FINAL STUDY REPORT
BIOLOGICAL AND ENGINEERING STUDIES OF AMERICAN EEL
RSP 3.3

CONOWINGO HYDROELECTRIC PROJECT

FERC PROJECT NUMBER 405

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EXECUTIVE SUMMARY

Exelon Generation Company, LLC (Exelon) has initiated with the Federal Energy Regulatory Commission (FERC) the process of relicensing the 573-megawatt (MW) Conowingo Hydroelectric Project (Project). The current license for the Conowingo Project was issued on August 14, 1980 and expires on September 1, 2014. FERC issued the final study plan determination for the Conowingo Project on February 4, 2010, approving the revised study plan with certain modifications.

The final study plan determination required Exelon to conduct Biological and Engineering Studies of American Eel, which is the subject of this report. The objectives of this study are as follows: (1) summarize available scientific and commercial information regarding the American eel; (2) identify suspected factors affecting American eel abundance; (3) describe the spatial distribution and size characteristics of American eels in the Conowingo tailrace; (4) examine the engineering feasibility and costs of upstream and downstream passage options, including consideration of potential fallback of eels after exiting an upstream passage device; (5) examine the potential impact of upstream and downstream passage of American eels on the Susquehanna River; (6) assess the cumulative impacts to the biodiversity of the Susquehanna River ecosystem of upstream and downstream passage of American eel; and (7) if deemed beneficial to American eel abundance, identify potential locations for an upstream passage facility.

The 2010 and 2011 results for Objective 3, listed above, were presented separately in reports titled Conowingo RSP 3.3 Eel Sampling below Conowingo Dam (Normandeau and Gomez and Sullivan 2012a, b). The other six objectives and the results of a workshop on downstream passage that was held on October 25 and 26, 2011 are addressed in this report. These reports address all aspects of the final study plan.

The American eel is a catadromous fish species whose range extends from Greenland and Iceland south to Venezuela. All American eels migrate to the Sargasso Sea to spawn. The Sargasso Sea is located in the south central portion of the North Atlantic Ocean, approximately 1,400 km east of Florida. During the maturation phase, the species utilizes a combination of freshwater, estuarine, and coastal ocean waters over a period of 4 to 24+ years coast-wide and 6 to 16 years specifically in the Chesapeake Bay region (DOI 2007). The species is panmictic and, as such, is composed of a well mixed single breeding population where the juveniles do not necessarily return to natal streams (Wirth and Bernatchez 2003). Eels' eggs and larvae (leptocephali) are dispersed across their entire range by ocean currents. Once the leptocephali reach the continental shelf, they metamorphose into glass eels. The glass eels actively migrate toward land and develop pigmentation in brackish or freshwater and are termed elvers. When elvers reach approximately age 2, they are termed yellow eels, which is their primary growth stage. Sexual differentiation occurs during the yellow eel phase. As the eels sexually mature they take on a silver pigmentation (silver eels) and begin their journey back to the Sargasso Sea to spawn.

Due to their migratory behavior, eels provide an ecologic link between the marine and freshwater environments. For example, American eels serve as hosts to the larval stage (known as glochidia) of freshwater mussels, allowing for the dispersion of mussels to upstream areas. As predators of fish and invertebrates primarily, eels also tie up and remove nutrients from their prey in growth and production. Some of this freshwater/estuarine accumulated biomass is returned to the Sargasso Sea when the eels spawn and die.

In February 2007, the US Department of Interior (DOI) issued its finding on a petition to list the American eel as threatened or endangered (DOI 2007). Based on trends of glass eel abundance indices, the DOI found that the overall eel population is stable. In its findings, the DOI also stated that indices of yellow eel abundance were good indicators of local or regional conditions. Yellow eel abundance in the Chesapeake Bay, one of the largest American eel fisheries in the United States, experienced a significant decline (50 percent) over the period 1994 to 2004 (DOI 2007)[1].

At a local level, there are no abundance indices available for the Susquehanna River. The Maryland Biological Stream Survey has compiled eel data in several Chesapeake Bay tributaries, including Deer and Octoraro Creeks, which are tributaries to the Susquehanna with confluences downstream of Conowingo Dam. An analysis of these data (EPRI 2011) indicates that the densities in Deer Creek (0.292-0.357 eels/m^2) and Octoraro Creek (0.347 eels/m^2) were in the middle to lower end of the density estimate range for all Chesapeake Bay tributaries analyzed (total range 0.253-0.975 eels/m^2).

There are a variety of factors that have been postulated as affecting American eel abundance. These factors include a) changes in ocean currents and the corresponding change in the dispersal of leptocephali; b) commercial fishing; c) increased predation due to increased densities downstream of barriers; d) increased parasitic vulnerability, particularly to the non-indigenous nematode *Anguillicola crassus*; e) loss of freshwater habitat; f) contamination and g) turbine mortality.

[1] On September 28, 2011, DOI issued its 90-day finding on a petition to list American eel filed in 2010 from the Council for Endangered Species Act Reliability. In the finding, DOI found that a 12-month status review was warranted, with the review currently ongoing.

The interaction and synergistic effects of these factors is poorly understood. However, the fact that American eel is a species generalist and will use fresh and estuarine waters, as well as the marine environment, as growth and maturation habitat helps mitigate these potential effects (Jessop et al. 2002, Lamson et al. 2006). Some American eels enter freshwater, while others complete their entire life-cycle in the marine or estuarine environment without ever entering fresh water (DOI 2007).

To better understand how American eel use the area in the immediate vicinity of the Conowingo tailrace, the United States Fish and Wildlife Service (USFWS) initiated a study in 2005. Eels have been sampled by the USFWS with ramps using Enkamat® substrate and pots near Conowingo's West Fish Lift (WFL) from 2005 to the present. In 2010, Exelon initiated eel sampling with ramps and pots in the spillway region of the project. For the 2010 Exelon sampling, one sampling ramp was placed adjacent to the dividing wall between the tailrace and East Fish Lift (EFL spillway ramp 2010) while the other ramp was placed on the east abutment end of the spillway at Spillbay 50 (spillbay 50 ramp 2010), both ramps used Enkamat® substrate. For the 2011 Exelon sampling, the ramps were placed in similar areas with the exception that tandem ramps were installed at each location with Enkamat® and AkwaDrain™ substrate fished side-by-side to compare efficacy. Eel pots were fished adjacent to the ramps for both 2010 and 2011. Both gear types are similar in design and deployment to those used by the USFWS. The results of the USFWS and Exelon sampling are presented on Table ES-1. The Enkamat® substrate used on the ramps is reportedly size-selective for eels less than 260 mm (Solomon and Beach 2004b), and neither the ramps nor the pots captured eels between 188 and 256 mm.

Table ES-1: Summary of eels collected at Conowingo Dam 2005 – 2010

Year/Source	Eels Caught with Ramps	Eel Length Range (mm)	Eels Caught with Pots	Length Range of Eels Caught in Pots (mm)
2005/USFWS WFL	42	-	78	93-733 (range given for all eels caught)
2006/USFWS WFL	19	-	208	83-735 (range given for all eels caught)
2007/USFWS WFL	3,837	76-169	51	256-734
2008/USFWS WFL	44,006 (824 on east side)	90-176	38 (25 recaptures)	321-770
2009/USFWS WFL	17,437	92-162	116 (49 recaptures)	318-655
2010/USFWS WFL	24,000	95-195	25 (9 recaptures)	335-696
2010/EXELON/EFL SPILLBAY RAMP 2010	8	103-148	1	525
2010/EXELON/SPILLBAY 50 RAMP 2010	158	92-154	91	115-650

Year/Source	Eels Caught with Ramps	Eel Length Range (mm)	Eels Caught with Pots	Length Range of Eels Caught in Pots (mm)
2011/EXELON/EFL SPILLWAY RAMPS 2011	405/156*	88-182	59	300-689
2011/EXELON/SPILLBAY 50 RAMPS/2011	133/406*	87-188	0	NA
2011/USFWS WFL	85,000	84-225	224 (55 recaptures)	333-659

*: Numbers displayed for eels caught on Enkamat®/AkwaDrain™ substrate.

Exelon conducted night reconnaissance surveys of the spillway plunge pool in 2011 to determine eel congregation areas relative to the ramp entrances. During these surveys, young eels (i.e., elvers and small yellow eels) were only observed in abundance below crest gate #30. Located immediately downstream of crest gate #30 is a plateau of concrete or macadam. Young eels were observed at this location during all three nighttime surveys. Young eels were also observed, (although not in abundance) near seeps, or areas where water trickled over the spillway sill and when water cascaded down bedrocks near these seeps. In these areas where these eels were observed, predatory fish such as channel catfish and striped bass were also observed.

A preliminary review of upstream eel passage facilities on several river systems provided background and information on the potential options for upstream eel passage at Conowingo Dam. At the St. Lawrence-FDR Power Project, with a comparable civil works configuration and operating head to Conowingo Dam, a state-of-the-art eel passage facility was constructed in 2006. It is anticipated that a permanent (fixed) eel passage facility at the Conowingo Project would include similar technologies incorporated in the St. Lawrence-FDR facility. These major features include a ramp with substrate that eels can climb to a holding area. From the holding area, eels would either pass upstream via a pipe containing a continuous flow that eels would swim through to a safe release point upstream of the Project in Conowingo Pond or be transported to selected water bodies above Conowingo Dam.

Based on data collected during studies from 2005 – 2010, eel passage facilities were evaluated at the east and west bank of Conowingo Dam. The west bank of the tailrace near the WFL presents challenges to direct passage because the powerhouse is also on the west side of the dam. In addition to passing eels over the dam, consideration was given to an exit location that will allow continued upstream movement. If the eels exit too close to the powerhouse, downstream currents could cause them to pass back through the turbines.

For this study, conceptual layouts and cost opinions were developed for five potential upstream eel passage alternatives. The alternatives ranged from eel passage facilities of limited length with a trap-and-transport program to full-length eel passage facilities that provide the opportunity for full volitional passage to Conowingo Pond. Table ES-2 presents a summary of the conceptual opinions of probable cost for the alternatives evaluated.

Table ES-2: Summary of Upstream Eel Passage Alternatives

Alternative	Brief Description	Capital Costs (2011 Dollars)	Annual Operations Costs, If Applicable (2011 Dollars)
West Bank - Trap and Transport	Limited length eel ramp with collection facility in existing parking lot.	$639,000	$585,000
West Bank - Volitional Passage near West Fish Lift	Full eel ramp with resting pools from tailrace to pond elevation, sited near West Fish Lift superstructure.	$1,695,000	$200,000 per year (assumed personnel cost)
West Bank - Volitional Passage near Administration Building	Full eel ramp with resting pools from tailrace to pond elevation, portion buried beneath parking lot daylighting near Administration Building.	$2,230,000	$200,000 per year (assumed personnel cost)
East Bank - Trap and Transport	Limited length eel ramp with collection facility in existing access area, below non-overflow section of dam.	$622,000	$585,000
East Bank - Volitional Passage	Full eel ramp with resting pools from tailrace below spillbay 50 to pond, cored through top of dam.	$1,125,000	$200,000 per year (assumed personnel cost)

In evaluating the impacts of eel passage, an assessment has to consider the expected overall upstream passage efficiency and the expected downstream passage survival. Information available from the eel passage facility on the 82-ft high Moses-Saunders Power dam on the St. Lawrence River was used to estimate expected upstream passage efficiencies at three dams on the lower Susquehanna (Conowingo, Holtwood, and Safe Harbor). The Moses-Saunders Power Dam has an estimated overall upstream passage efficiency (defined as the proportion of tagged eels released in the tailrace that later ascend the passage facility/ladder) of 33 to 39 percent. For the smaller dam at York Haven, overall upstream passage efficiency was estimated to be 36 to 45 percent based on information provided by a researcher with eel-passage experience at smaller dams (D. Desrochers, personal communication).

As would be expected with any volitional passage, a portion of the migrating eels will become residents in the impoundments through which they pass, so that the cumulative passage efficiency from the Conowingo tailrace to the York Haven (1.3 to 2.5 percent) impoundment was estimated as the product of the four dams' upstream passage efficiencies. In contrast to volitional passage, the comparable upstream passage efficiency of the trap-and-transport approach from Conowingo Dam to upstream of York Haven would be expected to be between 36 and 43 percent. With an expected very low mortality associated with transport, the overall efficiency of transported fish upstream of York Haven (or any reasonable distance of transport) would remain constant between 36 and 43 percent.

Upon maturity, eels transported or volitionally passed upstream on the Susquehanna River would have to migrate downstream and pass through one or more dam's turbines and/or through spillage if it is occurring. Survival estimates for downstream turbine passage is a function of turbine type. Based on the proportion of the types of turbines (*i.e.*, Francis or Kaplan) at each of the lower Susquehanna hydroelectric projects, the Electric Power Research Institute (EPRI) reported estimated silver eel survival at the York Haven, Safe Harbor, Holtwood and Conowingo Dams (EPRI 2011). These estimates were used to estimate cumulative downstream passage efficiencies from each of the four reservoirs.

In October 2011, a workshop was held with the relicensing stakeholders and eel experts to discuss options for the downstream passage of adult eels at hydroelectric projects generally and the Conowingo Project specifically. After discussing a variety of turbine passage, behavioral/guidance, structural, as well as trap and transport options, the group consensus was that trap and transport was the most practical alternative for the lower Susquehanna River. The specifics of the program have not been worked out as of the date of the submission of this report. For costing purposes, Exelon has assumed the program will start in small tributaries (~50 feet wide) upstream of York Haven Dam that have been stocked by the USFWS. The capital and operations costs for a single eel trapping weir of this nature are estimated to be $169,500 and $266,000/yr, respectively. Exelon anticipates that the cost of a trap and transport program would be shared among the licensees of the four dams the eels would be required to pass.

In order to determine the potential number of silver eels available for outmigration to the Sargasso Sea as well as the potential abundance of eels distributed via passage to upstream areas, a simple eel passage survival model was constructed for various passage scenarios. These models include: a.) low-end estimates of upstream passage efficiency and downstream survival for volitional passage; b) high-end estimates of upstream passage efficiency and downstream survival for volitional passage; c.) trap and transport efficiency to upstream of York Haven with low-end downstream survival for volitional passage; d.) trap and transport efficiency to upstream of York Haven with high-end downstream survival for volitional passage; and e) trap and transport efficiency to upstream of York Haven with trap and transport to both upstream of York Haven and downstream of Conowingo (a series of sensitivity analyses).

From a resource-management perspective, the model showed that the choice of methods for achieving upstream and downstream passage of American eel depends on the resource goals of an overall program. If the sole resource management objective is to provide the most silver eels leaving the Susquehanna River for the journey to the Sargasso Sea, the model shows that volitional upstream and downstream passage is likely to provide the most silver eels downstream of Conowingo Dam (90.0 percent of eels below Conowingo Dam) than options involving trap-and transportation (81.3 – 87.5 percent of eels below Conowingo). Complete volitional passage has such a high return rate of fish to the Sargasso Sea primarily because a large percentage (67%) of the eels remain below Conowingo Dam and never migrate upstream.

If the sole resource management objective is to maximize eel abundance upstream of York Haven Dam, the model shows that this goal would be accomplished with an option involving a trap-and transport program. Any trap-and-transport option program would deliver 36 to 43 percent of the eels below Conowingo upstream of York Haven while volitional passage at the four dams would only deliver 1.3 to 25 percent of these eels above York Haven.

If an upstream and downstream eel-passage program sought to balance these two resource objectives, the model predicts that an upstream and downstream trap-and-transport program would be the best approach. If capture efficiencies for the downstream trap-and-transport program are high (approximately 75% or more), this program would also provide more silver eels leaving the river than the volitional approach. Inter-annual variability of glass eels returning to the Susquehanna River, however, makes predictions of long-term benefits of any potential program uncertain.

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LIST OF ACRONYMS

Agencies

ASMFC	Atlantic States Marine Fish Commission
DOI	United States Department of Interior
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
ICES	International Council for the Exploration of the Sea
NOAA	National Oceanic and Atmospheric Administration
NYPA	New York Power Authority
SRAFRC	Susquehanna River Anadromous Fish Restoration Cooperative
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VIMS	Virginia Institute of Marine Science

Units of Measure

cfs	cubic feet per second
F	Fahrenheit
fps	feet per second
ft	feet
h	hour
hp	horsepower
in	inch
L	liter
min	minute
mm	millimeter
MW	megawatt
rpm	revolutions per minute

Environmental

PIT	Passive Integrated Transponder

Miscellaneous

CFR	Code of Federal Regulations
EFL	East Fish Lift
ILP	Integrated Licensing Process
MBSS	Maryland Biological Stream Survey
NOI	Notice of Intent
PAD	Pre-Application Document
PSP	Proposed Study Plan
RSP	Revised Study Plan
WFL	West Fish Lift

1.0 INTRODUCTION

Exelon Generation Company, LLC (Exelon) has initiated with the Federal Energy Regulatory Commission (FERC) the process of relicensing the 573-megawatt (MW) Conowingo Hydroelectric Project (Project). Exelon is applying for a new license using the FERC's Integrated Licensing Process (ILP). The current license for the Conowingo Project was issued on August 14, 1980 and expires on September 1, 2014.

