of the intermediate wall, upstream weir, Northern abutment endwall and “capped” with a channel section. Once the perimeter of the box is completed, the interior material will be excavated and replaced with rip rap. The installation of

the bypass fishway will be completed when the sheetpile cutoff section is burned to the level of downstream base slab and downstream rip rap step pool contouring will be completed.

No disturbance of the upstream sediment is anticipated during installation of the raised fixed crest other than associated with the placement and removal of the temporary portadam system and the removal of the material within the upstream bypass fishway “box” section.

Reduction of Downstream “Hydraulic”. The potential for a downstream “hydraulic” will be reduced by placing rip rap material on a slope of 10H:1V. The rip rap will be placed in the wet to within two feet of the raised slab crest and appropriately sized to resist displacement of the material during flow conditions. The downstream rip rap can be contoured to guide fish toward the step pool entrance to the shortened bypass fishway.

Impact on Lake Puckaway Levels. The placement of the raised fixed crest and shortened bypass fishway will not allow the seasonal drawdown of Lake Puckaway with the fishway flashboards in place, and may cause an increase in lake levels above those experienced with the flashboards removed during high flow events.

Safety Cable System. The raising of the crest will require a safety cable system to install or remove the 16.5-in-high stoplogs in the bypass fishway.

Fish Passage. The downstream sloping and contoured rip rap will direct fish to the opening of the 20-foot-wide bypass fishway located at the northern end of the dam’s fixed raised crest. A 60-foot-long by 20-foot-wide two step pool fish passage system similar to the system employed at Montello Dam will be featured with this conceptual layout. However, the final bypass fishway width will be set to be equal to the width of a section, or sections, of rock-filled timber cribbing.

Electric Fish Barrier. The upstream electric fish barrier may be required to work with the downstream endsill weir stop logs to hinder migration of carp over the dam during the summer months when water temperatures rise.

Site Improvements. The lock slide gate structure would be required after the raising of the fixed crest of the dam to allow the drawdown of Lake Puckaway for environmental improvements. Other site improvements to enhance operator and public safety, structural integrity of dam and lock walls, and lock gate operations will be required.

Conceptual Layout – 1a: Sketch and Costs. A sketch of Conceptual Layout – 1a is provided on Sheet 01 in Appendix A. The total conceptual-level cost estimate for the raised fixed crest and bypass fishway concept, including all of the related project improvements, is \$1,016,117. A breakdown of the conceptual-level costs for this concept is provided on Table 1.

4.2 Conceptual Layout -1: Raised Fixed Crest

Raised Fixed Crest Description. A 16.5-in-thick concrete slab will be installed over the crest of the existing dam. The slab will be placed in the dry during low flow conditions behind a portadam system which will be arranged to isolate the 30-foot-wide sections in a checkerboard fashion. The slab overly will be doweled into the existing 6-in-thick slab and wooden plank surface. No disturbance of the upstream sediment is anticipated during installation of the raised fixed crest other than associated with the placement and removal of the temporary portadam system.

Reduction of Downstream “Hydraulic”. The potential for a downstream “hydraulic” will be reduced by placing rip rap material on a slope of 10H:1V. The rip rap will be placed in the wet to within one foot of the raised slab crest and appropriately sized to resist displacement of the material during flow conditions. The rip rap can be contoured to provide step pools for fish passage.

Impact on Lake Puckaway Levels. The placement of the raised crest will not allow the seasonal drawdown of Lake Puckaway, and will cause an increase in lake levels above those experienced with the flashboards removed during high flow events.

Safety Cable System. The raising of the crest will eliminate the need to install or remove flashboards, and the safety cable system will no longer be required.

Fish Passage. The downstream sloping and contoured rip rap will provide access to the crest of the dam for fish passage. Fish passage upstream of the crest will be over the raised concrete slab. A fish passage system similar to the system employed at Montello Dam should potentially not be required with this conceptual layout.

Electric Fish Barrier. The upstream electric fish barrier may be required to hinder migration of carp over the dam during the summer months when water temperatures rise.

Site Improvements. The lock slide gate structure would be required after the raising of the fixed crest of the dam to allow the drawdown of Lake Puckaway for environmental improvements. Other site improvements to enhance operator and public safety, structural integrity of dam and lock walls, and lock gate operations will be required.

Conceptual Layout – 1: Sketch and Costs. A sketch of Conceptual Layout – 1 is provided on Sheet 02 in Appendix A. The total conceptual-level cost estimate for the raised fixed crest concept, including all of the related project improvements, is \$979,217. A breakdown of the conceptual-level costs for this concept is provided on Table 1.

4.3 Conceptual Layout – 2: Pneumatic Bladder Flashboard System

Pneumatic Bladder Flashboard System Description. A 16.5-in-high Obermeyer pneumatic bladder flashboard system will be installed over the existing spillway crest slab. The system will be placed in the dry during low flow conditions behind a portadam system which will be arranged to isolate the installation in sections to allow passage of flows through the lock slide gates and adjacent crest section. The pneumatic flashboard system will be anchored into the existing 6-in-thick slab surface. No disturbance of the upstream sediment is anticipated during installation of the raised crest other than associated with the placement and removal of the temporary portadam system.

Reduction of Downstream “Hydraulic”. The potential for a downstream “hydraulic” will be reduced by placing rip rap material on a slope of 10H:1V. The rip rap will be placed in the wet to within two feet of the existing crest and appropriately sized to resist displacement of the material during flow conditions.

Impact on Lake Puckaway Levels. The placement of the pneumatic bladder flashboard system will allow the continuous control of Lake Puckaway levels, but will cause a negligible increase in lake levels above those experienced with the existing flashboards removed during high flow events.

Safety Cable System. The installation of the bladder flashboard system will require periodic inspection and maintenance, and a safety cable system will be required.

Fish Passage System. The pneumatic bladder flashboard system when raised will have a maximum drop of more than 3.4 feet from the top of the flashboard to the top of the downstream rip rap surface. This drop is considered to be too great for upstream fish migration. Consequently a fish passage system similar to the system employed at Montello Dam will be required with this conceptual layout.

Electric Fish Barrier. The upstream electric fish barrier may be required to hinder migration of carp over the dam during the summer months when water temperatures rise.

Site Improvements. The lock slide gate structure would be required after the raising of the crest of the dam to allow the drawdown of Lake Puckaway for environmental improvements. Other site improvements to enhance operator and public safety, structural integrity of dam and lock walls, and lock gate operations will be required.

Conceptual Layout – 2: Sketch and Costs. A sketch of Conceptual Layout – 2 is provided on Sheet 03 in Appendix A. The total conceptual-level cost estimate for the pneumatic bladder

flashboard concept, including all of the related project improvements, is \$1,930,230. A breakdown of the conceptual-level costs for this concept is provided on Table 1.

4.4 Conceptual Layout - 3: New Hinged Flashboard System

New Hinged Flashboard System Description. A 16.5-in-high hinged flashboard system will be installed over the existing spillway crest slab. The hinged flashboard will allow better control of the rise in headwater levels during installation by sequencing the raising of the flashboards in two steps. The first step involves raising the lower flashboard section and bracing it with the knee brace with the top segment of the flashboard lowered. Once the first step is completed across the entire dam the top section of the flashboard can be rotated in place.

The new flashboard system will be placed in the dry during low flow conditions behind a portadam system which will be arranged to isolate the installation in sections to allow passage of flows through the lock slide gates and adjacent crest section. The flashboard system will be anchored into the existing 6-in-thick slab surface. No disturbance of the upstream sediment is anticipated during installation of the raised crest other than associated with the placement and removal of the temporary portadam system.

Reduction of Downstream “Hydraulic”. The potential for a downstream “hydraulic” will be reduced by placing rip rap material on a slope of 10H:1V. The rip rap will be placed in the wet to within two feet of the existing crest and appropriately sized to resist displacement of the material during flow conditions.

Impact on Lake Puckaway Levels. The placement of the new hinged flashboard system will allow the seasonal drawdown of Lake Puckaway, but will cause a negligible increase in lake levels above those experienced with the flashboards removed during high flow events.

Safety Cable System. The initial installation and annual raising and lowering of the hinged flashboard system, as well as inspection and maintenance, will require periodic access, and a safety cable system will be required.

Fish Passage System. The hinged flashboard system when raised will have a maximum drop of more than 3.4 feet from the top of the flashboard to the top of the downstream rip rap surface. This drop is considered to be too great for upstream fish migration. Consequently a fish passage system similar to the system employed at Montello Dam will be required with this conceptual layout.

Electric Fish Barrier. The upstream electric fish barrier may be required to hinder migration of carp through the fish passage system during the summer months when water temperatures rise.

Site Improvements. The lock slide gate structure would be required after the raising of the crest of the dam to allow the drawdown of Lake Puckaway for environmental improvements. Other site improvements to enhance operator and public safety, structural integrity of dam and lock walls, and lock gate operations will be required.

Conceptual Layout – 3: Sketch and Costs. A sketch of Conceptual Layout – 3 is provided on Sheet 04 in Appendix A. The total conceptual-level cost estimate for the new hinged flashboard concept, including all of the related project improvements, is \$1,694,632. A breakdown of the conceptual-level costs for this concept is provided on Table 1.

4.5 Conceptual Layout – 4: New Dam

New Dam Description. A new concrete dam will be constructed to replace the existing timber crib dam. The new dam will be constructed following the complete removal of the existing dam material behind a combination of both sheetpile and fill cofferdams. The construction will be sequenced to allow flows to pass around the construction area through the opened lock slide gates and adjacent section of the removed dam. The new dam will have a crest set at a level 16.5 inches higher than the existing timber crest.

Reduction of Downstream “Hydraulic”. The potential for a downstream “hydraulic” will be reduced by placing rip rap material on a slope of 10H:1V. The rip rap will be placed in the dry to within two feet of the existing crest and appropriately sized to resist displacement of the material during flow conditions.

Safety Cable System. The new dam will eliminate the need to install or remove flashboards, and the safety cable system will no longer be required.

Fish Passage System. The new concrete dam will have a maximum drop of more than 3.4 feet from the top of the crest to the top of the downstream rip rap surface. This drop is considered to be too great for upstream fish migration. Consequently a fish passage system similar to the system employed at Montello Dam will be required with this conceptual layout.

Electric Fish Barrier. The upstream electric fish barrier may be required to hinder migration of carp through the fish passage system during the summer months when water temperatures rise.

Site Improvements. The lock slide gate structure would be required after the raising of the crest of the dam to allow the drawdown of Lake Puckaway for environmental improvements. Other site improvements to enhance operator and public safety, structural integrity of dam and lock walls, and lock gate operations will be required.

Conceptual Layout – 4: Sketch and Costs. A sketch of Conceptual Layout – 4 is provided on Sheet 05 in Appendix A. The total conceptual-level cost estimate for the new dam concept, including all of the related project improvements, is \$4,202,124. A breakdown of the conceptual-level costs for this concept is provided on Table 1.

4.6 Conceptual Layout – 5: Dam Removal

Dam Removal Description. The existing dam and abutments would be completely removed such that only the top of the timber cutoff wall would remain. The dam would be breached and removed in the wet with a floating “swamp excavator”. Upstream sediment would be removed to a 2H:1V slope and be allowed to reestablish its natural river slope over time (and burying the top of the left-in-place timber cutoff wall).

Reduction of Downstream “Hydraulic”. The potential for a downstream “hydraulic” would be eliminated with the removal of the dam.

Safety Cable System. The safety cable system would no longer be required with the removal of the dam.

Fish Passage System. A fish passage system would no longer be required with the removal of the dam.

Electric Fish Barrier. The upstream electric fish barrier may be required to hinder migration of carp through the fish passage system during the summer months when water temperatures rise.

Site Improvements. The lock slide gate structure would be required after the removal of the dam to assist in the drawdown of Lake Puckaway for environmental improvements. Other site improvements to enhance operator and public safety, structural integrity of lock walls, and lock gate operations will be required.

Conceptual Layout – 5: Sketch and Costs. A sketch of Conceptual Layout – 5 is provided on Sheet 06 in Appendix A. The total conceptual-level cost estimate for the dam removal concept, including all of the related project improvements, is \$341,172. A breakdown of the conceptual-level costs for this concept is provided on Table 1.

4.7 Conceptual Layout – 0: Maintain Existing Flashboard System (Base Case)

Maintain Existing Flashboard System Description. The existing 16.5-in-high flashboard system will be installed and removed in the same manner as now. Fox River flows will be diverted through the lock gates to reduce water levels at the dam during flashboard installation and removal.

Reduction of Downstream “Hydraulic”. The potential for a downstream “hydraulic” will be reduced by placing rip rap material on a slope of 10H:1V. The rip rap will be placed in the wet to within two feet of the existing crest and appropriately sized to resist displacement of the material during flow conditions.

Impact on Lake Puckaway Levels. The use of the existing flashboards will have no additional impact on the Lake Puckaway levels other than those currently being experienced.

Safety Cable System. The initial installation and removal of the existing flashboard system, will require periodic access, and a safety cable system will be required.

Fish Passage System. The existing flashboard system, when installed, will have a maximum drop of more than 3.4 feet from the top of the flashboard to the top of the downstream rip rap surface. This drop is considered to be too great for upstream fish migration. Consequently a fish passage system similar to the system employed at Montello Dam will be required with this conceptual layout.

Electric Fish Barrier. The downstream electric fish barrier may be required to hinder migration of carp through the fish passage system during the summer months when water temperatures rise.

Site Improvements. The lock slide gate structure would be required to assist in the drawdown of Lake Puckaway for environmental improvements. Other site improvements to enhance operator and public safety, structural integrity of lock walls, and lock gate operations will be required.

Conceptual Layout – 0: Costs. A sketch of Conceptual Layout – 0 is not provided as it represents only the placement of the downstream rip rap and the construction of the bypass fishway. The total conceptual-level cost estimate for the dam removal concept, including all of the related project improvements, is \$1,110,907. A breakdown of the conceptual-level costs for this concept is provided on Table 1.

4.8 BYPASS FISHWAY

Bypass Fishway Description. The bypass fishway layout is similar to the fishway employed at Montello Dam, with the exception that the step pools are raised in 6-in increments. The upstream and downstream openings to the fishway are located sufficiently away from the dam to improve attraction away from the dam and toward the fishway. The bypass fishway is curved in plan so that it will not interfere with the construction of Conceptual Layouts 2, 3 4 and 0. Each of the five step pools is 20-feet-wide and approximately 30-feet-long. The step pools are lined with WISDOT light rip rap.

The bypass fishway features stoplog structures at both ends to close the fishway and prevent the upstream migration of carp in the summer. The stoplog structures will also allow a means of closing the fishway for dewatering and maintenance.

Bypass Fishway Layout: Sketch and Costs. A sketch of the bypass fishway 5 is provided on Sheet 07 in Appendix A. The total conceptual-level cost estimate for the bypass fishway, is \$591,159. A breakdown of the conceptual-level costs for this concept is provided on Table 1.

4.9 SITE IMPROVEMENTS

Site Improvements Description. The site improvements include the following:

- Removal of brush and trees near and in the dam and lock walls.
- Removal of the brush within the gate control panel area and north lock abutment, and lining the areas with geotextile material and stone to prevent future growth.
- Construction of concrete stairs at both entrances to the lock gate walkway.
- Replacement of the timber walkway decking with steel decking.
- Relocate the motor control panel to the walkway sufficiently high to prevent future water damage during high flow events.
- Install permanent gate extensions.
- Install security fencing around the perimeter of the lock abutments and walkway.
- Install an engineered anchorage on the south abutment of the dam to replace the cable anchorage to the tree.

Site Improvement Photos and Costs. Photographs illustrating the site conditions requiring improvements are provided in Appendix B. The total conceptual-level cost estimate for the all of the site improvements is \$63,992, but varies slightly with each conceptual layout. The variation of the conceptual-level costs for each concept is provided on Table 1.

5.0 SUMMARY

The raised fixed crest and bypass fishway (***Conceptual Layout 1a***) has the third lowest cost estimate (\$1,016,117). This concept also achieves the primary objective of operator and public safety and fish passage. The bypass fishway is shortened and located within the northern end of the dam to reduce its cost and features stop log slots to close its entrance during periods when carp migration is anticipated. This feature may eliminate the need to maintain the upstream electric fish barrier. While a safety cable system would be required for stop log installation and removal, the system would be limited to the width of the fishway. The fixed crest would be permanently raised, resulting in the inability to lower upstream water levels during large flood events.

The raised fixed crest concept (**Conceptual Layout 1**) has the second lowest cost estimate (\$979,217). The concept would also achieve the primary objective of operator and public safety by eliminating the need to access the crest for flashboard installation and removal, and providing the downstream rip rap for public safety. The concept demonstrates the potential of contouring the downstream rip rap to allow fish to pass over the dam. However, the crest would be permanently raised, resulting in the inability to lower upstream water levels during large flood events, and there are concerns regarding the ability of fish to safely pass over the raised fixed crest concrete slab.

The pneumatic bladder flashboard system (**Conceptual Layout 2**) provides the greatest flexibility in controlling water levels without entering the river. However, the system is expensive (\$1,930,230) and would require the safety cable system for regular maintenance, downstream rip rap, and bypass fishway.

The new hinged flashboard system (**Conceptual Layout 3**) is an improvement over the existing flashboard system, but is also expensive (\$1,694,632). The system can be raised and lowered in a controlled manner in any depth of flow over the dam, and can be done so in steps. It is a cumbersome system to raise and lower, requiring an effort similar to that with the existing flashboard system, and cannot be adjusted remotely to control water levels. In addition, the system is also expensive, and requires the safety cable system, downstream rip rap and bypass fishway.

The new dam (**Conceptual Layout 4**) is the most expensive concept (\$4,202,124), and while eliminating the safety cable system, it requires the downstream rip rap, bypass fishway, and may require operation of the electric fish barrier.

The removal of the dam (**Conceptual Layout 5**) would have the lowest cost estimate (\$341,172). The removal of the dam would eliminate the need for operation and maintenance to the dam structure, and achieve the primary study objective of eliminating concerns for operator and public safety. Fish passage concerns would be limited to prevention of carp migration and may require maintenance of the electric fish barrier. Removal of the dam would lower upstream levels during flood events and restore the river to a more natural condition. However, the removal of the dam would cause the gradual lowering of Lake Puckaway, essentially removing it as a recreational impoundment, as the Fox River stabilizes to its pre-Project profile.

The “base case” existing flashboard system (**Conceptual Layout 0**) has the second lowest cost estimate next to the complete removal of the dam. The system provides the proven means of seasonally adjusting the Fox River and Lake Puckaway water levels. However, the system

requires the safety cable system, downstream rip rap, the bypass fishway, and may require maintenance of the electric fish barrier.

The conceptual layout of the bypass fishway located between the dam and lock is similar to the fishway employed at Montello Dam, which provides a consistent basin-wide Fox River fish passage plan. The bypass fishway features two variations: 6-in-high pool steps and upstream and downstream stoplog system to prevent carp migration. The bypass fishway has a total length of 190 feet and is curved to miss the northern abutment of Conceptual Layouts 2, 3, 4 and 0. The length and cost (\$591,159) could be reduced by realigning the layout once the final concept is selected. The cost could also be reduced by increasing the step pool height to reduce the number of pools and overall length.