As required by the ILP, Exelon filed its Pre-Application Document (PAD) and Notice of Intent (NOI) with FERC on March 12, 2009. On June 11 and 12, 2009, a site visit and two scoping meetings were held at the Project for resource agencies and interested members of the public. Following these meetings, formal study requests were filed with FERC by several resource agencies. Many of these study requests were included in Exelon's Proposed Study Plan (PSP), which was filed on August 24, 2009. On September 22 and 23, 2009, Exelon held a meeting with resource agencies and interested members of the public to discuss the PSP.

Formal comments on the PSP were filed with FERC on November 22, 2009 by Commission staff and several resource agencies. Exelon filed a Revised Study Plan (RSP) for the Project on December 22, 2009. FERC issued the final study plan determination for the Project on February 4, 2010, approving the RSP with certain modifications.

The objectives of this study, which is part of the RSP, are as follows: (1) summarize available scientific and commercial information regarding the American eel; (2) identify suspected factors affecting the American eel abundance; (3) describe the spatial distribution and size characteristics of American eels in the Conowingo tailrace; (4) examine the engineering feasibility and costs of upstream and downstream passage options, including consideration of potential fallback of eels after exiting an upstream passage device; (5) examine the potential impact of upstream and downstream passage of American eels on the Susquehanna River; (6) assess the cumulative impacts to the biodiversity of the Susquehanna River ecosystem of upstream and downstream passage of American eel; and (7) if deemed beneficial to American eel abundance, identify potential locations for an upstream passage facility.

The 2010 and 2011 results for Objective 3, listed above, were presented separately in reports titled Conowingo RSP 3.3 Eel Sampling below Conowingo Dam (Normandeau and Gomez and Sullivan 2012a, b). The other six objectives and the results of a workshop on downstream passage that was held on October 25 and 26, 2011 are addressed in this report. These reports address all aspects of the final study plan.

2.0 BACKGROUND

2.1 Project Description

2.1.1 Conowingo Pond

The impoundment, known as Conowingo Pond and formed by Conowingo Dam, extends approximately 14 miles upstream from Conowingo Dam to the lower end of the Holtwood Project tailrace. The Conowingo Pond is typically fluctuated between elevations 105.2[2] feet (ft) and 109.2 ft, though the FERC license permits pond elevations between 101.2 ft and 110.2 ft. Conowingo Pond has a surface area of approximately 8,500 acres and a total impoundment volume of approximately 310,000 acre-ft.

2.1.2 Conowingo Dam and Spillway

The Conowingo Dam (Figure 2.1.1-1) is a concrete gravity dam with a maximum height of approximately 94 ft and a total length of 4,648 ft. The dam consists of four distinct sections from east to west: a 1,190-foot long non-overflow gravity section with an elevation of 115.7 ft; an ogee shaped spillway (the major portion, which is 2,250 ft long with a crest elevation of 86.7 ft and the minor portion, which is 135 ft long with a crest elevation of 98.7 ft); an intake-powerhouse section, which is 950 feet long; and a 100-foot-long abutment section. The powerhouse and spillway sections of the dam are separated by a dividing wall extending 300 feet downstream of the powerhouse. The dam also supports U.S. Highway Route No. 1.

Flow over the ogee spillway sections is controlled by 50 stony-type crest gates with crest elevations of 86.7 ft and two regulating gates with crest elevations of 98.7 ft. Each crest gate is 22.5 ft high by 38 ft wide and has a discharge capacity of 16,000 cfs at a reservoir elevation of 109.2 ft. The two regulating gates are 10 ft high by 38 ft wide and have a discharge capacity of 4,000 cfs per gate at a reservoir elevation of 109.2 ft. All gates are designed such that they must be locked in a fully open or fully closed position, with no partial openings.

2.1.3 Conowingo Powerhouse

The Conowingo Powerhouse contains eleven turbine/generating units. The turbines are comprised of seven Francis-type single runner hydraulic turbines (unit numbers 1 through 7) operating at 81.8 revolutions per minute (rpm) and four Kaplan-type turbines (unit numbers 8 through 11) operating at 120 rpm. Under a rated head of 89 ft, units 1, 3, 4, 6 and 7 have a rated output of 6,749 cfs, and units 2 and 5 have a rated output of 6,320 cfs. Units numbers 8 through 11 are mixed flow Kaplan turbines that operate

[2] Elevations in this document refer to the National Geodetic Vertical Datum of 1929 (NGVD 1929). NGVD 1929 elevations are 0.7 feet higher than Conowingo Datum, such that elevation 104.5 ft Conowingo Datum equals 105.2 ft NGVD 1929.

at 120 rpm. Under a rated head of 89 ft, unit 8 has a rated output of 9,352 cfs and units 9-11 have a rated output of 9,727 cfs. The Conowingo Project also includes two small Francis house turbines that operate at 360 rpm with a rated output of 247 cfs under a design head of 89 ft. The house units provide station service and "black-start" capability. Under normal conditions only one house unit is operated for station service. Flow to the house units is minimal (247 cfs per unit) compared to the generating units (6,320 to 9,727 cfs, maximum hydraulic capacity of 86,000 cfs). Water for the generating turbines is taken from the mid to lower levels of the pond. The ceiling of the turbine intake bays is 40 ft below the water surface at normal full pond (elevation 109.2 ft) and extends down to 98 ft below normal full pond. Thus, the intake opening extends from elevation 69.2 ft down to elevation 11.2 ft. Each large unit is screened by bar racks with a clear spacing of 5.375 inches, while the house units are screened by bar racks with a clear spacing of 2 inches. Table 2.1.3-1 depicts the turbine characteristics at Conowingo Dam.

2.1.4 Tailrace

The makeup of Conowingo Dam's tailrace varies laterally along the dam (Figure 2.1.1-1). The west section, downstream of the powerhouse, consists of a deep bedrock channel with depths up to 21 ft at full generation (86,000 cfs), with a generally rectangular cross-section shape. The center and east sections, downstream of the spillway, consist of a bedrock outcrop-dominated landscape with various interconnected shallow pools and channels.

The Conowingo tailrace experiences a wide fluctuation of tailwater elevations. The tailwater elevation versus flow relationship is shown in Figure 2.1.4-1. Normal operating tailwater, with all units generating, is nominally El. 21.5 ft. Tailwater elevations can range from El. 12.0 ft (~0 cfs) during temporary winter turbine shutdowns to greater than El. 25.0 ft (~175,000 cfs) during minor flooding events.

2.1.5 Fish Passage Facilities

Exelon currently operates two fish lifts at Conowingo Dam. The West Fish Lift (WFL), which passes approximately 350 cfs, is adjacent to the 100 ft long right abutment and is currently operated under a settlement agreement with the United States Fish and Wildlife Service (USFWS) for American shad egg production and other research purposes. The newer East Fish Lift (EFL) is located at the dividing wall between the powerhouse and spillway sections and is used primarily to pass American shad and other migratory fishes during the April to June migration season. The flow through the EFL can vary from 300 to 900 cfs depending on the gate setting.

2.1.6 Seasonal Flow Requirements

The current minimum flow regime below Conowingo Dam was formally established with a settlement agreement in 1989 between the Project owners and several federal and state resource agencies. The established minimum flow regime below Conowingo Dam is the following:

March 1 – March 31	3,500 cfs or natural river flow
April 1 – April 30	10,000 cfs or natural river flow, whichever is less
May 1 – May 31	7,500 cfs or natural river flow, whichever is less
June 1 – September 14	5,000 cfs or natural river flow, whichever is less
September 15 – November 30	3,500 cfs or natural river flow, whichever is less
December 1 – February 28	3,500 cfs intermittent (maximum six hours off followed by equal amount on)

The natural river flow is the discharge measured at the Susquehanna River at the Marietta United States Geological Survey (USGS) gage (No. 01576000). The Marietta USGS gage is located approximately 35 miles upstream of Conowingo Dam above the Safe Harbor Dam.

TABLE 2.1.3-1: TURBINE CHARACTERISTICS OF THE CONOWINGO HYDROELECTRIC FACILITY.

Unit Nos.	1,3,4,6,7	2,5	8	9-11	House Units (2)
Turbine Type	Francis	Francis	Kaplan (Mixed Flow)	Kaplan (Mixed Flow)	Francis
Trash rack spacing (in)	5 3/8	5 3/8	5 3/8	5 3/8	2
No. blades (buckets)	13	13	6	6	13
Rated head (ft)	89	89	86	86	89
Intake Elevation (ft)	11.2 to 69.2	11.2 to 69.2	11.2 to 69.2	11.2 to 69.2	11.2 to 69.2
Approximate rated flow (cfs)	6,749	6,320	9,352	9,727	247
Operating Speed (rpm)	81.8	81.8	120	120	360
Runner diameter (in)	203	203	225	225	43.5
Blade tip speed (ft/s)	72.5	72.5	117.8	117.8	68.3
No. wicket gates	24	24	24	24	16
Pad Height (in) [Clear distance between top & bottom of wicket gate]	72.1	72.1	108.5	108.5	15.5
Wicket gate spacing (in)	13.75	13.75	22.16	22.16	3.72

FIGURE 2.1.1-1: CONOWINGO HYDROELECTRIC PROJECT

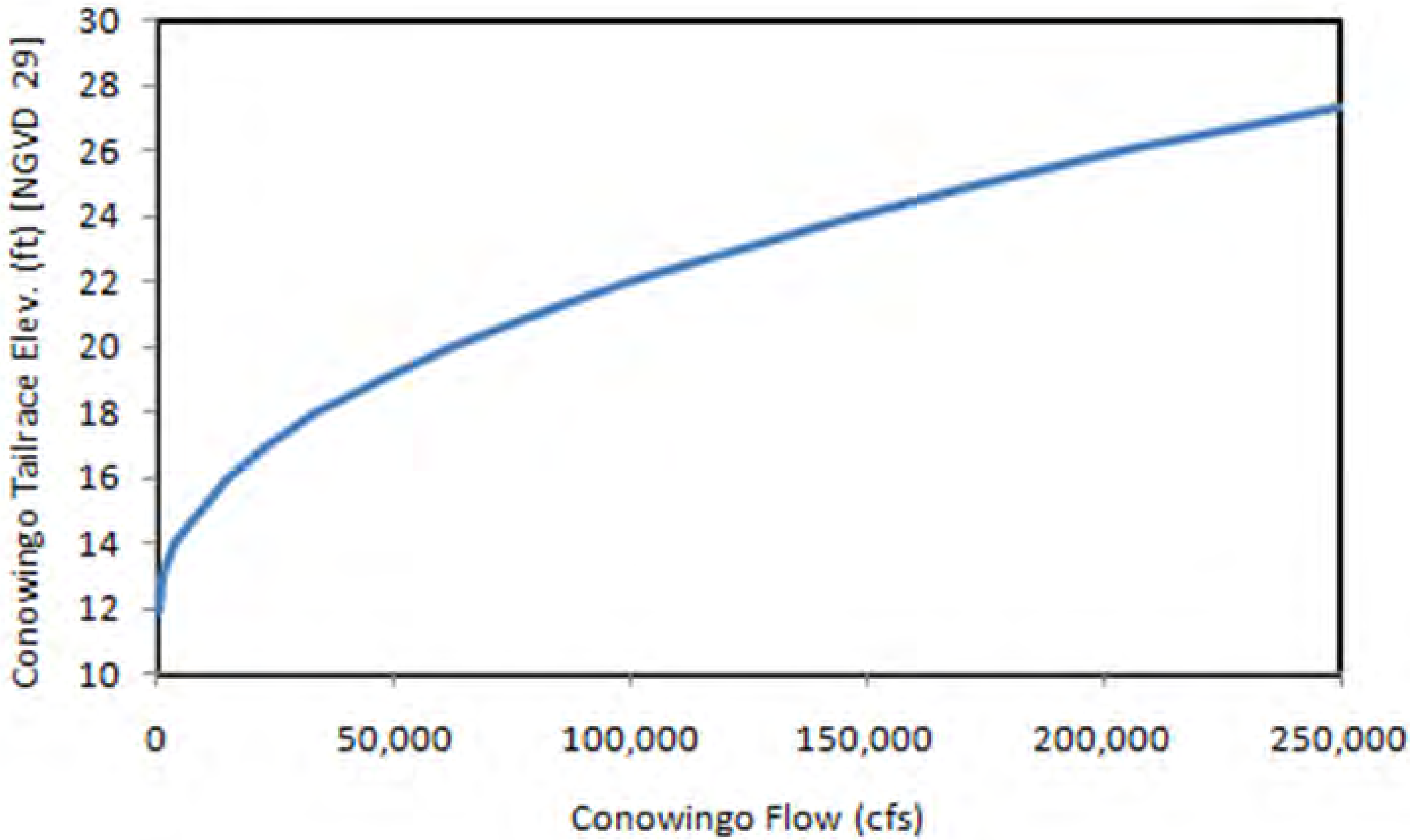

FIGURE 2.1.4-1: TAILWATER RATING CURVE BELOW CONOWINGO DAM

3.0 EXISTING DATA ON AMERICAN EEL

The information presented in this section of the report summarizes the life cycle and distribution of American eel, its ecological role, as well as the current population status and factors affecting abundance.

3.1 Life Cycle and Distribution

The American eel is a catadromous fish species with a broad geographic range that extends from Greenland south to the northeast coast of South America and includes the eastern coast of North America. It is a facultative catadromous species[3] that spends its life in freshwater, estuaries, or saltwater and then migrates to spawn in the Sargasso Sea, which is located in the south-central portion of the North Atlantic Ocean (Bonhommeau et al. 2009).

The American eel population is panmictic, referring to a well-mixed, single breeding population where the juveniles do not necessarily return to streams from which the parent eels came (Wirth and Bernatchez 2003). This single breeding population is the result of random mating of all individuals from the entire range in the spawning region of the Sargasso Sea and the dispersal of larvae via the Gulf Stream, North Atlantic Ocean, Caribbean Sea and coastal waters as influenced by the North Atlantic Oscillation[4]. The significance of panmixis is, unlike anadromous species such as American shad, there is no river-specific stock of American eel. Thus, specific systems' eel populations are dependent on the overall population's reproductive success and dispersal.

Life stages of the American eel include: egg, leptocephali (larval stage), glass eel, yellow eel, and silver eel. Spawning is thought to occur in late winter with a peak in the February to March timeframe (McCleave 2008). Following spawning, hatching begins in February and may continue until April (McCleave et al. 1987). The eggs hatch into leptocephali, which disperse and are transported by ocean currents from the Sargasso Sea toward coastal areas. Leptocephali have a limited ability to swim and are carried on the currents for several months to up to a year. The leptocephali metamorphose into miniature, transparent glass eels as they approach the continental shelf and begin active migration toward land. Glass

[3] As opposed to obligative catadromy, where species instinctively migrate to freshwater for required biological development.

[4] The North Atlantic Oscillation is the climatic fluctuation of the difference of air pressure at sea level between the Icelandic low and Azores high that through east-west oscillation movements controls the strength and direction of the westerly winds and storm tracks across the North Atlantic Ocean.

eels are typically found along the coastal United States from February through May in the south-central portion of the North American range and into June and July in the northern extent of their North American range (Sullivan et al. 2006).

At approximately 100 mm, the glass eels develop pigmentation as they move into brackish or freshwater and are termed elvers (ASMFC 2000). Some American eels enter freshwater, while others complete their life cycle in the marine or estuarine environment (Jessop et al. 2002; Morrison et al. 2003; Lamson et al. 2006). Recent investigations using otolith microchemistry report three groups: saltwater residents, freshwater residents and inter-habitat migrants (Jessop et al 2002; Lamson et al. 2006). DOI (2007) stated that it has been suggested that brackish (or estuarine) waters produce eels that grow faster, mature earlier and emigrate as silver eels sooner than eels in fresh water.