**PRINCETON DAM EVALUATION STUDY
UPPER FOX RIVER, GREEN LAKE COUNTY
STATE OF WISCONSIN DIVISION OF FACILITIES DEVELOPMENT**

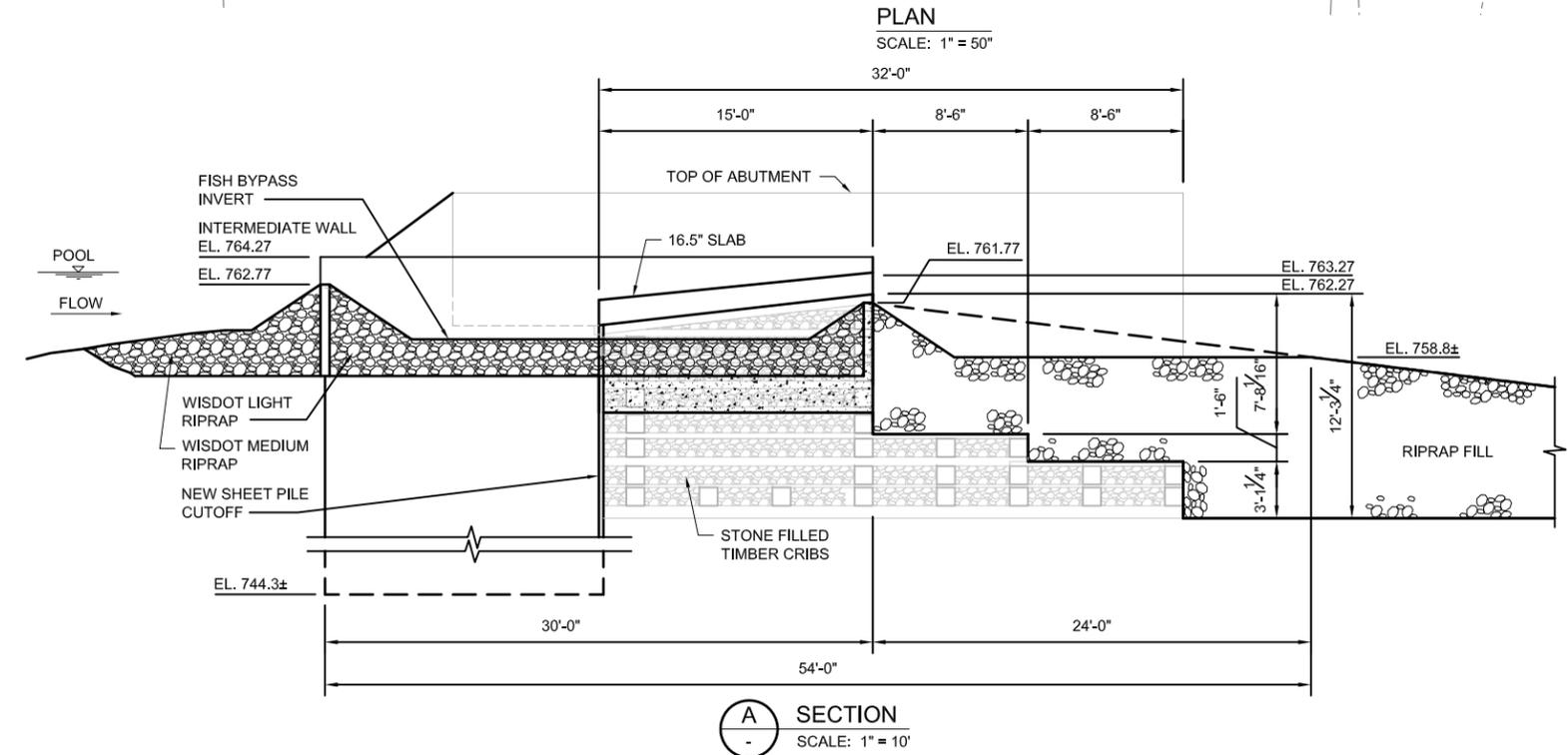
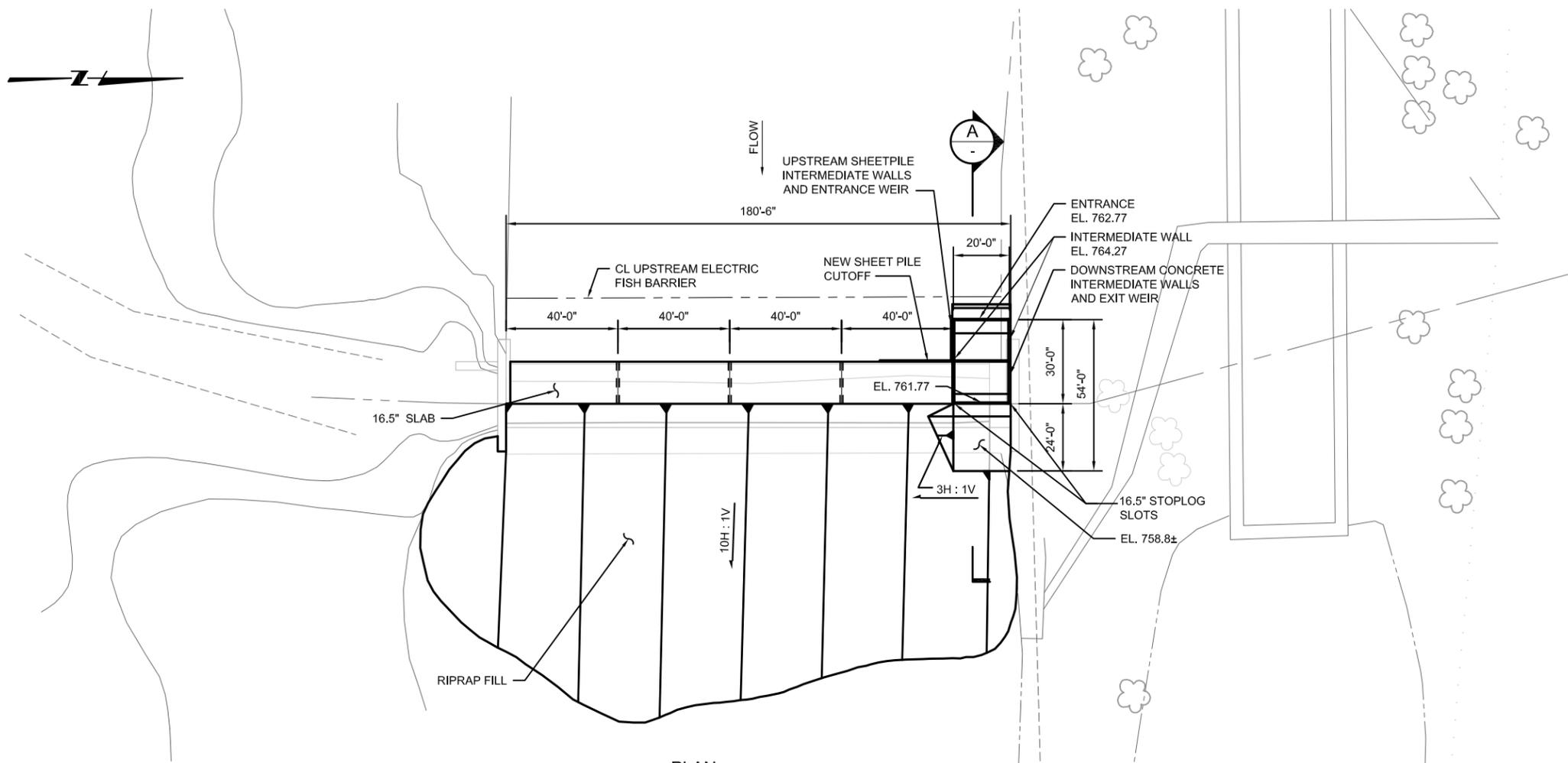
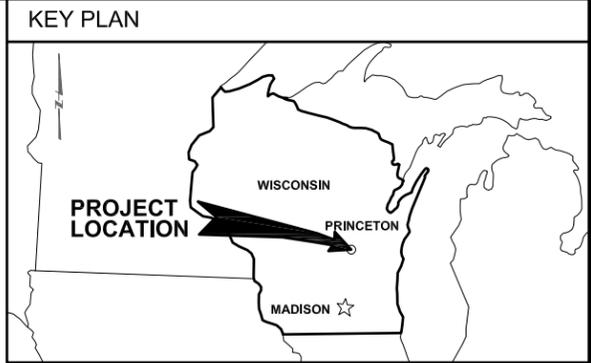
TABLE 1 - COMPARISON OF CONCEPTUAL LAYOUT COST ESTIMATES

<i>Conceptual Layout</i>	<i>Description</i>	<i>Basic Construction</i>	<i>Downstream Rip Rap</i>	<i>Safety Cable System</i>	<i>Bypass Fishway</i>	<i>Electric Fish Barrier</i>	<i>Site Improvements</i>	<i>Total</i>
0	Maintain Current Flashboard System	\$ -	\$ 446,006	\$ 2,250	\$ 591,159	\$ 7,500	\$ 63,992	\$ 1,110,907
1a	Raised Fixed Crest and Bypass Fishway	\$ 167,900	\$ 624,938	\$ 2,250	\$ 149,538	\$ 7,500	\$ 63,992	\$ 1,016,117
1	Raised Fixed Crest	\$ 174,900	\$ 735,075	\$ -	\$ -	\$ 7,500	\$ 61,742	\$ 979,217
2	Pneumatic Bladder Flashboard System	\$ 640,391	\$ 624,938	\$ 2,250	\$ 591,159	\$ 7,500	\$ 63,992	\$ 1,930,230
3	New Hinged Flashboard System	\$ 404,793	\$ 624,938	\$ 2,250	\$ 591,159	\$ 7,500	\$ 63,992	\$ 1,694,632
4	New Dam	\$ 2,918,185	\$ 624,938	\$ -	\$ 591,159	\$ 7,500	\$ 60,342	\$ 4,202,124
5	Dam Removal	\$ 273,330	\$ -	\$ -	\$ -	\$ 7,500	\$ 60,342	\$ 341,172



Appendix A

Conceptual Layout Sketches



FILE: R:\0505375 - Princeton Dam\Civil\Sheet-Ldap
 PRINT DATE: Dec 06, 2014 - 1:53 PM
 USER: mgsy

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SCALE

WARNING

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IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