Upstream migration of the elvers into fresh or estuarine waters occurs over a range of time from May through October, depending in part on latitude. The yellow eel stage generally begins when eels reach age 2 and this is considered the primary growth stage (DOI 2007). Yellow eels typically have a dark brown or black dorsal surface that transition to a pale yellow or olive-brown ventral surface. Eels are primarily benthic, utilizing rock, sand, mud and aquatic vegetation. They are largely nocturnal and feed mostly on invertebrates and smaller fishes. In as few as 4 and as many as 24 or more years with the mean outmigration age increasing with increasing latitude (6 to 16 years for Chesapeake Bay eels), yellow eels transform to sexually mature, adult silver eels, and begin a migration toward oceanic spawning grounds in the Sargasso Sea (DOI 2007). At the onset of and continuing throughout this migration, the eels undergo a number of physical changes. Some of the physical changes are substantially enlarged eyes, atrophy of the stomach and a change to a dark dorsal and silvery ventral color.

3.2 Population Status

In February 2007, the United States Department of Interior (DOI) issued its finding on a petition to list the American eel as threatened or endangered (DOI 2007). As part of that finding, the DOI conducted a comprehensive population status review. This type of status review typically consists of an assessment of the range-wide population size and structure. However, no range-wide estimate of abundance exists for American eel. Such an estimate is hampered by the panmictic nature of the species, the species' large and diverse geographic range, and growth rates and sex ratios that are environmentally dependent (DOI 2007). Absent range-wide estimates of abundance, the DOI elected to evaluate site-specific information on eels in the context of its significance to the entire population.

In evaluating site-specific information, the DOI analyzed four indices each for glass and yellow eels. The DOI evaluated glass eel indices from two sites in the US that have long-term data sets (North Carolina and New Jersey) as well as two sites in Nova Scotia. None of these indices showed a declining trend in glass eel production over a 13 to 15 year period beginning in 1989 (DOI 2007). Based on this trend, the DOI concluded the following:

> *"…of the available index data for the different American eel life history stages, we have determined that glass eel indices best represent the species status range-wide. Although we do not have glass eel indices from the entire range, the random nature of the leptocephali dispersal allows us to consider these data representative of the reproductive success of the species. As described above, there is no evidence of a sustained downward trend of these glass eel indices; therefore, we conclude that the American eel is not undergoing a sustained downward trend at a population level."*

Relative to yellow eel abundance, the DOI found the following:

> *"…indices from freshwater and tidal sites distributed from the mid-Atlantic region north to Canada and the St. Lawrence River indicated a statistically significant trend in yellow eel abundance at three sites. Two of these indices, Lake Ontario and the Chesapeake Bay index, had strong and statistically significant declining trends over the recent 1994 to 2004 time period, with 10-year declines in the order of 50% in the Chesapeake Bay…"*

The ongoing Chesapeake Bay surveys as referenced in DOI 2007 (ASMFC 2006) are conducted by the Virginia Institute of Marine Science (VIMS). Figure 3.2-1 is a replica of a graph in a summary report submitted by VIMS reporting the Chesapeake Bay eel index. It shows a highly variable index with a general trend of declining abundance of juvenile eels throughout the Bay (random stratified catch) and tributaries (river only catch) beginning approximately in 1988 and continuing through 2007.

A petition to list American eel as a threatened species under the Endangered Species Act was filed with the USFWS by the Council for Endangered Species Reliability (CESR) on April 30, 2010. CESR commented that the basis for this petition was new information as well as information not considered in the FWS 2007 determination that listing was not warranted.

The USFWS conducted a 90-day review of the CESR petition that was published in the Federal Register on September 29, 2011 (FR Vol. 46, No. 189, Pages 60431-60444). The USFWS, in summary, stated:

We find that the information provided in the petition, as well as other new information in our files, presents substantial scientific or commercial information indicating that the petitioned action may be warranted by a causal link between oceanic changes (increasing sea surface temperature with a corresponding shift in spawning location, decrease in food availability, or shift in leptocephali transport by currents, tied to global warming) and decreasing glass eel recruitment. We will further explore any current o future population level impacts that may result from climate change in our new 12-month status review. However, we find that the information provided in the petition, as well as baseline and other new information in our files, does not present substantial scientific or commercial information indicating that the petitioned action may be warranted due to hydropower impacts, contaminants, electro-magnetic fields, acoustic disturbance, or the harvest of seaweed for biofuel. Information in our files and in the petition does not present new information to change the Service's previous conclusion in the 2007 12-month finding that hydropower and contaminants are not significant threats to the American eel population.

3.3 Ecological Role

Generally, little quantitative information has been published about the ecological role of American eel. Due to their migratory behavior, eels provide an ecologic link between the marine and freshwater environments. This link manifests itself in the predator-prey relationships of the species, as well as in its ability to act as a host for a variety of parasitic organisms.

Elvers and small yellow eels are prey species for larger aquatic predators such as largemouth bass and striped bass as well as avian species such as gulls, cormorants and bald eagles. The species also exhibits cannibalistic behavior, with larger yellow eels preying on incoming glass eels and elvers (Facey and Van Den Avyle 1987).

As predators, eels have a diverse diet that depends on their life stage and available food. Generally, eels are bottom feeders, and the diversity of their diet increases with size. Elvers feed on aquatic insects, cladocerans, amphipods and fish parts (Facey and Van Den Avyle 1987). As the elvers continue to grow into yellow eels, their diet can expand to include crustaceans, frogs and fishes (Facey and Van Den Avyle 1987, MacGregor et al. 2010). Large yellow eels compete directly with other piscivores such as bass, northern pike and walleye that feed on similar prey. However, it should be noted that Canadian angler surveys on the Bay of Quinte and the St. Lawrence River including Lake St. Francis revealed very little impact on sport fisheries (presumably for the above species) when eel populations declined (MacGregor et al. 2010).

As predators, eels utilize nutrients and energy stores from their prey in growth and production. Some of this freshwater/estuarine accumulated biomass and energy stores are released into the Sargasso Sea once the fish die and decompose, post spawning.

In addition to being nutrient exporters via consumed biomass, eels serve as importation vehicles for several parasitic organisms. Parasites of American eel include a variety of protozoans, trematodes, nematodes, cestodes and copepods (Facey and Van Den Avyle 1987). American eels also serve as a host species for the larval stage (known as glochidia) of freshwater mussels. Freshwater mussels filter and remove bacteria, algae, and fine particles from large quantities of water, playing an important role in water quality.

Mussel species depend on their hosts for dispersal, which completes a mussel's life cycle. Minkkinen and Park (2008) report that American eels may have a unique role as a host species for the mussel eastern elliptio (*Elliptio complanata*) and cite work conducted by the United States Geological Survey (USGS) Northern Appalachian Research Laboratory that found higher abundances of eastern elliptio on the nearby Delaware River than on the Susquehanna River. The Minkkinen and Park (2008) report suggests that low recruitment of eastern elliptio on the Susquehanna River could be attributed to the lack of eel passage at the four dams on the lower Susquehanna.

Over its range (Georgia to the St. Lawrence River and west to Lake Superior and Hudson Bay), eastern elliptio use several fish species as hosts, including white perch, yellow perch, American eel, alewife, blueback herring, three-spine stickleback, banded killifish, white sucker, pumpkinseed sunfish, redbreast sunfish, black crappie, largemouth bass, smallmouth bass, brook trout, lake trout and mottled sculpin (Wiles 1975, Watters 1994, Lellis et al. 2001, Kneeland and Rhymer 2008 as cited in Nedeau 2008).

Attempts to obtain and review the documentation of the original USGS research establishing the American eel-eastern elliptio link were made. On March 12, 2012, Exelon received information from USGS in response to a FOIA request regarding mussels in the Susquehanna River. The cover letter indicated that the package contained information on eastern elliptio in New Jersey, New York along with manuscripts, emails and abstracts of posters and oral presentations. Two abstracts included with this information are of relevance to the Susquehanna River. The abstracts of interest are titled: Host Identification for *Elliptio complanta* (Bivalvia: Unionidae) from the upper Susquehanna River Basin, Pennsylvania and Assessing the Importance of American Eel (*Anguilla rostrata*) to Freshwater Mussel Populations in the Susquehanna River.

The first abstract[5] described a laboratory experiment where multiple fish species were exposed to infestation by freshly-released glochidia of eastern elliptio. The results of the experiment showed metamorphosed individuals on American eel, brook trout, lake trout and mottled sculpin. Juvenile mussels were recovered from 18 to 48 days. No metamorphosed individuals were observed on American toad tadpoles, Atlantic sturgeon, blacknose dace, bluntnose minnow, central stoneroller, common shiner, cutlips minnow, fallfish, longnose dace, margined madtom, red-spotted newt, river chub, rock bass, shield darter, smallmouth bass, spottail shiner, tessellated darter or white sucker.

The second abstract[6] linked the low number of eastern elliptio in the Susquehanna River to the lack of upstream eel passage at hydropower dams. The abstract suggests that large populations of eastern elliptio in neighboring rivers and streams results from their their larger eel populations compared to low elliptio and eel numbers in the Susquehanna River. The abstract indicates that host fish studies showed that American eels were likely the primary host for eastern elliptio prior to dam construction. The study used qualitative and quantitative surveys above and below the Conowingo Dam to compare eastern elliptio recruitment. The results presented showed that population estimates in high density areas in the Susquehanna River were much lower than high density areas in the Delaware River. Other results presented showed that the eastern elliptio below Conowingo Dam are smaller than those at the six sites sampled above the dam. The conclusion presented in the abstract is that this indicates limited recruitment, presumably above the dam.

The remaining information supplied is various email correspondence concerning eastern elliptio. The correspondence identifies American eel and lake trout as the best hosts for eastern elliptio and mottled and slimy sculpin as minor hosts. The correspondence also identifies many other unsuccessful host species not listed in the abstract above. The correspondence mentions the incongruity of these results to results of other published studies as well as the common knowledge about eastern elliptio.

Unfortunately, the information presented in the FOIA concerning the relationship between American eel and eastern elliptio was limited, with very little supporting data or technical reports.

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[5] Host Identification for *Elliptio Complanata* (Vivalvia: Unionidate) from the upper Susquehanna River Basin, Pennsylvania . W.A. Lellis, E.S. Gray, J.C. Cole, B.S. White and J.S. Hotter. U.S. Geological Survey, Northern Appalachian Research Laboratory.

[6] Assessing the Importance of American Eel (*Anguilla Rostrata*) to Freshweater Mussels Populations in the Susquehanna River. Julie Devers, Jeffrey Cole, Barbara St. John White, Steve Minkkinen (Maryland Fishery Resource Office, USFWS), and William Lellis (Northern Appalachian Research Laboratory, USGS)..

3.4 Factors Affecting Abundance

There are a variety of factors that have been postulated as affecting the abundance of American eel. These factors include ocean conditions, commercial fisheries, predation, parasites, freshwater habitat loss, contaminants, and turbine mortality. The potential effect of each of these factors is described below. A complete discussion of each of these factors is beyond the scope of this report. The discussion presented below is meant to summarize these factors with the purpose of giving general context for American eel abundance in the Susquehanna drainage basin.

3.4.1 Ocean Conditions

Evidence indicates that changes to the North Atlantic Oscillation have been affecting the dispersal of juvenile eels in the Atlantic. Analyses have shown a negative correlation between Sargasso Sea surface temperatures and European eel abundance with a 12-year lag and that the North Atlantic Oscillation index and inflow of North Atlantic water into the North Sea were also negatively correlated with an 11-year lag (Durif et al. 2010). It is apparently not the first time this has happened, as Wirth and Bernatchez (2003) found that American and European eels have undergone several population contractions with the most recent in the Wisconsinan glaciation and that eels are sensitive to the strength and position of the Gulf Stream. Bonhommeau et al. (2009) indicated that changes in oceanic productivity related to climate change may have influenced the decline of European, American and Japanese eel populations and that shifts in the marine temperature regime in the late 1970s were followed by shifts in glass eel recruitment of the same three species. Friedland et al. (2007) also found a strong negative correlation between the North Atlantic Oscillation and long term variations in catches of European glass eels lagged by one year. They also indicated that the relationships between several ocean parameters and the Den Oever recruitment index (a long term (1940 to present) fishery independent glass eel recruitment index in the Netherlands) suggest that changing oceanic conditions may be contributing to declining recruitment of European and probably American eels.

3.4.2 Commercial Fisheries

American eels have supported local and coastal fisheries prior to and since European occupation of North America. Historical records of commercial eel harvest in the Susquehanna River are sparse, but indicate a fairly substantial fishery in the late-1800s and early-1900s. SRAFRC (2010) estimated that the approximate annual catch ranged from 44,002 to 147,222 pounds with an average of 88,339 pounds of eels caught in the Susquehanna River from 1909 to 1912 and up to 197,000 pounds in 1920.

Maryland showed eel landings of over 300,000 pounds in 2007 and along with New Jersey and Delaware comprised 73 percent of total commercial landings in the United States (ASMFC 2009). Indications are that nearly all commercial eel landings in the United States are from saline waters (ICES 2009). Commercial landings in Chesapeake Bay were 369,890 pounds in 2008, and the preliminary number for 2009 is 306,563 pounds (SRAFRC 2010).

The Chesapeake Bay commercial fishery is the main fishery for American eel in the United States (50 percent of yellow eel landings) with an exploitation rate (percentage of mortality associated with harvest) of silver eels estimated at less than 25 percent (DOI 2007). American eel are vulnerable to commercial harvest because it takes place before the species has had an opportunity to spawn (glass eels, elvers, yellow and silver eels all harvested). The fact that all continental life stages are subject to harvest in some portion of the species' range means that multiple year classes can be negatively affected in any given harvest year and the same year class can be negatively affected in multiple years.

The DOI found that commercial harvest affects the American eel only at a local or regional level as opposed to a population level (DOI 2007). Modeling by Weeder and Uphoff (2003) as cited in DOI (2007) found that commercial harvest has depleted the abundance of eels in the Chesapeake Bay.

3.4.3 Predation

Predation impacts American eel as eels are fed upon by piscivorous fish and by mammals throughout their life history, and in high-density situations it is apparent that there can be a significant degree of cannibalism as well (DOI 2007). Also, juveniles and adults are likely a seasonal food item for finfish, birds and mammals such as mink; however, the degree of dependence on the various eel life stages by these predators is unknown (ASMFC 2000). It can be assumed that there may be increased predation in high density situations as well; however, there is only anecdotal evidence to suggest increased predation by predators such as striped bass. As a result, the predation impact on eels below dams has not been quantified.

3.4.4 Parasites

American eels are vulnerable to parasites. One parasite in particular, the non-indigenous nematode *Anguillicola crassus*, which becomes sexually mature in the swim bladder of the eel, may impair the capacity of the eel to undertake migration to the Sargasso Sea (Palstra et al. 2007). As of 1997, 10 to 29 percent of American eels in the Chesapeake Bay were infected by *A. crassus*. In 2000, greater than 60 percent of American eels in the freshwater portions of the Hudson River were infected (DOI 2007) and the parasite was documented, with relatively high infection rates, in eels throughout New England (Aieta and Oliveira 2009).

A. crassus have the potential to significantly affect silver eels on their migration to the spawning grounds in the Sargasso Sea by consuming the eel's energy reserves. These parasites may also impair the eel's swimming capacity and adversely affect buoyancy regulation needed during the ocean migration to the Sargasso Sea (as cited in EPRI 2011). It appears that infection rates and severity of infection of *A. crassus* are higher in freshwater than in estuarine water (as cited in EPRI 2011).

3.4.5 Freshwater Habitat Loss

Freshwater habitat includes both lacustrine (lake/pond) and riverine areas. Some studies have shown that the greater the amount of lacustrine habitat within a watershed, the more the sex ratio favors females (DOI 2007). Riverine habitat utilized within the range of American eel exhibits a high variability in terms of water depth, temperature and flow. Researchers have found that the amount of habitat rather than the specific type of habitat within a river determines how many eels a river can support (DOI 2007).

Dams, particularly large dams with a nearly vertical downstream face such as Conowingo Dam, represent a barrier to the upstream migration of American eel. Although, dams reportedly reduce the available freshwater habitat over the species' entire range by approximately 25 percent, DOI (2007) concluded that "*the loss of this habitat does not threaten the species' long-term persistence*". The presence of the four dams on the lower Susquehanna River impedes access to the watershed above the dams although young eels have passed Conowingo Dam in past years via the EFL. Few eels have been recorded in the EFL since the 1990's.