DESIGNED _____

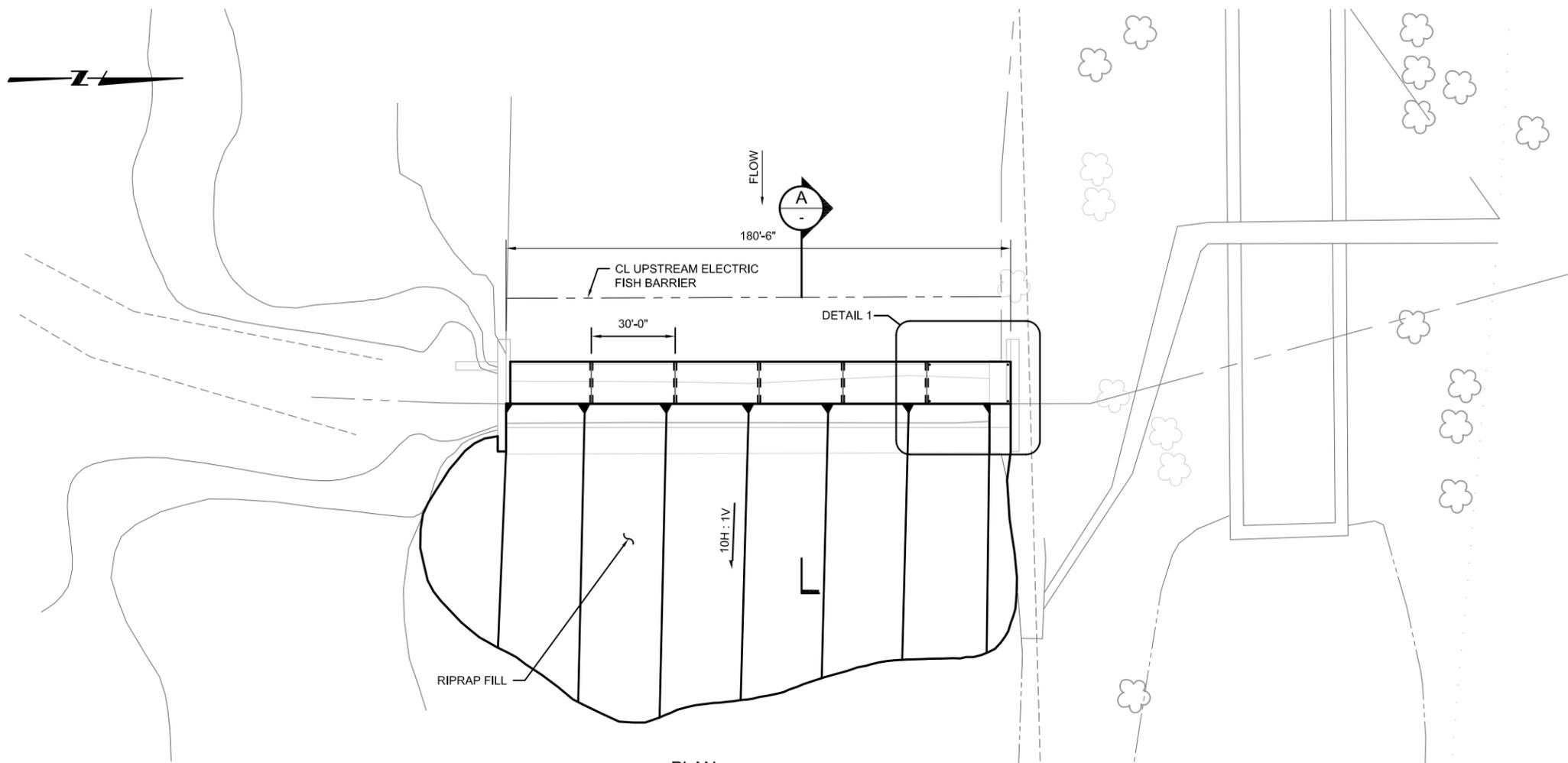
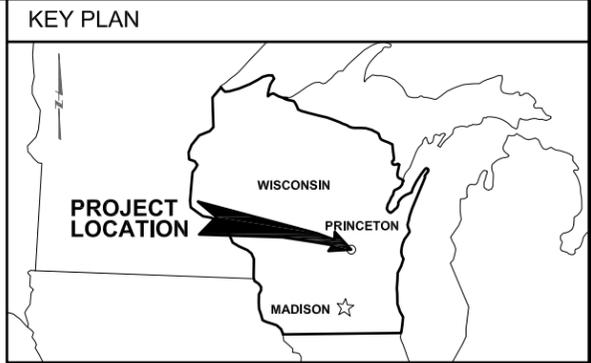
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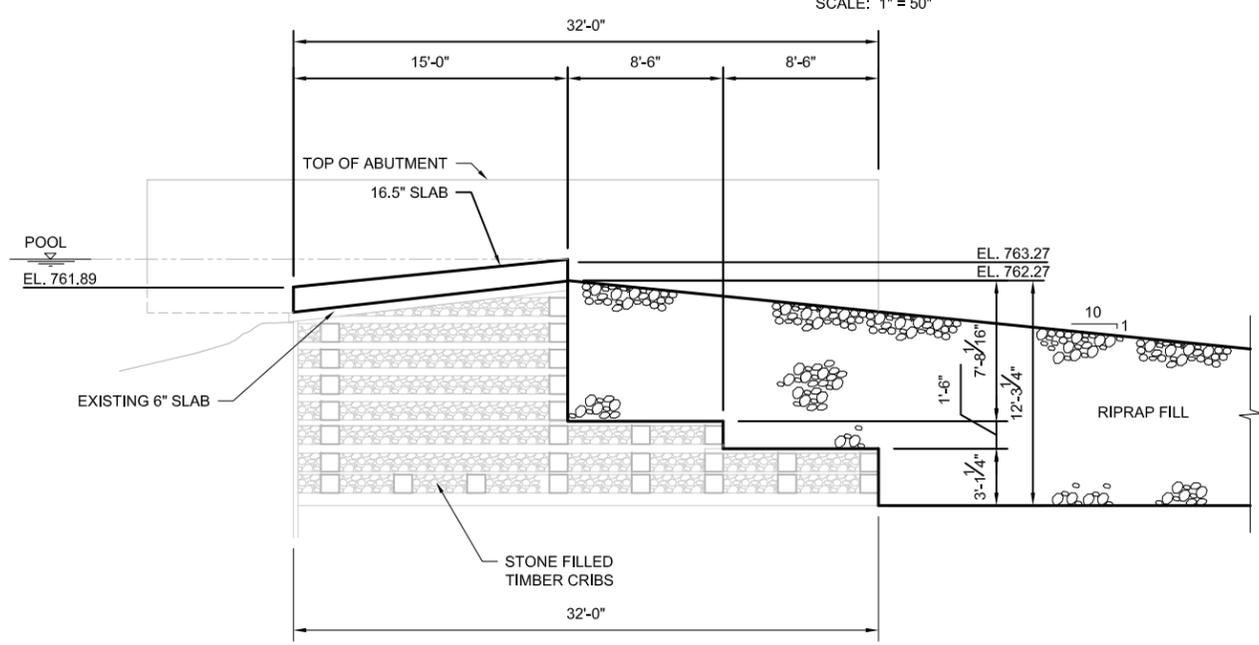


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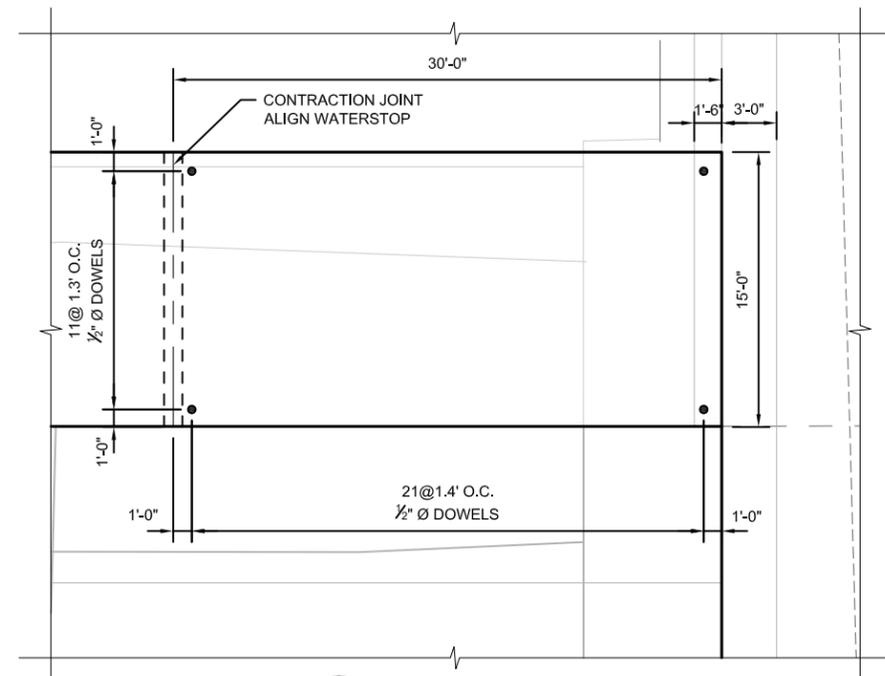
CONCEPTUAL LAYOUT 1a
 RAISED FIXED CREST
 AND BYPASS FISHWAY



PLAN
SCALE: 1" = 50"



A SECTION
SCALE: 1" = 10'