The fate of eels that are unsuccessful in passing Conowingo Dam is unknown, but Drinkwater and Frank (1994) as cited in Craig (2000) suggested that catadromous species, unlike anadromous species, are more likely to move to another river if their path is blocked by a dam. Additionally, the species will use freshwater, estuarine and marine habitat to grow and mature. However, overcrowding below barrier dams may increase the likelihood that eels will become male, increase competition, increase predation, and reduce food availability (which negatively affects growth rates). One study found that densities are highest below barriers, while age, growth (in length) and the average number of females increased above barriers (ICES 2009).

Notwithstanding these general conclusions regarding the effects of barriers, an analysis by EPRI (2011) found no indication that eels recruited to the upper Chesapeake Bay are habitat limited. As illustrated in Table 3.4.5-1 from the EPRI report, EPRI analyzed data from 25 Maryland Biological Stream Survey (MBSS) sites and found that eel densities in Susquehanna River tributaries downstream of Conowingo

Dam are similar to or lower than densities elsewhere in the Chesapeake Bay watershed. Lower densities in the tributaries below Conowingo Dam suggest that these habitats may not be fully utilized.

3.4.6 Contaminants

Eels are a relatively long-lived fish species that are exposed to a wide variety of environmental contaminants through direct exposure and through ingestion of contaminated prey. The DOI (2007) assessment of American eel included a comprehensive review of potential contaminant effects. They found that yellow and silver eel tissue contained several contaminants including polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), pesticides and heavy metals (DOI 2007). They found that the contaminant concentrations were at levels that have affected other fish species, and further noted that some eels were surviving with contaminant loads at or above concentrations that would kill other fish. In summary, they found that there was a potential for contaminants to impact eels, particularly during younger life-stages.

Geeraerts and Belpaire (2009) conducted a more recent comprehensive review of contaminant effects on European eel. Given the similarity in the biology of American eel and European eel and the likelihood that American eels face similar contaminant exposure, their findings are relevant to American eel. Geeraerts and Belpaire (2009) concluded that:

> *"Eels are more vulnerable than other fish as they accumulate contaminants to a much higher degree than other species. In many fish species in Western Europe, pollution has been reported to hamper normal reproduction and larval development (endocrine disruption). Considering the high levels of contamination in eels for many areas, endocrine disruption in mature silver eels can be expected, jeopardizing normal reproduction (Belpaire 2008). Many contaminants are widespread and measured concentrations are at a level which more than likely is causing ecotoxicological effects in eel."*

3.4.7 Turbine Mortality

During outmigration through river systems with hydroelectric dams, some eels become entrained and enter hydroelectric turbines, which can result in injury or death, depending on dam size, turbine type, load, and specific opening conditions. The degree of injury and mortality increases with larger eels, suggesting that mortality rates of large female eels may be higher than mortality rates of smaller males.

Cumulative turbine mortality, which refers to the estimated combined turbine mortality within a watershed, is thought to cause significant reductions in a watershed's reproductive contribution to the eel population. This is true even when survival rates of eel passage are relatively high through each successive turbine or dam project on the river system. Downstream adult migrants would have to pass over or through some or all of the four hydroelectric dams on the Susquehanna River. A report prepared by EPRI (2011) determined the cumulative survival of eels passing downstream through the four Lower Susquehanna River's dams, based on the number and type of turbines at each dam. Eels passing only one, two, or three of the dams would have higher cumulative survival.

While the impact of turbines on the American eel might result in a decrease in local or regional abundance, it is unlikely that impacts will have a noticeable direct effect on recruitment of eels to the Susquehanna River basin. Given the panmictic nature of the species, recruitment is not directly related to the number of adults leaving a specific system in a given year. Furthermore, turbines principally affect migrants from freshwater, leaving the portion of the population that inhabits estuarine and marine waters unaffected. As a consequence, any loss of migrating adults resulting from turbine mortality would be buffered by the spawning input from eels residing in unaffected freshwater habitats and the estuarine or marine habitats throughout its wide range.

The 2007 DOI assessment in their 12-month finding on a petition to list the American eel as threatened or endangered generally agreed with this assessment and concluded:

> *"…that turbines are responsible for decreases in abundance at a local or regional scale, but turbine mortality is not a significant threat to the American eel at a population level."*

TABLE 3.4.5-1: AMERICAN EEL ABUNDANCE IN 25 MARYLAND BIOLOGICAL STREAM SURVEY SITES. SOURCE MBSS DATABASE AS CITED IN EPRI 2011.

Rank	Site ID	Basin	Avg. Width (m)	Number	Density (no./m^2)
1	STMA-113-R-2000	Lower Potomac River	2.38	174	0.975
2	LANG-204-R-2002	Chester River	3.18	189	0.792
3	LOCR-114-R-2002	Chester River	1.10	60	0.727
4	NEWP-116-R-2001	Ocean Coastal	3.47	177	0.680
5	SASS-104-R-2001	Elk River	2.70	84	0.415
6	STMA-104-R-2000	Lower Potomac River	2.58	75	0.388
7	AA-N-160-215-97	West Chesapeake Bay	4.80	128	0.356
8	CHIN-119-R-2001	Ocean Coastal	1.33	35	0.351
9	DEER-414-R-2001	Susquehanna River	21.38	557	0.347
10	OCTO-107-R-2004	Susquehanna River	0.73	19	0.347
11	LOGU-202-R-2002	Gunpowder River	3.03	78	0.343
12	BOHE-105-R-2003	Elk River	2.48	62	0.333
13	CH-S-044-303-95	Lower Potomac River	6.08	149	0.327
14	TRAN-219-R-2004	Nanticoke/Wicomico Rivers	6.70	162	0.322
15	LOGU-109-R-2002	Gunpowder River	1.45	35	0.322
16	DO-S-003-202-95	Nanticoke/Wicomico Rivers	3.13	72	0.307
17	QA-N-033-321-95	Chester River	4.43	100	0.301
18	WI-S-023-112-95	Nanticoke/Wicomico Rivers	1.98	44	0.296
19	DEER-408-R-2001	Susquehanna River	25.58	560	0.292
20	STMA-119-R-2003	Lower Potomac River	0.98	21	0.286
21	TA-N-042-104-95	Chester River	1.68	36	0.286
22	WYER-206-R-2003	Chester River	5.00	105	0.280
23	BA-P-203-215-96	Gunpowder River	3.85	79	0.274
24	WI-S-057-309-97	Pocomoke River	4.68	93	0.265
25	LANG-109-R-2002	Chester River	2.42	46	0.253

FIGURE 3.2-1: AMERICAN EEL RANDOM STRATIFIED (RSI) AND RIVERS ONLY (RO) FIXED TRANSECT INDICES USING THE WEIGHTED GEOMETRIC MEAN CATCH OF EELS PER TRAWL IN TRIBUTARIES TO THE CHESAPEAKE BAY AS PUBLISHED IN FABRIZIO AND MONTAINE (2007).

4.0 UPSTREAM EEL STUDIES

Conowingo Study 3.3 Biological and Engineering Studies of the American Eel at Conowingo Project – 2010 Eel Sampling below Conowingo Dam (Normandeau and Gomez and Sullivan 2012a, b)was developed to investigate the locations where eels congregate below Conowingo Dam with the goal of determining an appropriate location for more permanent upstream eel passage facilities.

The USFWS initiated eel studies on upstream migrant eels at the Conowingo Dam in 2005 and they continue to the present. Eels have been sampled with ramp traps and pots near the West Fish Lift (WFL). Elvers collected in the traps have been transported upstream beginning in 2007. Additionally, Exelon sponsored sampling at other locations below the Conowingo Dam in 2010, with a second sampling season in 2011.

As described below, captured eels generally fell into two size groups: 76 – 195 mm and 256 – 770 mm. Aging studies of 77 eels in 2011 showed both juvenile eels (age 1 and 2) and small yellow eels (age 3 – 5) in the smaller size range. Rather than differentiating eels in this range into the two life stages, eels in this range are described in this report as young eels. The larger size range generally corresponded to yellow eels older than age 5, and these eels are subsequently referred to in this section as yellow eels.

4.1 Results of USFWS Studies in the Conowingo Tailrace

The first two years of sampling in 2005 and 2006 collected relatively few young eels as only 42 and 19 were captured, respectively. There were 78 and 2,008 eels caught in pots for 2005 and 2006, respectively. The lengths of all eels caught in 2005 ranged from 93 to 733 mm and those caught in 2006 ranged from 83 to 735 mm. Sampling was conducted from May 18th through August 10th in 2005 and from May 10 to June 26 in 2006. In 2007, sampling occurred from May 30 through August 8 and 3,837 young eels were captured in the ramp trap. Peaks in young eel abundance occurred at the end of June and July. Lengths of young eels ranged from 76 to 169 mm. Fifty one yellow eels were collected in pots and they ranged in size from 256 to 734 mm. In 2008, substantially more young eels, 43,059, were captured than in previous years. Sampling occurred from May 13 through August 4 2008. Approximately 17,500 of the collected young eels were released into Conestoga Creek (upstream of Holtwood Dam) in Pennsylvania. Lengths of young eels ranged from 90 to 176 mm. The lengths of 38 yellow eels collected in pots ranged from 321 to 770 mm. Of the yellow eels captured, 13 were new captures and 25 were recaptures. In 2009, the number of young eels caught in the May 29 through September 2 sampling decreased to 17,437. A total of 15,316 were stocked in Conowingo Creek, PA (above Conowingo Dam). Lengths of young eels collected in the ramp trap ranged from 92 to 162 mm while the lengths of the 116 yellow eels captured in the pots ranged from 318 to 655 mm. Of the yellow eels captured, 68 were new captures and 49 were recaptures. In the May 31 through August 2, 2010 sampling, the USFWS collected 24,000 young eels with approximately 17,500 transported to Buffalo and Conowingo Creeks in Pennsylvania. The young eels ranged in size from 95 to 195 mm in length. Eel pots collected 25 yellow and silver eels ranging in size from 335 to 696 mm with 11 new captures, 9 recaptures and 5 that were not scanned for tags.

4.2 Results of 2010 Exelon Eel Studies

Conowingo Study 3.3 Biological and Engineering Studies of the American Eel at Conowingo Project – 2010 Eel Sampling below Conowingo Dam (Normandeau and Gomez and Sullivan 2012a) provides the results of an eel ramp and eel pot sampling study conducted from June 15, 2010 through September 30, 2010 to assess potential locations for upstream eel passage facilities at Conowingo Dam. One sampling ramp was placed adjacent to the dividing wall between the tailrace and EFL (EFL spillbay ramp 2010) while the other ramp was placed on the east abutment end of the spillway at Spillbay 50 (spillbay 50 ramp 2010). Figure 4.2-1 illustrates the locations of the ramps. Eel pots were fished adjacent to the ramps. Both gear types were similar in design and deployment as those used by the USFWS in their comparable study programs.

The ramps were fastened to the spillway lip and located at or near spillway drainage or overflow. The EFL spillway ramp entrance was located at a constant discharge from a spillway lip drain. The spillbay 50 2010 ramp extended toward several small spillway overflows in case these were attracting upstream migrants.

There was difference in the number of young eels caught between the two locations. The spillbay 50 ramp 2010 caught 158 young eels, while the EFL spillway ramp only captured 8 individuals. The opposite pattern was seen for the eel pots as the EFL spillbay 2010 pots caught 91 yellow eels, while the spillbay 50 2010 pots yielded only a single yellow eel.

Lengths of young eels collected at the EFL spillbay ramp were 103 to 148 mm, while those collected from the spillbay 50 ramp ranged from 92 to 154 mm. A few yellow eels were also taken at the ramps; their lengths ranged from 301 to 640 mm. The young eels were age 1 or 2, while the ages of the yellow eels were mainly 7, 8 or 9. Eels of ages 4 through 6 were not represented in the catch from either gear, which may be due to gear selectivity. The Enkamat® substrate used on the ramps is reportedly size-selective for eels less than 260 mm (Solomon and Beach 2004b), and neither the ramps nor the pots captured eels between 154 and 260 mm. The length range of eels collected in the spillbay 50 pots ranged from 115 to 650 mm and the lone yellow eel collected in the EFL spillbay pots measured 525 mm. Since neither Enkamat® nor two sizes of pots caught eels in the 155-300 mm size range, attempts were made during the 2011 field sampling season to capture the age classes not represented in the 2010 study.

The inception of the Exelon 2010 study lagged the start of the USFWS study, due to high flows delaying installation of the Exelon ramps. The Exelon traps had to be set in relatively exposed positions below the spillway and were subject to effects of high water, while the USFWS ramp sat higher on the bank and thus was not as exposed to high water conditions. The beginning portion of the upstream migration of eels may have been missed in the Exelon study, however, the majority of the eels collected at the USFWS ramp trap occurred in June and July and far fewer were collected in May, thus suggesting that little was missed. In addition to the initial delay in the Exelon 2010 upstream eel study, remnants of a tropical storm caused high river flows that resulted in the study ending in late September, slightly ahead of the planned mid-October end date.

4.3 Results of 2011 Exelon Eel Studies

Conowingo Study 3.3 Biological and Engineering Studies of the American Eel at Conowingo Project – 2011 Eel Sampling below Conowingo Dam (Normandeau and Gomez and Sullivan 2012b)provides the results of year two of an eel ramp and eel pot study below Conowingo Dam. Year two was conducted from June 23, 2011 to September 5, 2011 and was a continuation of the assessment of potential upstream eel passage locations at Conowingo Dam. In 2011, two ramps per site, each with different substrates (Figure 4.3-1) were deployed. In addition to the Enkamat® substrate utilized in 2010, a second substrate called AkwaDrain™ was placed in a separate ramp adjacent to the Enkamat® ramp.

The EFL spillway ramps 2011 were constructed and placed parallel to the wing wall near the EFL on June 23, 2011 (Figures 4.3-2 and 4.3-3), with additional water cascading down from the top of the wing wall to create disturbance and additional flow for attraction purposes. The EFL spillway ramps 2011 operated for nearly two weeks prior to the installation of the spillbay 50 ramps 2011.

The spillbay 50 sampling location used in 2010 was structurally damaged by heavy spring rainfall. Therefore, on July 1, 2011, the ramps (Figure 4.3-4) were deployed at a location adjacent to the location used in 2010. The spillbay 50 ramps 2011 were constructed on scaffolding located near the mouth of a small intermittent stream entering the Susquehanna River near the base of the dam (Figure 4.3-5). This provided natural water flow patterns that may have attracted eels to the ramp. Eel pots were fished adjacent to both sets of ramps as in the 2010 sampling.

A total of 1,159 eels were collected. Of these, 1,100 were young eels collected from the ramps. The spillbay 50 ramps 2011 collected 539 young eels, with 133 harvested in the Enkamat® substrate and 406 captured from the AkwaDrain™ substrate. The EFL spillway ramps 2011 collected 561 young eels, with 405 harvested in the Enkamat® substrate and 156 collected in the AkwaDrain™ substrate. Lengths of these eels ranged from 87 to 188 mm total length (TL), with an average size of 124.9 mm. Yellow eels harvested from the eel pots totaled 59; all yellow eels were collected from the EFL spillway pots 2011. The length range of eels collected in pots ranged from 300 to 689 mm TL, with an average length of 515.4 mm.

Hourly water temperatures were recorded throughout the study period. Water temperatures typically rose and fell three to four degrees Fahrenheit (°F) every day. The water temperature in the Conowingo spillway ranged from a low of 73.7° F on September 3 to a high of 90.8° F on July 24. A comparison of water temperatures to catch at the ramps revealed no apparent relationship.

The study period encompassed three new moon periods and two full moon periods. A possible, but weak and limited relationship between the number of eels collected and moon periods was observed during part of the study period.

In 2011, 77 eels were preserved for otolith ageing. A total of 73 of the 77 otoliths preserved were aged successfully. The majority of eels were split at age 1 or 2, and 3 to 5 years of age. A large gap in age at years 6 to 8 is apparent due to a lack of specimens in the 189 to 299 mm size range. Larger eels were aged as 9 to 17, plus one at age 19.

Nighttime surveys along the base of the spillway portion of the dam were conducted to document areas of eel congregation in the spillway. During these surveys, eels were only observed in abundance below crest gate #30. Located immediately downstream of crest gate #30 is a plateau of concrete or macadam. Young eels were observed at this location during all three nighttime surveys. Young eels were also observed, (although not in abundance) near seeps, or areas where water trickled over the spillway sill, and when water cascaded down bedrocks associated near these seeps. In these areas where young eels were observed, predatory fish such as channel catfish, and striped bass also were observed.