1 DETAIL
SCALE: 1" = 10'

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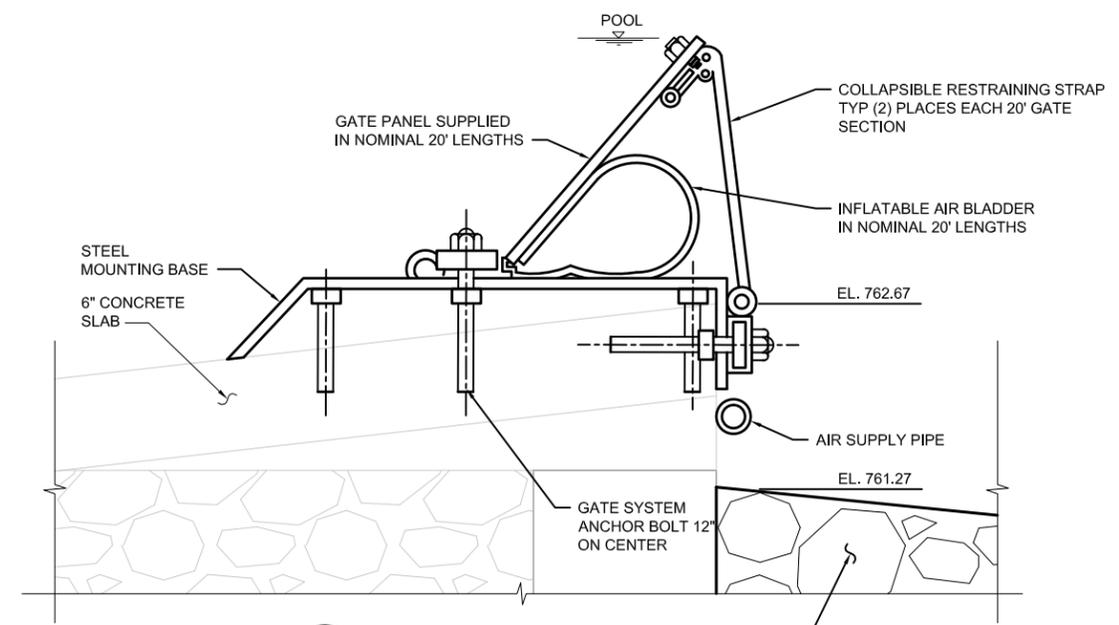
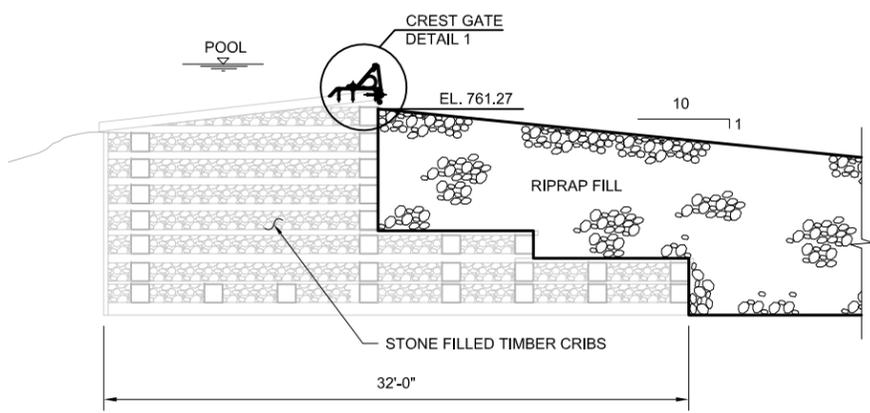
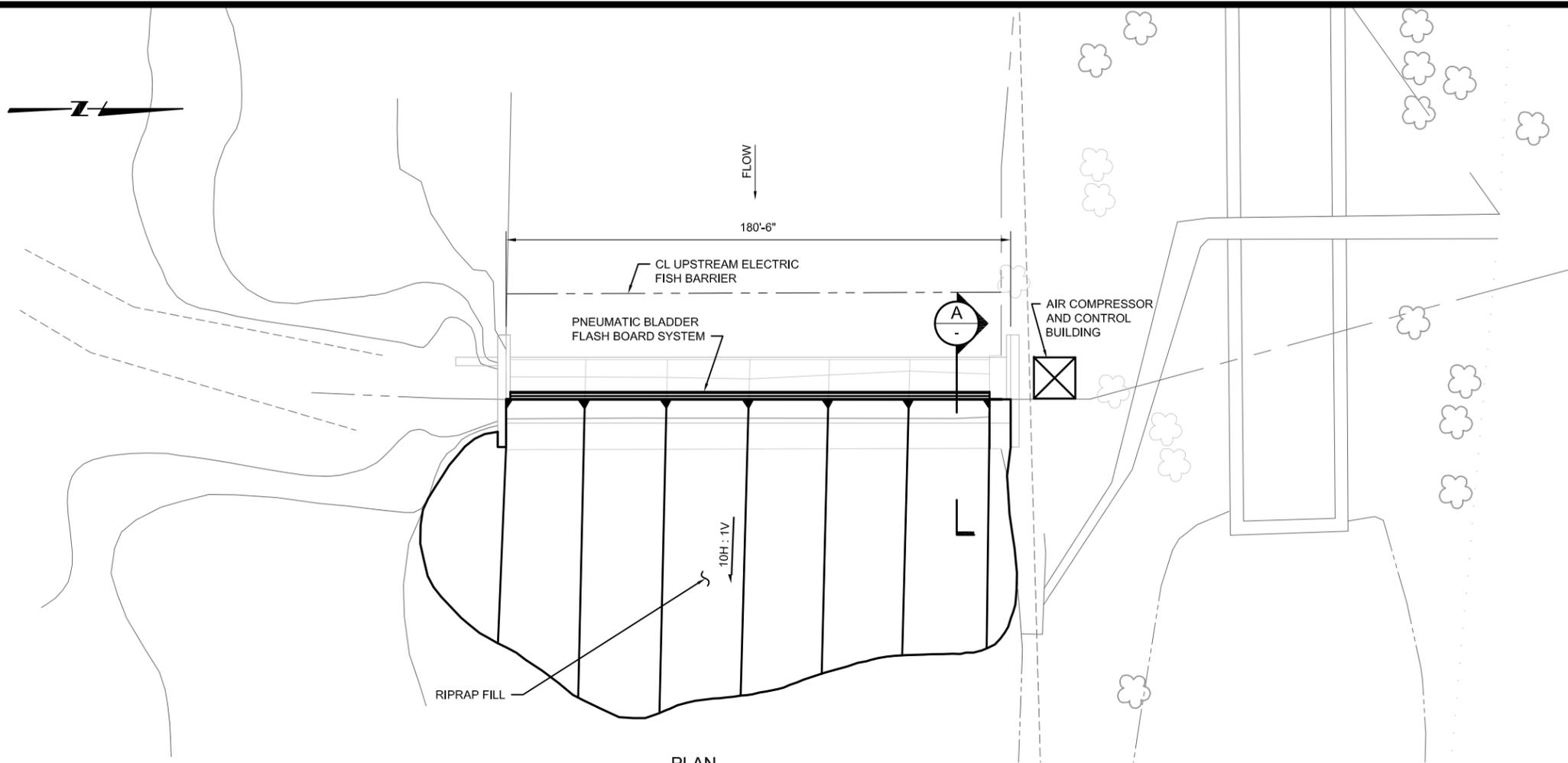
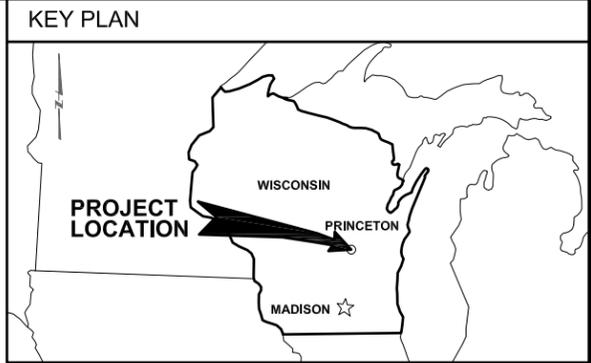
REV	DATE	BY	DESCRIPTION

SCALE	WARNING IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE	DESIGNED _____ DRAWN _____ CHECKED _____
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STATE OF WISCONSIN
DEPARTMENT OF ADMINISTRATION
DIVISION OF FACILITIES DEVELOPMENT

CONCEPTUAL LAYOUT 1
RAISED FIXED CREST



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REV	DATE	BY	DESCRIPTION

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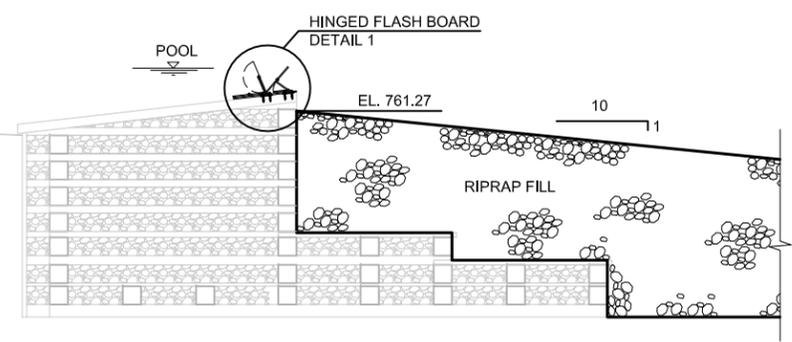
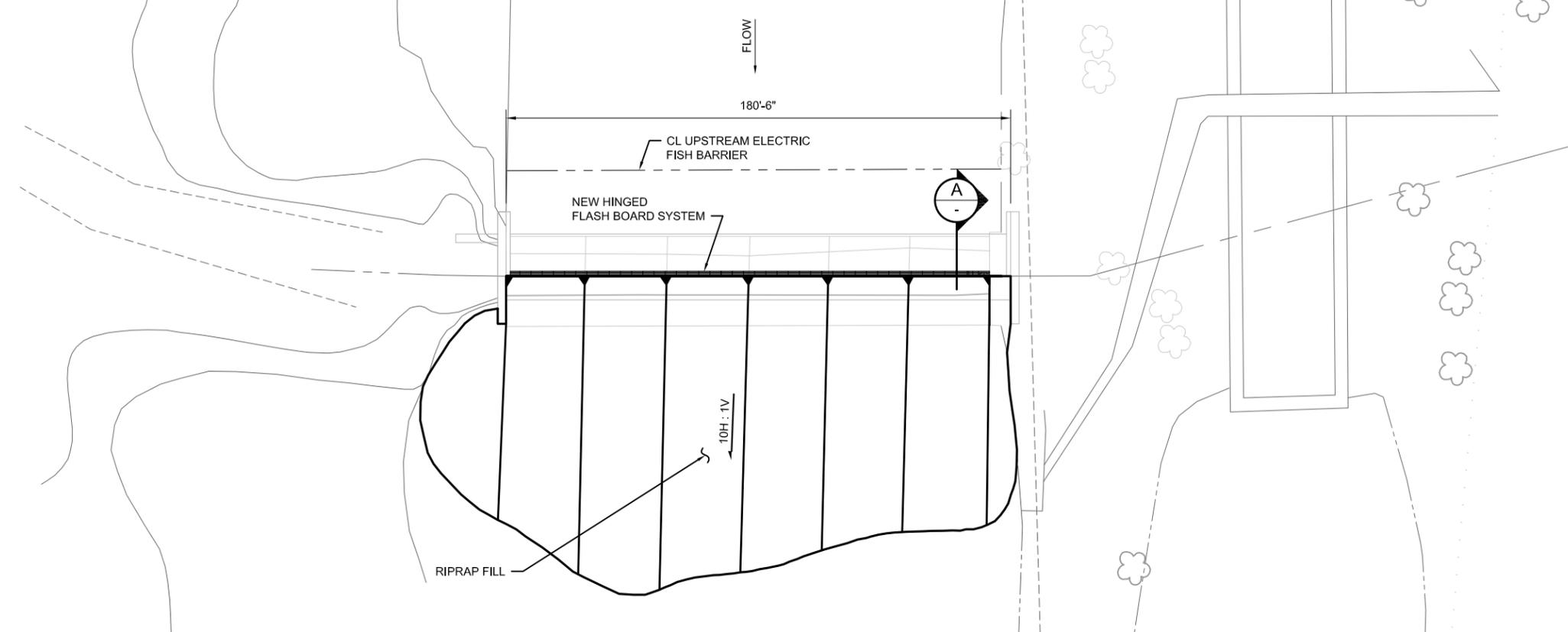
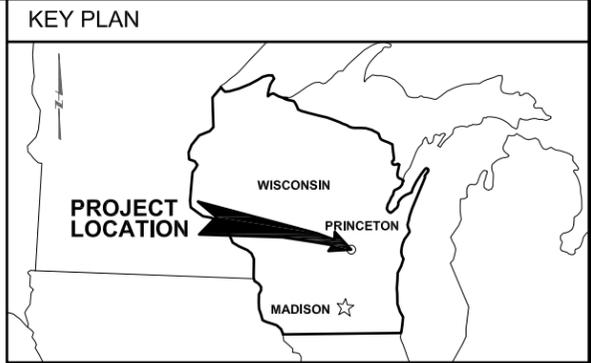
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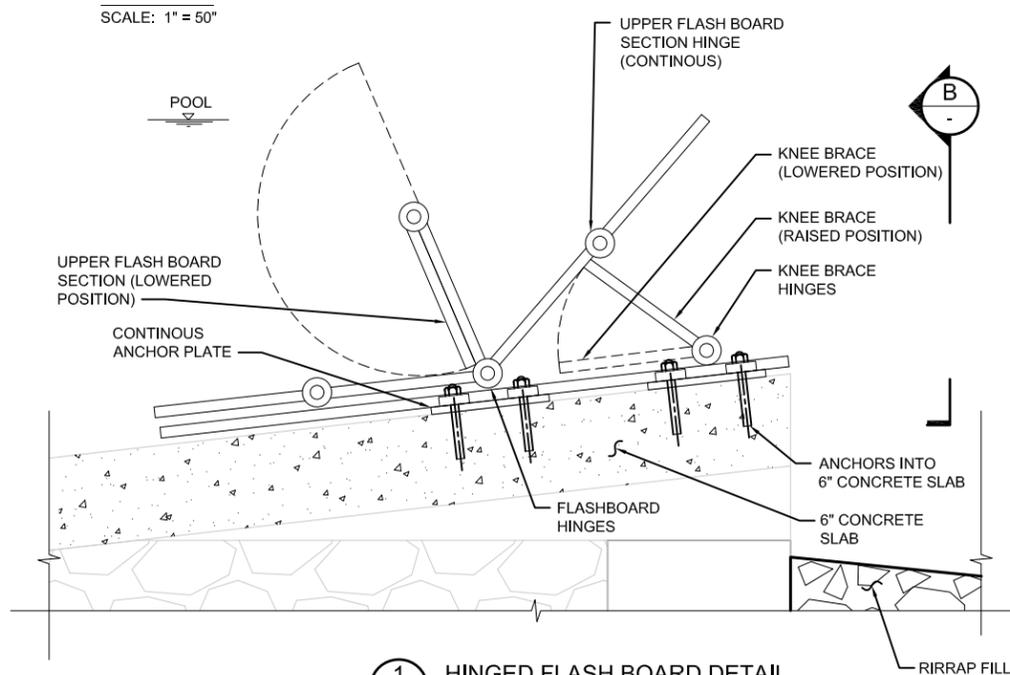