Although the 2011 study period was bookended by heavy rains that attributed to a late start and early finish, the overall catch of young eels was substantially higher in 2011 (1,159), than in 2010 (258) . Once the study was underway, the ramps sampled eels for 74 days as compared to 106 days in 2010. Collection of young eels and yellow eels was consistent throughout the entire study period with a few exceptions. The spillbay 50 2011 facility collected 239 young eels from a single ramp on July 11, 2011.

Predation from both land-based animals and birds was not directly observed but may have occurred at the east side. On several collection days, raccoon tracks were present in the muddy areas near the ramps. This same area exhibited an abundance of avian fecal matter and feathers littered on and around the ramp platform. The 2011 catch of young eels was much higher than the total collected in 2010.

An increase in young eel catch during the 2011 study period may be attributed to additional ramps, (four in 2011, as opposed to two in 2010), additional attraction water and the addition of scent attraction.

In contrast to 2010, both sides of the spillway captured nearly equal numbers of young eels, with the EFL spillway 2011 ramps collecting slightly more than the spillbay 50 2011 ramps. The absence of eels from ~189 to 299 mm is generally similar to previous year's collections by Normandeau Associates and USFWS. Attempts to collect this size range of eels with smaller-mesh pots (.25 inch) failed. Enkamat® is reportedly size-selective for eels less than 260 mm (Soloman and Beach 2004), but neither Enkamat® nor either type of pot deployed was successful catching eels in the 189 to 299 mm size range.

FIGURE 4.2-1 LOCATIONS OF EEL RAMPS AND POTS AT CONOWINGO DAM FOR THE 2010 AND 2011 UPSTREAM EEL SURVEYS

FIGURE 4.3-1: ENKAMAT® AND AKWADRAIN™ SUBSTRATE.

FIGURE 4.3-2: WEST SIDE ELVER RAMPS WITH ADDITIONAL ATTRACTION WATER, 2011.

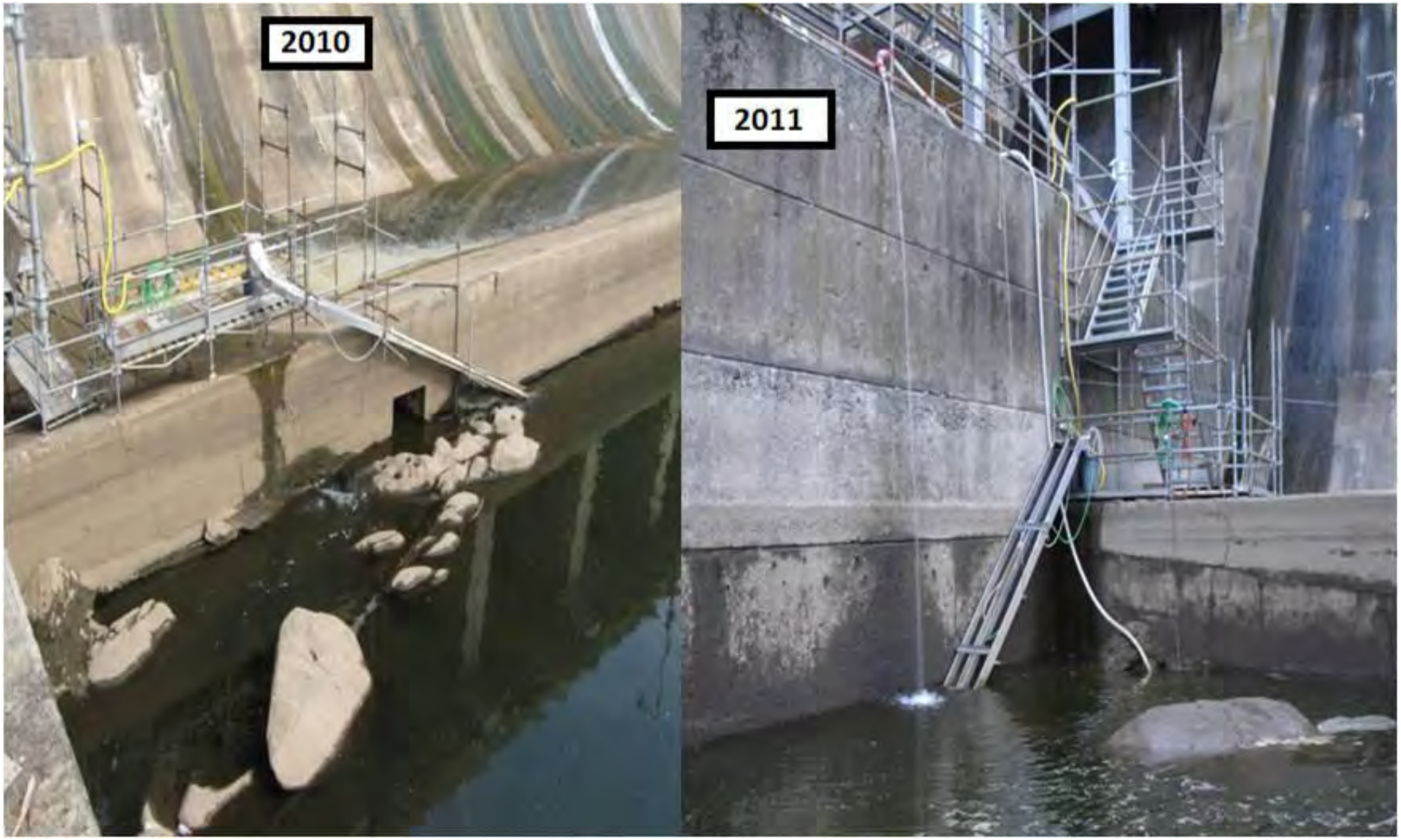


FIGURE 4.3-3: COMPARISON AND SAMPLING LOCATIONS OF 2010 AND 2011 WEST SPILLWAY RAMP LOCATION.

FIGURE 4.3-4: LOCATION AND CONFIGURATION OF EAST SIDE ELVER RAMPS IN 2010 AND 2011.

FIGURE 4.3-5: EAST RAMP WITH NATURAL ATTRACTION FLOW FROM INTERMITTENT STREAM, 2011.

5.0 UPSTREAM PASSAGE

This section of the report consists of a desktop analysis of the feasibility for potential upstream migrating eel passage facilities at the Conowingo Project. The analysis is based on engineering and biological considerations of upstream eel passage facilities at other hydroelectric projects and Conowingo specific studies on the size of the eels and the seasonality of the migration in the Susquehanna River. Preliminary cost data associated with various upstream passage facilities are also identified.

5.1 Background

Upstream eel passage for several eel species and varying sizes of eels has been successful at many hydroelectric facilities and water control dams around the world (Solomon and Beach 2004a). Eel ladders appear to be the most successful; however, eels have been passed through fish lifts (largely as incidental catch), traditional fish passes, such as Denil ladders (again largely incidental), as well as moved upstream with trap-and-transport programs.

The USFWS has studied upstream eel passage at Conowingo Dam since 2005. As stated in section 4.1, the temporary USFWS eel ramp is installed near the WFL on the west bank of the tailrace. These results will be used in conjunction with the results of Exelon's eel sampling program, to evaluate passage options at Conowingo Dam.

Solomon and Beach (2004a) in a comprehensive review of upstream migrating eel passage facilities offered some fundamental design considerations for a passage facility. These were:

- The eels must be able to locate the passage entrance;
- The eels must be able to enter the structure without unnecessary stress;
- The eels must be able to complete passage through a facility without overexertion or too much stress (reduce fallback within the ramp);
- The eels must exit in an area to minimize entrainment through project turbines or spillage over the dam, alternatively the eels can be trapped at the top of the ramp and transported upstream (reduce drop-back after passing upstream);
- The structure must be operational under all head and tail water conditions experienced at the site during the migration period or, at the very least, for the prevailing conditions for the majority of the period;

- The structure should be protected from excessive predation;
- When possible, measures to determine passage effectiveness should be incorporated into the design of the structure; and
- Structures should be protected from high flows and debris and, if necessary, removed in the winter.

For the most part, all upstream eel passage facilities consist of the following: a climbing ramp with appropriate substrate; a thin layer of water flowing down the ramp to allow the eels to remain wetted and to provide some behavioral stimuli to encourage the eels to climb the ramp; and typically some larger volume of attraction flow to draw the eels to the entrance of the ramp. The length of the ramp, angle and the type of climbing substrate are the only things that physically differentiate most eel passage facilities.

An eel ladder is typically quite long and extends the full height of the dam. It transports the migrating eels, of their own volition, from the tailrace to the forebay. Because of the substantial height of some dams and the potential for steep climbing angles, the ramp of an eel ladder can frequently zigzag up the face of the dam, making it less steep, but also longer. Resting pools are sometimes located in the switchback locations. For a fish lift type passage facility, there typically is a relatively short climbing ramp which is used to attract, collect and deposit the eels into a transport vessel that is then mechanically lifted to the top of the dam where the eels are released into the forebay. In a trap and transport passage system, the eels are attracted via a short section of climbing ramp and are deposited into some form of holding facility. Periodically the collected eels are removed from the holding facility, transported, and then released at locations upstream of the dam.

There are advantages and disadvantages to each type of facility. In the next sections we will discuss these more thoroughly, particularly as they relate to the Conowingo Project.

5.1.1 Eel Ladders

Eel ladders for upstream passage essentially consist of five elements:

- Inclined ramp;
- Water flowing down the ramp to wet the eels and to encourage the upward climbing behavior;
- Climbing substrate that is suitable to the size of the eels;

- Attraction flow to draw the eels to the entrance of the ramp; and
- Holding tank or appropriate egress structure to gently release the eels into the forebay/upstream pond.
- There potentially is a sixth component: some form of a passage pipe or sluice to move the eels upstream of the forebay, thus minimizing possible entrainment and drop-back through project turbines.

Properly located and constructed eel ladders tend to function efficiently and effectively. Assuming the pumps and plumbing function properly; ladders can operate with minimal human intervention.

There are also disadvantages to ramps. They require a number of different pumps that can fail from overuse, clogging or power failure. One of the more significant potential disadvantages of an eel ramp at Conowingo is that the eels at this location are relatively small as the site is close to the ocean. As the majority of the eels will be small, the angle of the ramp or ramps may need to be reduced and additional resting pools added. This will increase the length of the ladder and the climbing time required to make the ascent, both of which can reduce efficiency and increase stress to the eels.

The ramp and supporting superstructure required at a Conowingo eel ladder will be large and potentially subject to damage due to high flows and ice. The structure would have to be protected from these potentially damaging events, particularly during the winter for ice and in the early spring during the freshet in order to allow continued passage of elvers and small yellow eels each year.

The angle of the ramp should be no greater than 45° and should include a cover to limit ambient light and provide overhead protection from predation (Solomon and Beach 2004a, 2004b). Table 5.1.1-1 provides a baseline slope and the associated length per 3.3 ft of head suggested for ramps associated with eel ladders. Substrate can consist of many different materials, including Enkamat, AkwaDrain, Milieu substrate, bristle/brush, or natural substances. The primary function of the substrate is to provide structure to assist climbing eels. Upstream eel passage has been monitored at the St. Lawrence-FDR power project on the St. Lawrence River for several years. Passage efficiency (the number of eels exiting the ladder divided by the number entering the ladder) was 86.7 percent during the 2010 survey period and was consistent with previous results in 2006 (83.2 percent), 2007 (84.4 percent), 2008 (88.2 percent) and 2009 (87.5 percent) (NYPA 2010). It should be noted that the St. Lawrence eels utilizing the ladder were, generally, larger (380 – 405 mm) than young eels that were taken with eel ramps in 2010 and 2011 at

Conowingo (76 – 195 MM). Table 5.1.1-2 provides information about ramps used for eel passage at other facilities with associated information about the facilities.

The widths of the eel ramps listed in Table 5.1.1-2 ranged from 1.0 to 2.3 ft. This is wide enough to accommodate most upstream eel passage needs. As a rule, wider does not necessarily mean greater passage. Most of the ramps had independent water sources and did not rely upon headwater, so water distribution within the ramp allowed the entire width to be used. Solomon and Beach (2004a, 2004b) recommend a width of 1.0 to 1.5 ft and a channel depth of 4.0 inches to pass elvers and yellow eels.

Flows for the ramps in the studies reviewed range from less than 1 to 36.2 gpm (0.002 to 0.17 cfs). Water depth measurements within the ramps were generally not made, but, depending on the slope, there was likely less than 0.2 inch water depth. It has been postulated that restricted water depth is essential for the efficient passage of small elvers (Solomon and Beach 2004a). Within the studies reviewed by Solomon and Beach (2004a, 2004b), the best passage results were obtained for ramps with water depths less than 0.8 inches for a 15° slope, 0.4 inches for a 30° slope and 0.2 inches for a 45° slope.

To minimize drop-back, a passage pipe has been used at several facilities to ensure that eels are introduced upstream at a safe distance from the turbines. Water in the pipe flows from the release location toward the ladder, and migrating eels naturally swim into the flowing water to transit the pipe There may be substrate in the pipe to reduce water velocity and to allow the eels or elvers to crawl more than swim; however, it is not required for passage. The substrate would be of similar material to a ramp. Debris fouling can be a problem, which is why pipe passes are better suited to large impoundments where settling can occur (Solomon and Beach 2004b). Pipe passes tend to require more maintenance and offer no advantages over open channel designs where the open channel is feasible, assuming the open channel can have a closed cover to minimize predation and to provide a dark environment for eel passage.

5.1.2 Lifts

Fish lifts have been used for a long time to pass fish above barriers, and they have been operating at Conowingo since 1972. Fish lifts have the ability to pass eels; however, only two lifts in France have been constructed exclusively for this purpose. Typically, a short section of climbing ramp deposits eels into a hopper that is periodically lifted by an electric winch and the fish are deposited above the barrier or into a facility that has access above the barrier. The major drawback of eel lifts is that they are expensive to construct, and have many mechanical parts that are subject to failure. They are, like eel ladders, subject to flow and ice damage. They also have the same restriction in that the eels typically are released close to the dam face where they are potentially subject to entrainment, and their use is generally restricted to high head situations (Solomon and Beach 2004b).

A number of fish lifts such as at the Holyoke Dam, in Springfield, Massachusetts pass eels; however, it is wholly coincidental with the operation of the lift for other species (e.g., American shad on the Connecticut River).

5.1.3 Trap and Transport

There are many trap-and-transport programs for elvers and small eels throughout the world. Several of the facilities described in Table 5.1.1-2 were actually "trap-pass" facilities or facilities where the eels ascend all or part way above an obstruction, exit the ramp into a holding tank or facility and are transported upstream. The USFWS currently has a trap-and-transport program below Conowingo Dam where the eels are captured near the WFL and are transported to various locations upstream.

The advantages to trap and transport are that the infrastructure requirements are less than a volitional system and essentially consist of just a short climbing ramp with appropriate flows, substrate and holding facilities. One significant advantage is that the eels can be released at numerous locations upstream, thus avoiding the likelihood of drop-back and entrainment and also potentially avoiding the need for additional passage facilities at other dams/hydro-projects upstream. As long as water quality is maintained in the collection and transport facilities, survival of elvers and yellow eels is typically very high.

Some of the disadvantages of trap and transport are that it requires manual collection of the eels and upstream transportation and the holding of eels can result in some additional stress and skin abrasion.

The upstream release location for transported eels is an important consideration. Releasing young eels into areas where their presence may impact other aquatic resources or where subsequent collection of maturing eels for downstream transport is a potential impact. Such impacts can be minimized by careful selection of the release locations in consultation with the appropriate resource agencies

5.2 Upstream Passage Options at Conowingo Project

A preliminary review of eel passage facilities on several river systems provided background and information on the practical alternatives for eel passage at Conowingo. At the St. Lawrence-FDR Power Project, with a comparable civil works configuration and operating head to Conowingo, a state-of-the-art eel passage facility was constructed in 2004 that passed eels with a mean length range of 380 to 405 mm. If an eel passage ladder is installed at Conowingo, it would likely include technologies similar to the 110-ft long eel ramp and 985-ft long upstream passage pipe at the St. Lawrence-FDR facility, although the size range of eels using the temporary ramps at Conowingo since 2005 is 76 to 195 mm with larger eels ranging from 256 to 770 mm being captured in eel pots. An additional difference in the St. Lawrence eel passage facility and any similar facility that may be constructed at the Conowingo Dam is the roadway over the Dam. Any design to move eels from the tailrace of the Dam to Conowingo Pond would need to bypass US Highway 1.

As summarized in Section 4.0, eels have been collected concurrently in 2010 and 2011 at three trial locations: the West bank of the tailrace near the WFL (USFWS), the spillway near the EFL (EFL Spillway Ramp 2010), and on the East bank below the dam (Spillbay 50 Ramp 2010). Over the course of the 2-year study, more eels were collected on the West bank followed by the East bank and the EFL.

Eel passage options were evaluated at both the East and West bank of Conowingo Dam. Based on data from 2010 and 2011, the West bank appears to be a better location because more eels were captured in this location and is summarized in Section 4.0. Three options were assessed for upstream passage facilities located on the West bank; two are presented for the East bank. They are described in more detail below.

For all potential eel ladder configurations, consideration was given to an exit location that will allow continued upstream movement with minimal drop-back. If the eels exit the ladder too close to the powerhouse, downstream currents could cause them to be entrained through the turbines, which could result in the need for a passage pipe or similar type structure to move the eels further upstream, away from the turbines.

5.2.1 West Bank Option 1, Trap and Transport

The first option presents a configuration for trap-and-transport operations, see Figure 5.2.1-1 for a plan view of the option and Figure 5.2.1-2 for an elevation view. For this option and the additional alternatives described below, the ramp entrance is designed to be at the minimum expected tailwater at El. 12 ft. As noted in Section 2.1.4, normal operating tailwater, with all units generating, is nominally El. 21.5 ft. It is not uncommon for tailwater elevations to fluctuate from El. 12.0 ft to El. 25.0 ft. The lower section of the ramp will have removable covers or grating to allow eels to enter with differing water surface elevations. For this option and all options presented subsequently, it is assumed that an attraction flow will be provided at the ramp entrance. The exact flow rate will be determined as field studies proceed. The attraction flow pumping system will also be used to provide water to wet the media of the ramp.

From the entrance, located near the downstream end of the WFL foundation, the ramp climbs to an elevation slightly above the parking lot elevation. The length of the proposed ramp is approximately 65 ft. It then exits into a collection tank housed in a small enclosed structure, which will also hold pumps, a compressor, and other necessary equipment. The proposed 45^{o} eel ramp would have a stairway running along the shore-side for personnel access, along with access platforms at the entrance and exit areas. The platform near the entrance would also be equipped with an access ramp to reach the entrance at low tailwater elevations.

The proposed eel ramp or trough for all west bank and east bank options would be approximately 3-ft wide. A sectional detail is presented on Figure 5.2.1-3. The ramp will provide two side by side 18-in wide channels for climbing media. The primary purpose for this is redundancy, having two eel ramps operating in tandem will reduce the likelihood that the system would suffer extended outages during the critical passage season. It will also allow for trials to determine the most effective media type for the size eels being observed in the system. Another consideration in this approach is that there may be different size eels using the system. The preliminary design provides for two side-by-side troughs with different media so that both various sized eels may efficiently use the same ramp.

The conceptual opinion of probable construction cost (Cost Opinion) for this alternative is presented as Table 5.2.1-1, with a total of $639,000. Also included in this table is an estimate of annual operational costs for staffing the facility and transporting eels to upstream tributaries, which was estimated as approximately $585,000 per year. The frequency of trips and duration of the passage season is uncertain at this time. For the operational costs presented, one trip per day was assumed to Buffalo Creek or a location of comparable distance from the project (300 mile round trip); this cost would be reduced with a shorter round-trip distance. The length of the season was assumed as six months. Purchase of one transport vehicle is included in the capital (non-operational) portion of the Cost Opinion. This transport vehicle would be a flat-bed pickup outfitted with a 1,500-gallon transport tank, two trash pumps and piping for water circulation, a dissolved oxygen injection system (two oxygen cylinders, a regulator, and hosing), and a temperature monitor. As mentioned above, the exact needs of the transport program are unknown. This transport vehicle was carried in the costs to include an allowance amount; the actual transport needs may differ.

5.2.2 West Bank Option 2, Eel Ladder with Pipe to West Shore

The second option for the West bank presents a configuration that would allow full volitional passage of eels from the tailrace to Conowingo Pond upstream of the dam. The plan view of this option is presented as Figure 5.2.2-1, with an elevation view shown in Figure 5.2.2-2.

The entrance to the eel ramp would be near the downstream end of the existing WFL foundation at El. 12 ft. At the base of this first section would be a personnel access platform to service the eel ramp entrance. This is proposed to be at El. 25 ft, which is the top of the WFL foundation structure. The ramp would run below the travel rail for the fish lift hopper at approximately 45^{o} to the elevation of the existing asphalt with a stairway along the shore-side. For the options presented for the West and East banks, if there is a section of eel ramp there is generally a parallel stairway system with periodic landings and railings located immediately to one side.

At El. 46 ft, there would be a platform with a catwalk to the top of the existing retaining wall. This platform would hold a resting pool that could serve as an eel collection point if desired. It is also expected that the attraction water pumping system would be on this platform. For this and the other resting or transfer pools presented, the incoming eel ramp would exit 6-in above the water surface after an apex with short section of eel ramp without climbing media. The outgoing entrance section would begin 6-in below the water surface of the pool. This section of ramp would run at 45^{o} towards the column of the powerhouse, to the right of the existing maintenance door. An access platform with railing would be fastened to the side of the building, at approximately El. 77.5 ft, with another resting pool. From here the eel ramp would turn to run along the powerhouse towards the West bank, climbing at approximately 35^{o} until it reaches the headpond level and exits into the transfer pool. The total length of proposed eel ramp is approximately 180 ft.

The transfer pool would be on a platform at El. 106 ft, with a 6-in diameter insulated transfer pipe exiting the West side. The flow through the pipe will be on the order of 0.3 cfs, to provide a velocity in the pipe of approximately 1.5 fps. The transfer pipe would run at an approximately level grade towards the dam and US HWY 1. It will be necessary to bore beneath the roadway and encase the transfer pipe. The road is at approximately El. 117 ft in this location, providing suitable cover over the transport pipe proposed at El. 108 ft. The transfer pipe would end approximately 600-ft upstream of the dam (total length is approximately 835-ft) at a shoreline discharge facility, as shown on Figure 5.2.2-1 with a corresponding detail on Figure 5.2.2-3. The shoreline discharge facility will have a small structure to protect and secure the equipment, which will include the redundant pumping system for the transport pipe. This facility has the ability to deliver eels to the pond over the normal range of water surface elevations.

Within the shoreline discharge facility will be an exit pool, where the eels finish their up-current swim through the transfer pipe. The pool will have a short section of eel ramp, an apex, and then a section of trough with no climbing media into a 4-ft diameter iron pipe that will run along the slope of the river bank out into the Susquehanna River. This 4-ft pipe will have periodic 2-in diameter holes for the eels to exit the system into the river over the range of expected headpond levels. Above the pipe will be large angular stone or riprap for predator and ice/debris protection. The stone will need to be placed loosely to allow the eels to exit.

It should be noted that the portion of this option from the tailwater entrance to the resting pool at El. 46 ft could be constructed as a first phase and initially operated as a trap-and-transport facility until it is determined that the entrance is in a suitable location (enough eels are entering) and constructing the upper portion of the system to the headpond is warranted.

The Cost Opinion for this option was estimated to be $1,695,000 and is presented as Table 5.2.2-1, which presents capital cost only.

It is assumed that this and the other volitional passage alternatives would require full time oversight during the passage season. It is expected that one full time employee would be required for six months of the year (i.e. the assumed passage season), with an additional full time employee needed for the first and last month of the season. This would result in an order of magnitude cost of $200,000 annually. This does not include the additional labor and materials that will likely be necessary during the commissioning period of calibrating the equipment and facility for reliable operation, which would likely occur during the first several seasons.

5.2.3 West Bank Option 3, Partially Buried Ramp with Pipe to West Shore

The third upstream passage option evaluated for the West bank is presented as Figures 5.2.3-1 and 5.2.3-2. This alternative would provide full volitional passage over the dam and is also an approach that utilizes a ramp-to-pipe system similar to West Bank Option 2. The major difference for this alternative is that a portion of the eel ramp would be installed beneath the surface of the asphalt parking area near the administrative building. This design concept was pursued to limit interference with vehicle circulation and space needs for operations and maintenance staff.

The ramp entrance would be near the downstream end of the WFL foundation with an access platform and ramp as in the previous two options. The eel ramp would climb at approximately 20^{o} to the southern corner of the administration building; the majority of this section would be beneath the asphalt parking area. To provide access, a 5-ft wide trench with concrete retaining walls and floor would house the below-ground portion of the ramp covered with a grating capable of being driven over. The eel ramp would daylight to the left of the central door on the southeast side of the administration building and then enter a resting pool constructed at the asphalt grade with a water surface at approximately El. 49 ft. This pool could also be used as an eel collection point if desired. The total length of the eel ramp would be approximately 210 ft.

From the resting pool, the eel ramp climbs at 45° to the approximate headpond level along the southwest side of the administration building. It will be necessary to construct a steel support system for the eel ramp and access stairs and platforms, which could be partially integrated with the building structure. At El. 106 ft is an access platform with a transfer tank. The 6-in transfer pipe would exit this transfer tank and run approximately 785 ft to a shoreline discharge facility located upstream on the west shore of the river, in a similar location as in Option 2. The estimated costs for this alternative are presented in Table 5.2.3-1, with a total cost of $2,230,000.

As with Option 2, the portion of this option from the tailwater entrance to the resting pool at El. 46 ft could be constructed as a first phase and initially operated as a trap-and-transport facility until it is determined that the entrance is in a suitable location (enough eels are entering) and constructing the upper portion of the system to the headpond is warranted.

5.2.4 East Bank Eel Ramp

The passage options considered on the East bank include a volitional passage option that would pass eels from the tailrace to the headpond, and a trap-and-transport program that could be constructed as a first phase as described for Options 2 and 3 for the West bank.

Both of these options are presented on Figure 5.2.4-1, located at the East end of the spillway at the beginning of the non-overflow abutment section of the dam. The trap-and-transport option comprises the 35-ft long lower section of eel ramp running at 45° from the normal tailwater up to El. 38 ft, plus the resting pool at this elevation. The lower section of the ramp will have removable covers or grating to allow eels to enter with differing water surface elevations. The eel ramp would have a stairway with railing and access platform at the lower end. This part of the system could be installed as a stand-alone system prior to building the full eel ramp to the elevation of the headpond. If sufficient eels are collected, the remainder of the system could be implemented. Table 5.2.4-1 presents costs for this alternative including purchase of one transport vehicle and daily trips for stocking collected eels in upstream tributaries, including the corresponding annual operations, costs. The capital cost was estimated to be $622,000, with an annual operations cost of approximately $585,000 per year.

Constructing the entire system would provide full upstream passage from the tailrace elevation to the normal headpond level. The eel ramp would continue from the resting pool at 45° to the headpond level where it would exit into a transfer pool. The total length of proposed eel ramp is approximately 135-ft.

Eels would exit the transfer pool via a 6-in pipe cored through the dam below the expected minimum headpond elevation. The flow through the transfer pipe would be fed by the headpond and controlled by a gate. Screening or other predation control will be necessary on the upstream end of the transfer pipe. The cost for this option was estimated to be $1,125,000, as shown in Table 5.2.4-2.

TABLE 5.1.1-1 METRICS TO DETERMINE SLOPE AND LENGTH OF EEL RAMPS.

Slope	Length (ft.) for 3.3 feet of head
10°	19.0
15°	12.8
20°	9.5
30°	6.6
35°	5.6
45°	4.6

Source: Solomon and Beach 2004a, 2004b

TABLE 5.1.1-2 INFORMATION ON RAMPS ASSOCIATED WITH EEL PASSAGE FACILITIES.

Project Name	Project Location	Dam or Weir Height (ft.)	Passage Type	Substrate	Length (ft.)	Ramp Angle	Flow in Ramp (cfs)	Average Size (mm)	Eel Size (elver, small yellow)
Saunders (old ramp)	Cornwall, Ontario	82.0	Ramp	Artificial Vegetation	513.1	12°	0.08		small yellow
Saunders (new ramp)	Cornwall, Ontario		Ramp/Pipe	Eel-Ladder (Milieu)					small yellow
St. Lawrence-FDR	Massena, NY	82.0	Ramp/Pipe	Eel-Ladder	110/985	35°		380-405[1]	small yellow
Roanoke Rapids (north)	Roanoke Rapids, NC	92	Ramp	Eel-Ladder	105		0.08	170[2]	elver/small yellow
Roanoke Rapids (south)	Roanoke Rapids, NC	92	Ramp	Eel-Ladder	27		0.17	170	elver/small yellow
Fort Halifax Dam	Winslow, ME	16.1	Ramp	Enkamat®	24.3	30°	0.005		elver/small yellow
Benton Falls	Winslow, ME	24.0	Ramp	Enkamat®	52.8	39-47°	NA		elver/ small yellow
Greenville Dam	Norwich, CT	NA	Ramp	Bristle/ AkwaDrain™	52.2	27°	0.002-0.004		elver/small yellow
Westfield Dam	MA	9.8	Ramp	AkwaDrain™	NA	40°	0.01		elver/small yellow
Woronco Hydroelectric Project	MA	25	Ramp	AkwaDrain™	NA	N/A			elver/small yellow
Chambly Dam	Quebec, Canada	16.4	Ramp	Plastic	30.5	52°	0.02		small yellow
Beauharnois Dam	Quebec, Canada	78.7	Ramp	Eel-Ladder	170.0	up to 45°	0.01		small yellow
Upper Lode Weir	Tewkesbury, England	3.9	Ramp (V-shaped channel)	Coarse gravel/bristle	NA	10˚			Elver
Stanchard Pit	Tewkesbury, England	4.9	Ramp	Bristle	NA	45˚			Elver
Stanchard Pit	Tewkesbury, England	NA	Ramp	Bristle		16˚			elver
Strenshem Weir	River Avon, England	NA	Pipe	NA	6.6	40˚			elver/small yellow
Fladbury Weir	Warwickshire Avon, England	NA	Ramp	Bristle	50.2	30˚			elver
Eveshire Weir	Warwickshire Avon, England	NA	Ramp	Bristle	75.1	23˚			elver
Sunbury Lock	River Thames	NA	Ramp (channel)	Enkamat®	65.6	5.2˚			elver/small yellow
Sunbury Weir	River Thames	NA	Ramp	Bristle	38.4	10˚			elver/small yellow
Abingdon Weir	River Thames		Ramp	Bristle/baffle	5.9	9˚			elver/small yellow

Project Name	Project Location	Dam or Weir Height (ft.)	Passage Type	Substrate	Length (ft.)	Ramp Angle	Flow in Ramp (cfs)	Average Size (mm)	Eel Size (elver, small yellow)
Moulin a Pigné	Renne, France	5.3	Ramp	Bristle	NA	45°	NA		elver/small yellow
Pont-es-Omnès	St. Malo, France	11.8	Ramp	Bristle	NA	30°	NA		elver/small yellow
Chadbury Weir	Avon, England	5.0	Ramp	Bristle	30.8	9°	NA		elver/small yellow
Rophemel Dam	St. Malo, France	NA	Ramp	Bristle	NA	35°	NA		
Ville Hatte Dam	Jugon, France	45.9	Eel Lift	Bristle	16.4	35°	NA		elver/small yellow

1 = Range of mean lengths of eels collected from 2006 through 2010.

2 = Mean length of eels collected in 2010.