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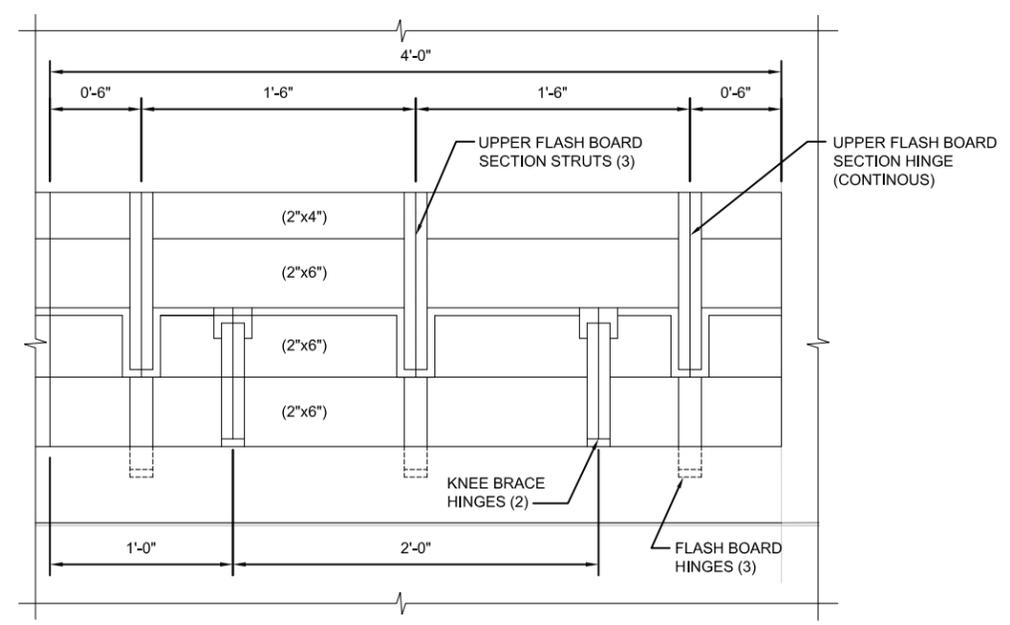
CONCEPTUAL LAYOUT 2
 PNEUMATIC BLADDER
 FLASH BOARD SYSTEM



A SECTION
SCALE: 1" = 10'



1 HINGED FLASH BOARD DETAIL
SCALE: 1" = 1'



B SECTION
SCALE: 1" = 1'

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 PRINT DATE: Dec 06, 2014 - 1:51 PM
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SCALE

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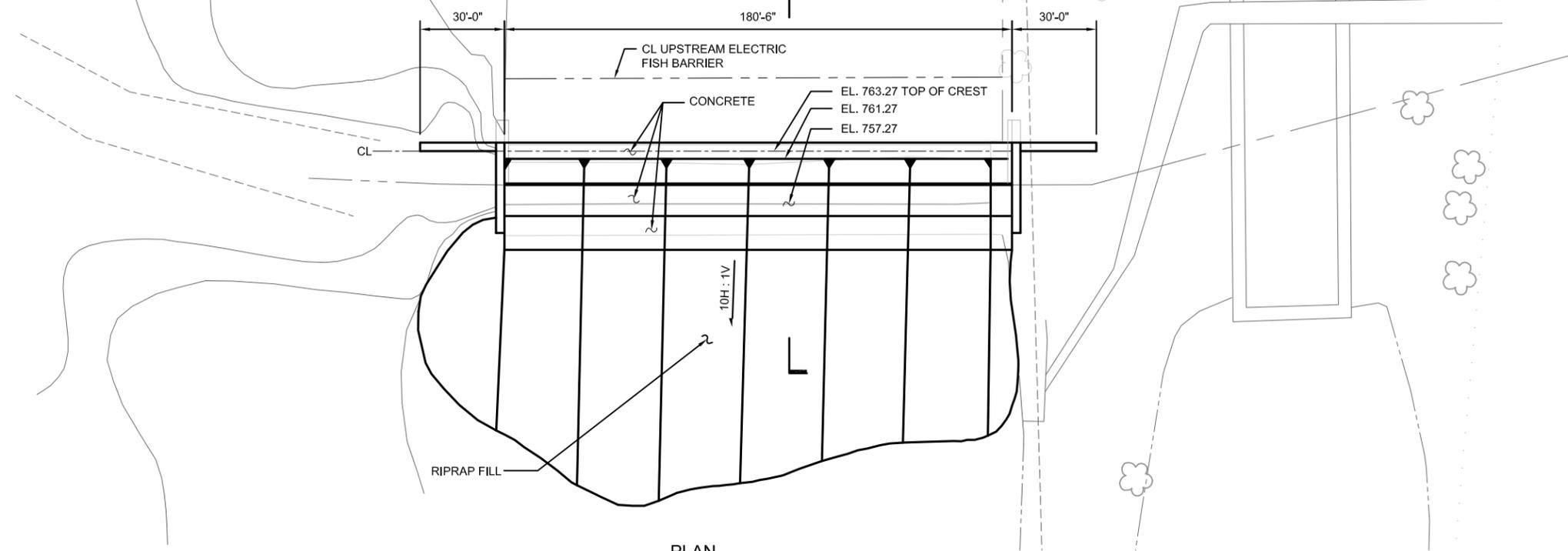
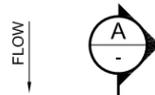
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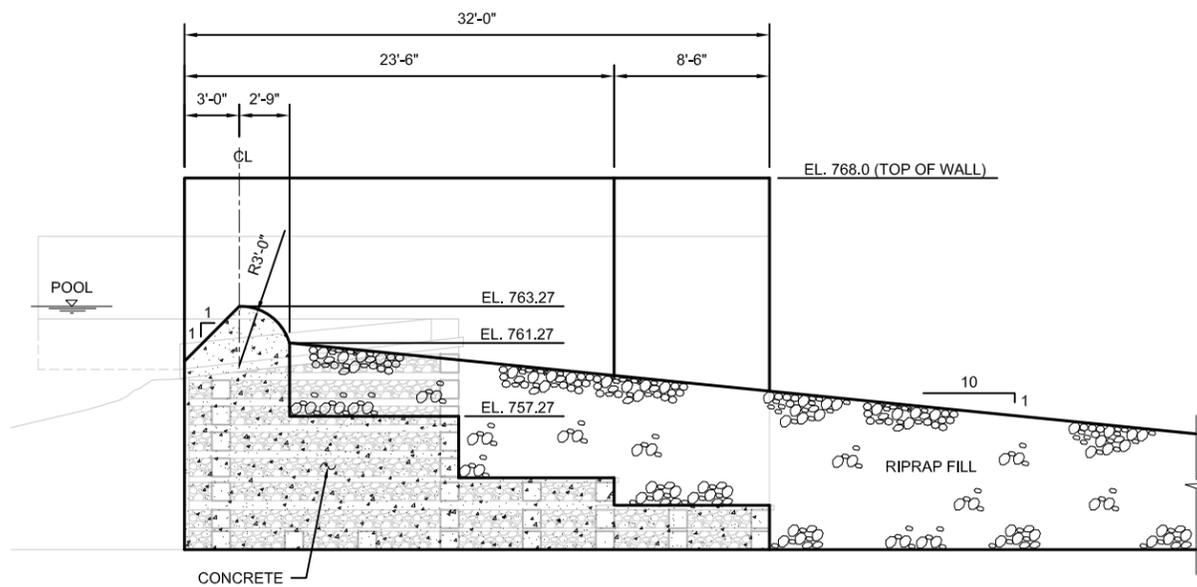