NA: Not Available

Table 5.2.1-1. Cost Opinion, West Eel Pass - Trap and Transport (Option 1)

Item No.	Item	Quantity	Unit	Unit Price	Cost
331	**Structures and Improvements**				
	Stairs	52	EA	$500	$26,000
	Handrail	60	LF	$150	$9,000
	Grating	80	SF	$50	$4,000
	Access Ladder	12	LF	$150	$1,800
	Concrete	22	CY	$800	$17,600
	Pre-Engineered Building (14' x 42')	588	SF	$25	$14,700
	Overhead Door	1	EA	$2,500	$2,500
	331 Subtotal*				**$76,000**
332	**Reservoirs, Dams, and Waterways**				
	Eel Ladder Tray	66	LF	$35	$2,310
	Eel Ladder Media	132	LF	$100	$13,200
	Eel Ladder Turn	2	EA	$500	$1,000
	Pipe (Attraction Flow)	150	LF	$25	$3,750
	Pump (Attraction Flow)	4	EA	$5,000	$20,000
	Compressor (Attraction Flow system)	2	EA	$2,500	$5,000
	Collection Tank	1	EA	$2,500	$2,500
	Eel Counter	2	EA	$10,000	$20,000
	PIT Tag Detector	2	EA	$10,000	$20,000
	Sheet Piling	1,000	SF	$30	$30,000
	Silt Curtain	1,000	SF	$5	$5,000
	Diversion and Care of Water	30	DAY	$1,000	$30,000
	Transport Tank (1,500 gal)	1	EA	$2,000	$2,000
	Trash Pump	2	EA	$1,500	$3,000
	Dissolved Oxygen Injection System	1	LS	$1,000	$1,000
	Temperature Monitor	1	EA	$500	$500
	332 Subtotal*				**$159,000**
334	**Accessory Electric Equipment**				
	Electrical (15% of 331 and 332)	1	LS	$35,250	$35,250
	Mechanical (10% of 331 and 332)	1	LS	$23,500	$23,500
	334 Subtotal*				**$59,000**
335	**Miscellaneous Power Plant Equipment**				
	Haul Truck	1	EA	$50,000	$50,000
	335 Subtotal*				**$50,000**

Mobilization/Demobilization (10%)*	**$34,000**
Subtotal Direct Cost	**$378,000**
Contingencies (25%)*	$95,000
Total Direct Cost	**$473,000**
Design (20%)*	$95,000
Permitting (10%)*	$47,000
Construction Administration (5%)*	$24,000
Total	**$639,000**

**Note: Rounded to nearest $1,000*

Item No.	Item	Quantity	Unit	Unit Price	Cost
901	**Annual Operations - Non-Labor**				
	Mileage *(assumes 300 mile round trip, per day)*	54,000	MI	$0.50	$27,000
	Fuel	18,000	GAL	$5	$90,000
	Salt (Stress Reduction)	5	TON	$500	$2,500
	Tank Refills (Oxygen)	1	LS	$1,000	$1,000
	901 Subtotal*				**$121,000**
902	**Annual Operations - Labor**				
	Eel Biologist *(assumes 7 months per year, full time)*	1,600	HR	$100	$160,000
	Eel Technician *(assumes 6 months per year, full time)*	1,440	HR	$75	$108,000
	Drivers *(assumes 6 months per year, full time)*	1,440	HR	$55	$79,200
	902 Subtotal*				**$347,000**

Subtotal Annual Operations Cost	**$468,000**
Contingencies (25%)*	$117,000
Annual Operations Total	**$585,000 /YR**

**Note: Rounded to nearest $1,000*

Table 5.2.2-1. Cost Opinion, West Eel Pass - Pipe to West Shore (Option 2)

Item No.	Item	Quantity	Unit	Unit Price	Cost
331	**Structures and Improvements**				
	Stairs	162	EA	$500	$81,000
	Handrail	210	LF	$150	$31,500
	Grating	385	SF	$50	$19,250
	Access Ladder	18	LF	$150	$2,700
	Concrete	74	CY	$800	$59,200
	3x3 Concrete	8	EA	$650	$5,200
	Base Plates & Hardware	8	EA	$50	$400
	Concrete Piers	5	EA	$1,500	$7,500
	Structural Steel	6,250	LB	$4	$25,000
	Pre-Engineered Building (18' x 10')	180	SF	$25	$4,500
	Clearing & Grading	0.33	AC	$15,000	$4,950
	Riprap	30	CY	$65	$1,950
	Fine Crushed Gravel	15	CY	$50	$750
	Access Road (12-ft wide, 12-in depth)	600	LF	$45	$27,000
	Jack & Bore Rte. 1	30	LF	$1,000	$30,000
	331 Subtotal*				**$301,000**
332	**Reservoirs, Dams, and Waterways**				
	Eel Ladder Tray	182	LF	$35	$6,370
	Eel Ladder Media	364	LF	$100	$36,400
	2" dia. Pipe (Attraction Flow)	320	LF	$25	$8,000
	Pump (Attraction Flow)	4	EA	$5,000	$20,000
	6" dia. Pipe w/Supports & Footings (Transport Flow)	835	LF	$100	$83,500
	Pump (Transport Flow)	2	EA	$7,500	$15,000
	Compressor (Attraction Flow & Transport System)	4	EA	$2,500	$10,000
	Collection/Transfer Tank	3	EA	$2,500	$7,500
	4-ft dia. Pipe, Ductile Iron	50	LF	$500	$25,000
	Screen	30	SF	$50	$1,500
	Eel Counter	4	EA	$10,000	$40,000
	PIT Tag Detector	4	EA	$10,000	$40,000
	Sheet Piling	2,300	SF	$30	$69,000
	Silt Curtain	2,300	SF	$5	$11,500
	Diversion and Care of Water	90	DAY	$1,000	$90,000
	332 Subtotal*				**$464,000**
334	**Accessory Electric Equipment**				
	Electrical (15% of 331 and 332)	1	LS	$114,750	$114,750
	Mechanical (10% of 331 and 332)	1	LS	$76,500	$76,500
	Electric Service	600	LF	$50	$30,000
	334 Subtotal*				**$221,000**

Mobilization/Demobilization (10%)*	**$99,000**
Subtotal Direct Cost	**$1,085,000**
Contingencies (25%)*	$271,000
Total Direct Cost	**$1,356,000**
Design (15%)*	$203,000
Permitting (5%)*	$68,000
Construction Administration (5%)*	$68,000
Total	**$1,695,000**

**Note: Rounded to nearest $1,000*

Table 5.2.3-1. Cost Opinion, West Eel Pass - Buried Trench, Pipe to West Shore (Option 3)

Item No.	Item	Quantity	Unit	Unit Price	Cost
331	**Structures and Improvements**				
	Stairs	172	EA	$500	$86,000
	Handrail	145	LF	$150	$21,750
	Grating	215	SF	$50	$10,750
	Access Ladder	12	LF	$150	$1,800
	Concrete	64	CY	$800	$51,200
	Structural Steel	20,000	LB	$4	$80,000
	Pre-Engineered Building (18' x 10')	180	SF	$25	$4,500
	Clearing & Grading	0.33	AC	$15,000	$4,950
	Riprap	30	CY	$65	$1,950
	Fine Crushed Gravel	15	CY	$50	$750
	Access Road (12-ft wide, 12-in depth)	600	LF	$45	$27,000
	Jack & Bore Rte. 1	30	LF	$1,000	$30,000
	Retaining Walls (Trench)	55	CY	$800	$44,000
	Trench H20 Grating	325	SF	$140	$45,500
	Excavate & Backfill Trench	750	CY	$100	$75,000
	Shoring	1,700	SF	$50	$85,000
	Demo & Reset Asphalt	1,500	SF	$20	$30,000
	Demo & Reset Sidewalk/Curb	400	SF	$30	$12,000
	Fencing/Bollards	1	LS	$10,000	$10,000
	331 Subtotal*				**$622,000**
332	**Reservoirs, Dams, and Waterways**				
	Eel Ladder Tray	212	LF	$35	$7,420
	Eel Ladder Media	424	LF	$100	$42,400
	2" dia. Pipe (Attraction Flow)	424	LF	$25	$10,600
	Pump (Attraction Flow)	4	EA	$5,000	$20,000
	6" dia. Pipe w/Supports & Footings (Transport Flow)	785	LF	$100	$78,500
	Pump (Transport Flow)	2	EA	$7,500	$15,000
	Compressor (Attraction Flow & Transport System)	4	EA	$2,500	$10,000
	Collection/Transfer Tank	2	EA	$2,500	$5,000
	4-ft dia. Pipe, Ductile Iron	50	LF	$500	$25,000
	Screen	30	SF	$50	$1,500
	Eel Counter	4	EA	$10,000	$40,000
	PIT Tag Detector	4	EA	$10,000	$40,000
	Sheet Piling	1,500	SF	$30	$45,000
	Silt Curtain	1,500	SF	$5	$7,500
	Diversion and Care of Water	60	DAY	$1,000	$60,000
	332 Subtotal*				**$408,000**
334	**Accessory Electric Equipment**				
	Electrical (15% of 331 and 332)	1	LS	$154,500	$154,500
	Mechanical (10% of 331 and 332)	1	LS	$103,000	$103,000
	Electric Service	600	LF	$50	$30,000
	334 Subtotal*				**$288,000**

Mobilization/Demobilization (10%)*	**$132,000**
Subtotal Direct Cost	**$1,450,000**
Contingencies (25%)*	$363,000
Total Direct Cost	**$1,813,000**
Design (15%)*	$272,000
Permitting (5%)*	$91,000
Construction Administration (3%)*	$54,000
Total	**$2,230,000**

**Note: Rounded to nearest $1,000*

Table 5.2.4-1. Cost Opinion, East Eel Pass - Trap and Transport (Option 1)

Item No.	Item	Quantity	Unit	Unit Price	Cost
331	**Structures and Improvements**				
	Stairs	36	EA	$500	$18,000
	Handrail	25	LF	$150	$3,750
	Grating	25	SF	$50	$1,250
	Access Ladder	12	LF	$150	$1,800
	Concrete	16	CY	$800	$12,800
	Base Plates & Hardware	16	EA	$50	$800
	Structural Steel	1,500	LB	$4	$6,000
	331 Subtotal*				**$44,000**
332	**Reservoirs, Dams, and Waterways**				
	Eel Ladder Tray	35	LF	$35	$1,225
	Eel Ladder Media	70	LF	$100	$7,000
	Pipe (Attraction Flow)	70	LF	$25	$1,750
	Pump (Attraction Flow)	4	EA	$5,000	$20,000
	Compressor (Attraction Flow system)	2	EA	$2,500	$5,000
	Collection Tank	1	EA	$2,500	$2,500
	Eel Counter	2	EA	$10,000	$20,000
	PIT Tag Detector	2	EA	$10,000	$20,000
	Sheet Piling	2,000	SF	$30	$60,000
	Silt Curtain	2,000	SF	$5	$10,000
	Diversion and Care of Water	30	DAY	$1,000	$30,000
	Transport Tank (1,500 gal)	1	EA	$2,000	$2,000
	Trash Pump	2	EA	$1,500	$3,000
	Dissolved Oxygen Injection System	1	LS	$1,000	$1,000
	Temperature Monitor	1	EA	$500	$500
	332 Subtotal*				**$184,000**
334	**Accessory Electric Equipment**				
	Electrical (15% of 331 and 332)	1	LS	$34,200	$34,200
	Mechanical (10% of 331 and 332)	1	LS	$22,800	$22,800
	334 Subtotal*				**$57,000**
335	**Miscellaneous Power Plant Equipment**				
	Haul Truck	1	EA	$50,000	$50,000
	335 Subtotal*				**$50,000**

Mobilization/Demobilization (10%)*	**$34,000**
Subtotal Direct Cost	**$369,000**
Contingencies (25%)*	$92,000
Total Direct Cost	**$461,000**
Design (20%)*	$92,000
Permitting (10%)*	$46,000
Construction Administration (5%)*	$23,000
Total	**$622,000**

**Note: Rounded to nearest $1,000*

Item No.	Item	Quantity	Unit	Unit Price	Cost
901	**Annual Operations - Non-Labor**				
	Mileage *(assumes 300 mile round trip, per day)*	54,000	MI	$0.50	$27,000
	Fuel	18,000	GAL	$5	$90,000
	Salt (Stress Reduction)	5	TON	$500	$2,500
	Tank Refills (Oxygen)	1	LS	$1,000	$1,000
	901 Subtotal*				**$121,000**
902	**Annual Operations - Labor**				
	Eel Biologist *(assumes 7 months per year, full time)*	1,600	HR	$100	$160,000
	Eel Technician *(assumes 6 months per year, full time)*	1,440	HR	$75	$108,000
	Drivers *(assumes 6 months per year, full time)*	1,440	HR	$55	$79,200
	902 Subtotal*				**$347,000**

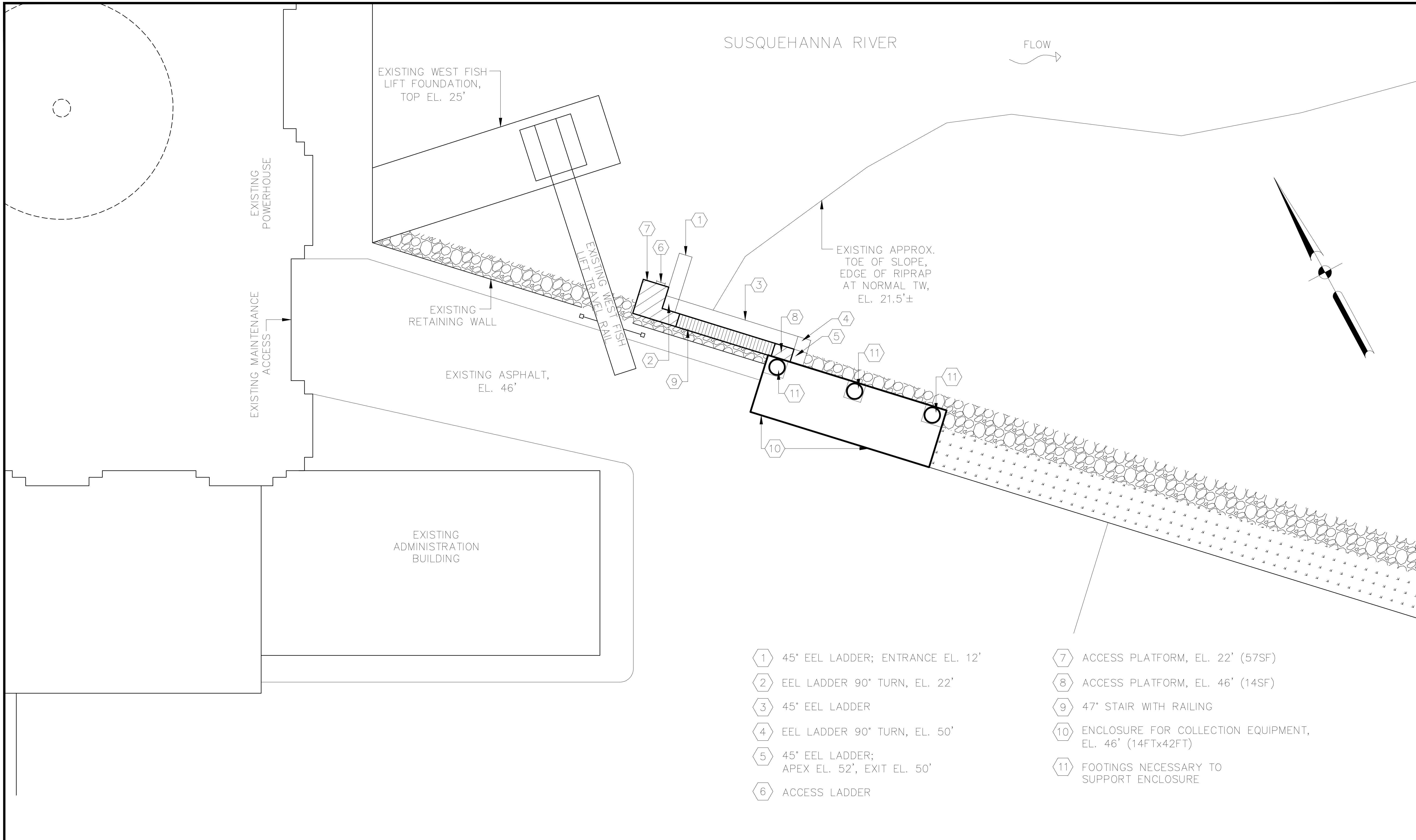
Subtotal Annual Operations Cost	**$468,000**
Contingencies (25%)*	$117,000
Annual Operations Total	**$585,000 /YR**

**Note: Rounded to nearest $1,000*

Table 5.2.4-2. Cost Opinion, East Eel Pass to Conowingo Pond (Option 2)

Item No.	Item	Quantity	Unit	Unit Price	Cost
331	**Structures and Improvements**				
	Stairs	172	EA	$500	$86,000
	Handrail	214	LF	$150	$32,100
	Grating	205	SF	$50	$10,250
	Access Ladder	12	LF	$150	$1,800
	Concrete	16	CY	$800	$12,800
	Base Plates & Hardware	16	EA	$50	$800
	Structural Steel	16,500	LB	$4	$66,000
	331 Subtotal*				**$210,000**
332	**Reservoirs, Dams, and Waterways**				
	Eel Ladder Tray	135	LF	$35	$4,725
	Eel Ladder Media	270	LF	$100	$27,000
	Pipe (Attraction Flow)	270	LF	$25	$6,750
	Pump (Attraction Flow)	4	EA	$5,000	$20,000
	Compressor (Attraction Flow and Transport Pipe)	4	EA	$2,500	$10,000
	Collection/Transfer Tank	2	EA	$2,500	$5,000
	6" dia. Pipe (Transport Flow)	10	LF	$100	$1,000
	Core Through Dam	10	LF	$2,000	$20,000
	Eel Counter	4	EA	$10,000	$40,000
	PIT Tag Detector	4	EA	$10,000	$40,000
	Sheet Piling	2,000	SF	$30	$60,000
	Silt Curtain	2,000	SF	$5	$10,000
	Diversion and Care of Water	30	DAY	$1,000	$30,000
	332 Subtotal*				**$274,000**
334	**Accessory Electric Equipment**				
	Electrical (15% of 331 and 332)	1	LS	$72,600	$72,600
	Mechanical (10% of 331 and 332)	1	LS	$48,400	$48,400
	334 Subtotal*				**$121,000**

Mobilization/Demobilization (10%)*	**$61,000**
Subtotal Direct Cost	**$666,000**
Contingencies (25%)*	$167,000
Total Direct Cost	**$833,000**
Design (20%)*	$167,000
Permitting (10%)*	$83,000
Construction Administration (5%)*	$42,000
Total	**$1,125,000**



NO.	DATE	ISSUED FOR	BY

DESIGNED
DRAWN
CHECKED
SECT.CHIEF
PROJ.ENGR.