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CONCEPTUAL LAYOUT 3
NEW HINGED
FLASH BOARD SYSTEM

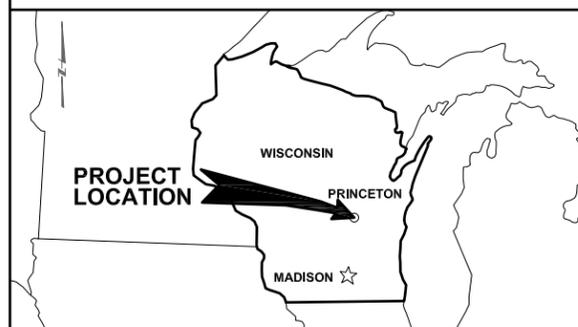


PLAN
SCALE: 1" = 50"



A SECTION
SCALE: 1" = 10"

KEY PLAN



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 USER: mgsyfl

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SCALE



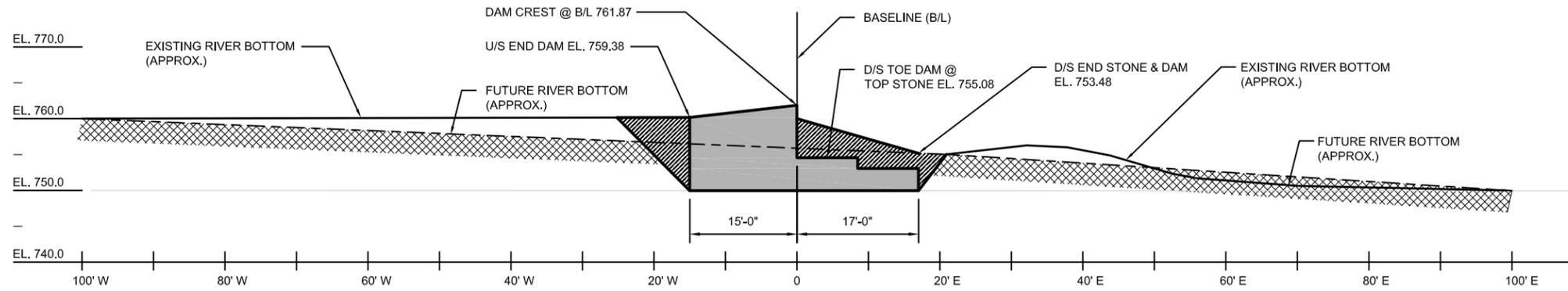
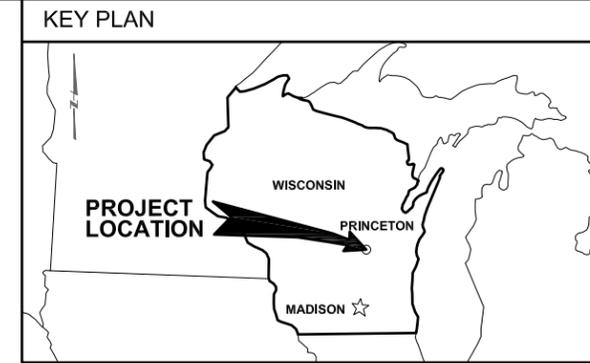
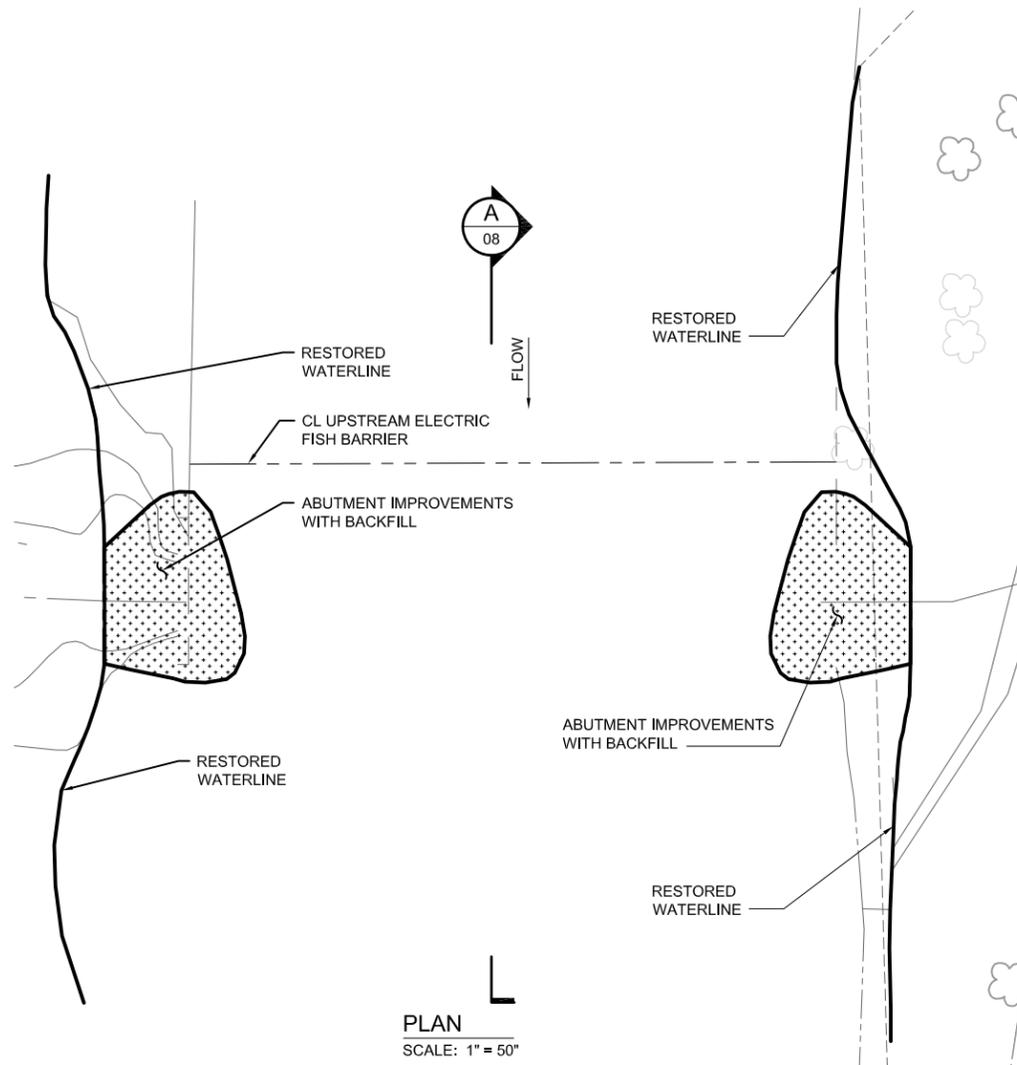
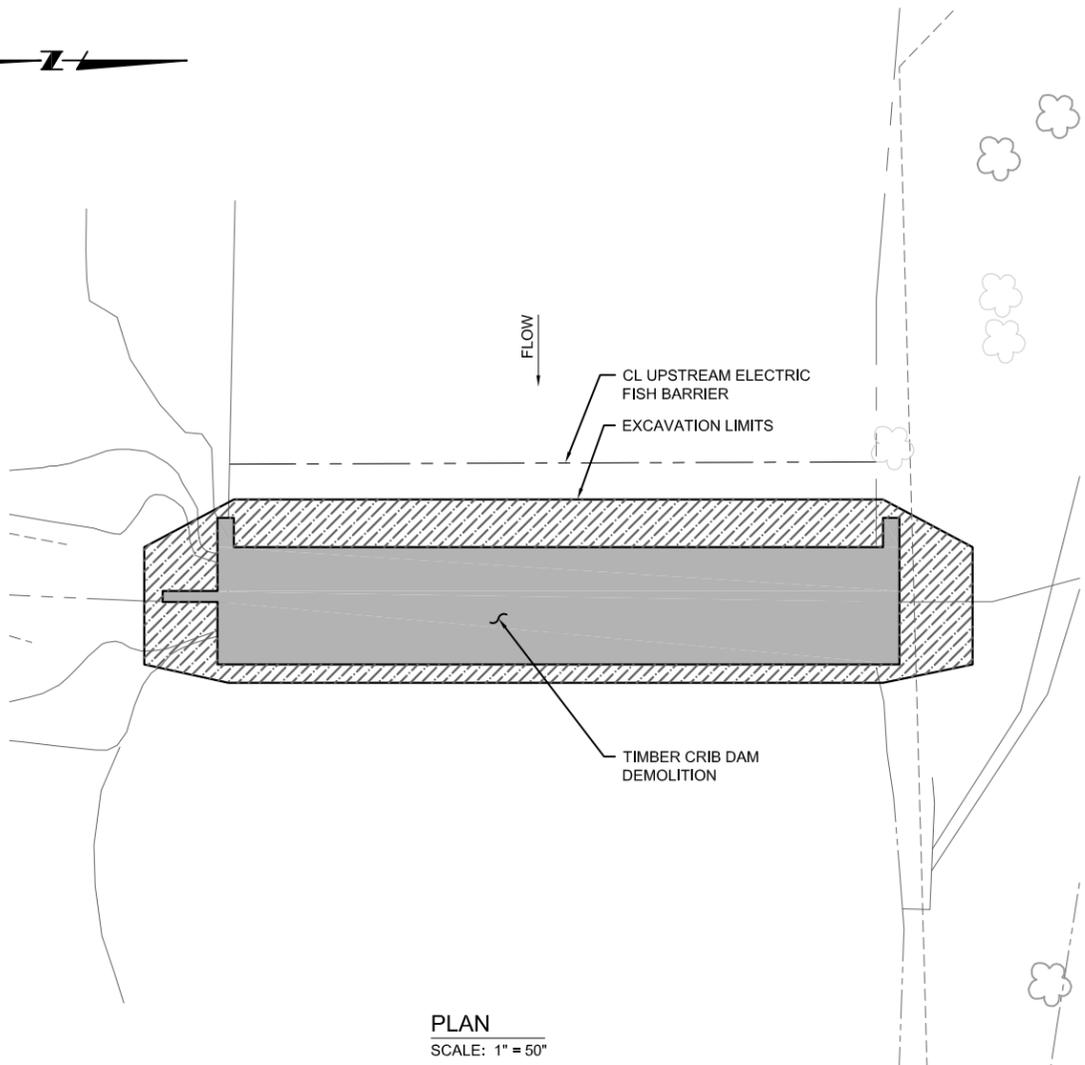
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STATE OF WISCONSIN
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CONCEPTUAL LAYOUT 4
 NEW DAM

SHEET
 05



A SECTION
SCALE: 1" = 20'

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SCALE



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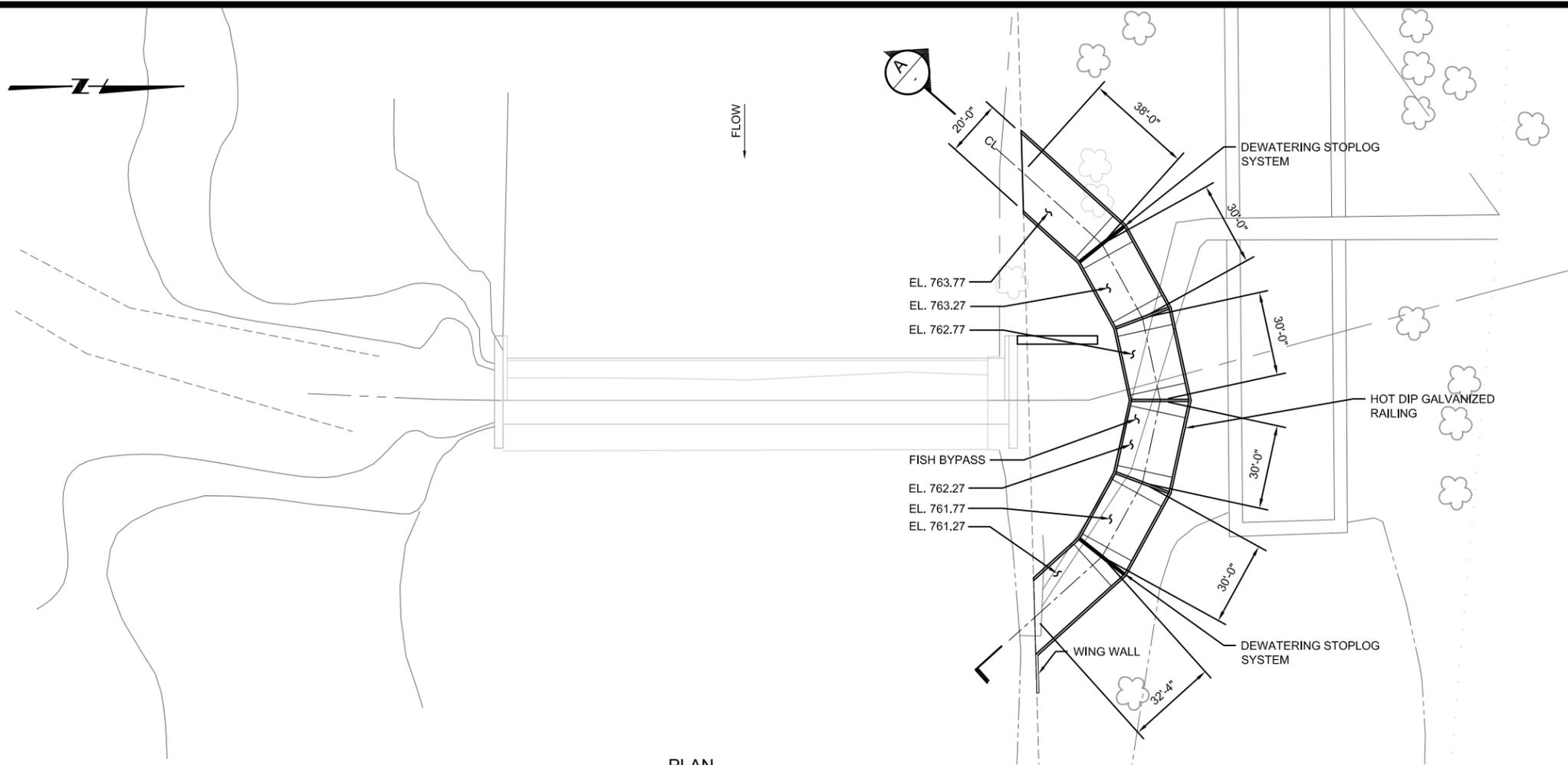
STATE OF WISCONSIN
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DIVISION OF FACILITIES DEVELOPMENT

CONCEPTUAL LAYOUT 5
DAM REMOVAL

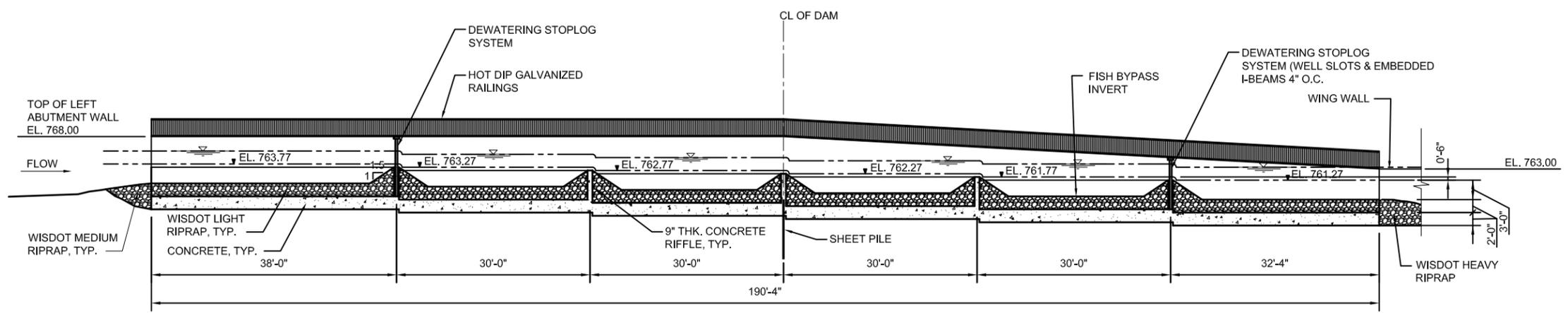
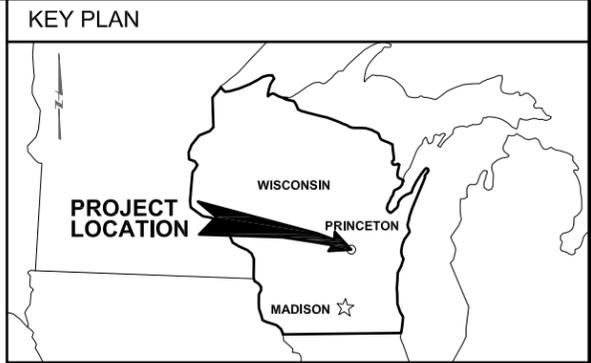
SHEET
06



FLOW



PLAN
SCALE: 1" = 50"



A FISH BYPASS PROFILE
SCALE: 1" = 20"

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USER: mgsy

REV	DATE	BY	DESCRIPTION

SCALE



DESIGNED _____
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CHECKED _____



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BYPASS FISHWAY

SHEET
07

Appendix B

Site Improvement Photographs



Photograph 1 – Flashboard Installation with Safety Cable System



Photograph 2 – Flashboard Installation with Safety Cable System



Photograph 3 – South Access to Lock Gate Structure



Photograph 4 – North Access to Lock Gate Structure



Photograph 5 – South Lock Abutment Brush



Photograph 6 – North Lock Abutment Brush



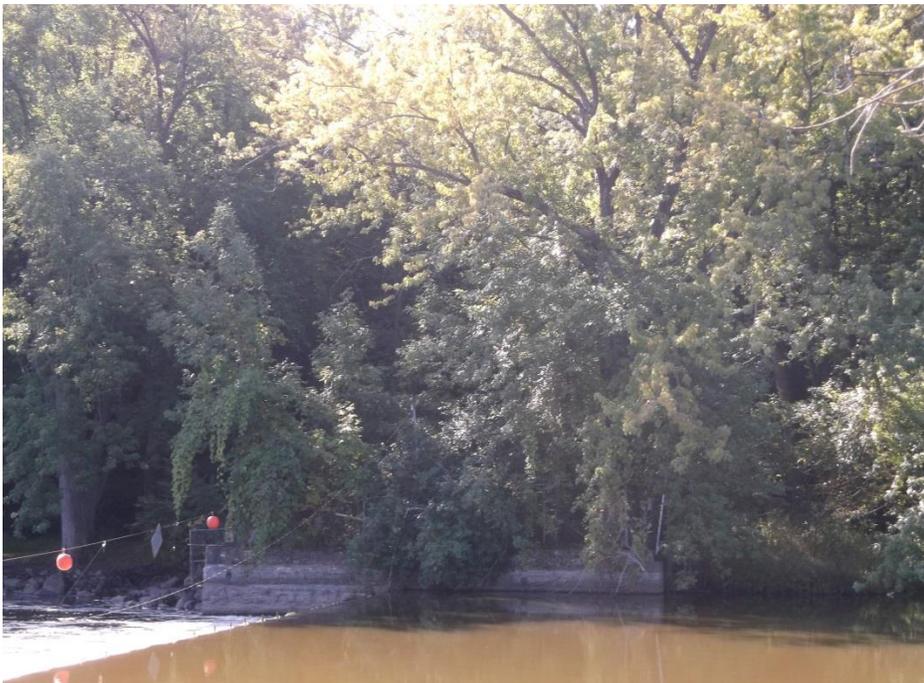
Photograph 5 – North Lock Wall Brush



Photograph 6 – North Lock Wall Tree



Photograph 7 – South Lock Wall Tree



Photograph 8 – South Dam Abutment Brush and Trees



Photograph 9 – North Dam Abutment Brush and Trees



Photograph 10 - Lock Gate Motors, Switches and Screw Drives