10' 0 10' 20'
SCALE: 1" = 20'

Gomez and Sullivan Engineers, P.C.
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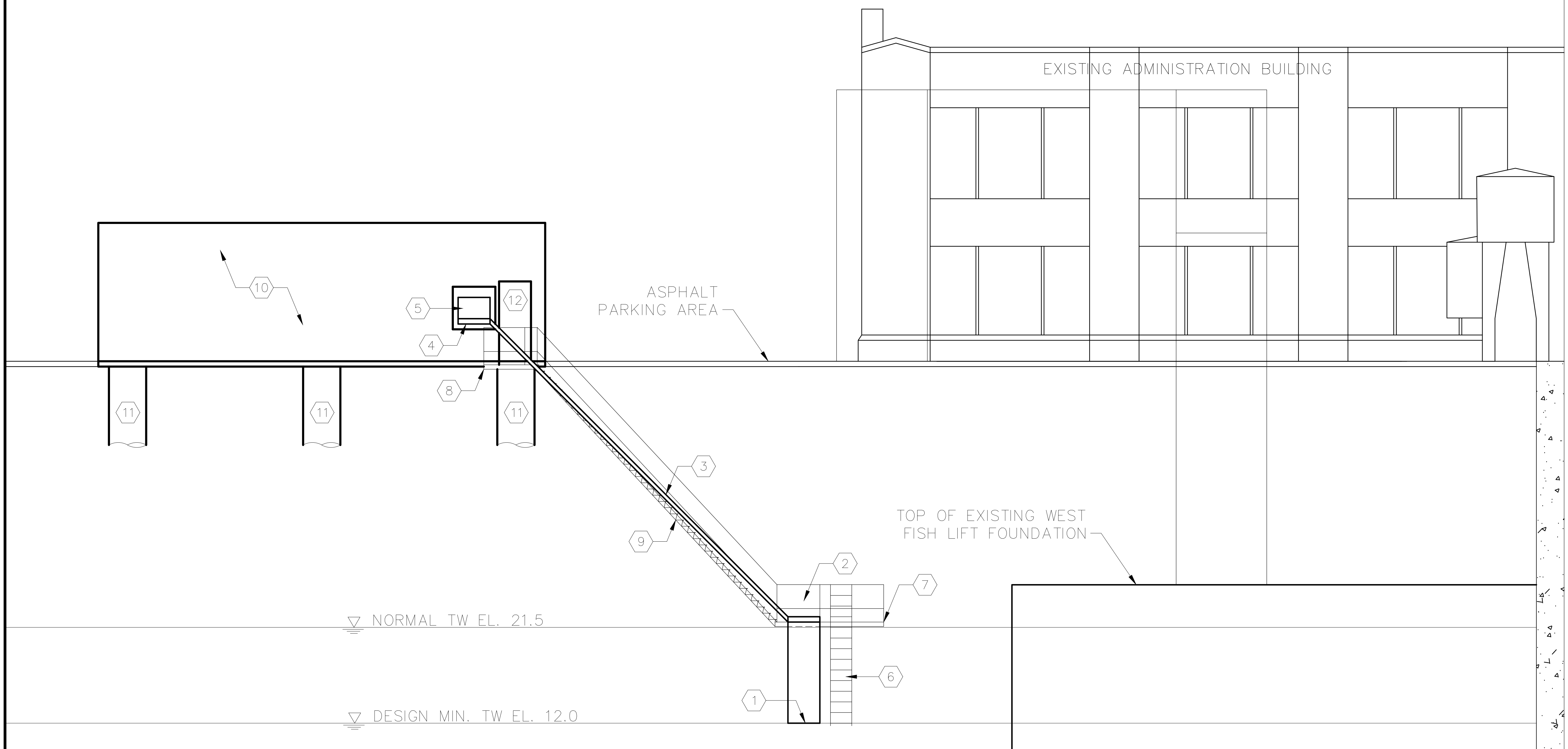
CONOWINGO RELICENSING
UPSTREAM ALTERNATIVES
WEST BANK, OPTION 1
TRAP AND TRANSPORT – PLAN

DATE AUGUST 2012

FIGURE NO: 5.2.1-1

1. 45° EEL LADDER; ENTRANCE EL. 12'
2. EEL LADDER 90° TURN, EL. 22'
3. 45° EEL LADDER
4. EEL LADDER 90° TURN, EL. 50'
5. 45° EEL LADDER; APEX EL. 52', EXIT EL. 50'
6. ACCESS LADDER
7. ACCESS PLATFORM, EL. 22' (57SF)
8. ACCESS PLATFORM, EL. 46' (14SF)
9. 47° STAIR WITH RAILING
10. ENCLOSURE FOR COLLECTION EQUIPMENT, EL. 46' (14FTx42FT)
11. FOOTINGS NECESSARY TO SUPPORT ENCLOSURE
12. DOOR



NO.	DATE	ISSUED FOR	BY

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CHECKED
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PROJ.ENGR.

5' 0 5' 10'
SCALE: 1" = 10'

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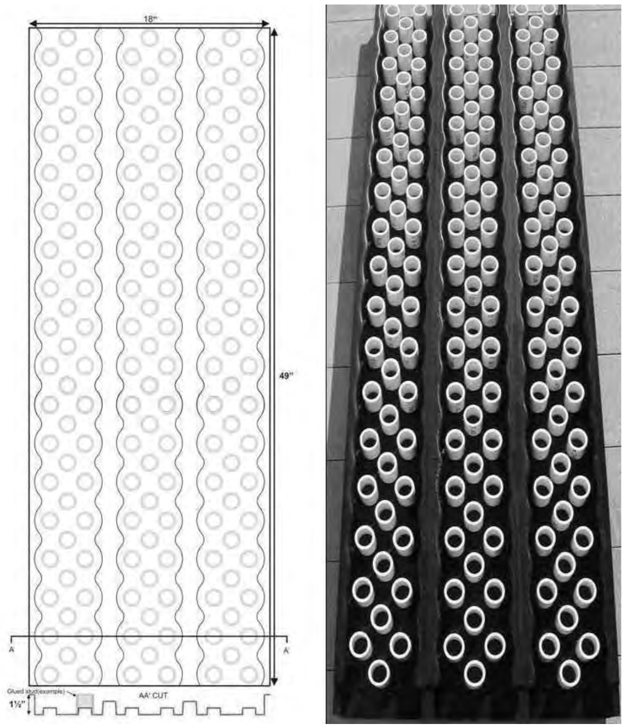
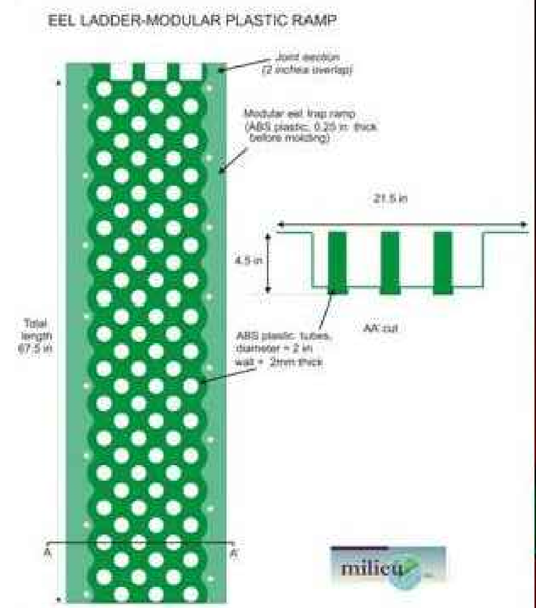
CONOWINGO RELICENSING
UPSTREAM ALTERNATIVES
WEST BANK, OPTION 1
TRAP AND TRANSPORT – ELEVATION

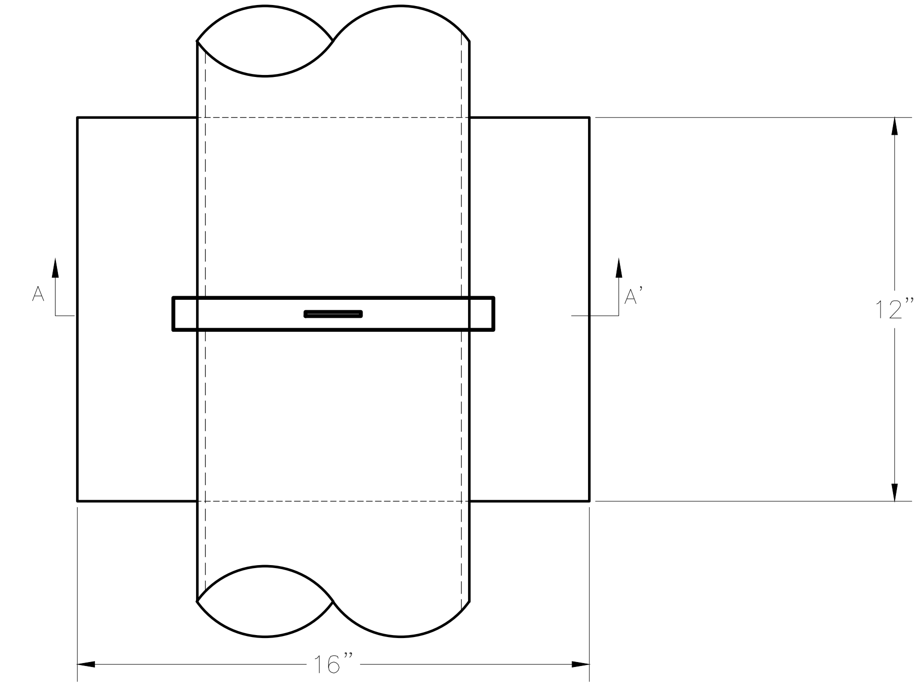
DATE AUGUST 2012
FIGURE NO: 5.2.1-2



SOURCE: MILIEU, INC.



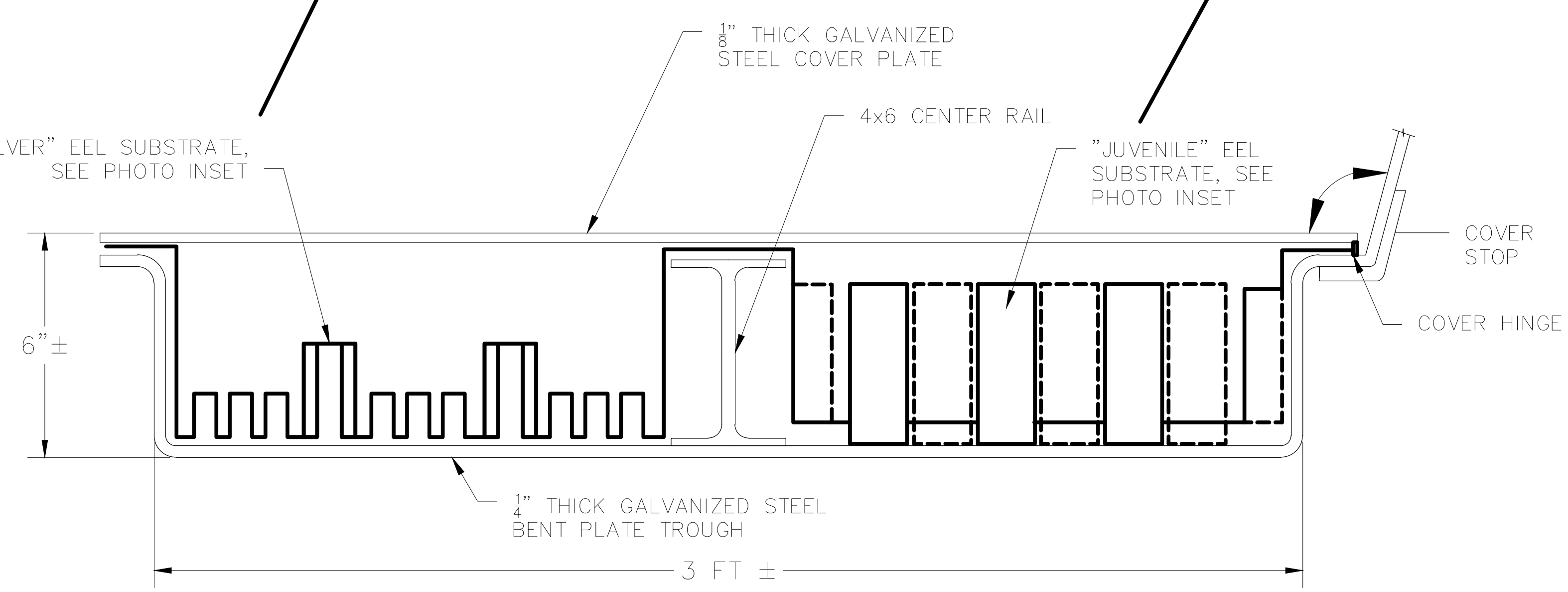
SOURCE: MILIEU, INC.



2
4.2.1-3

TRANSPORT PIPE PLAN

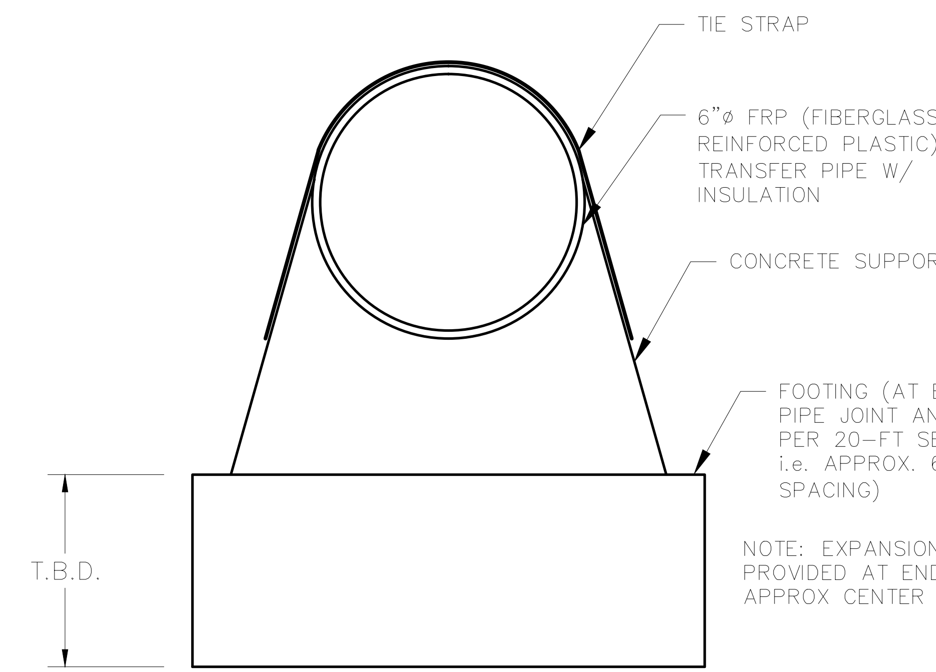
Scale: 1" = 6"



1
4.2.1-3

EEL LADDER SECTION (TYPICAL)

Scale: 1" = 6"



NOTE: EXPANSION JOINTS TO BE PROVIDED AT ENDS AND ONE IN APPROX CENTER OF RUN.

3
4.2.1-3

TRANSPORT PIPE SECTION A-A'

Scale: 1" = 6"

NO.	DATE	ISSUED FOR	BY

DESIGNED
DRAWN
CHECKED
SECT.CHIEF
PROJ.ENGR.

3" 0 3" 6"
SCALE: 1" = 6"

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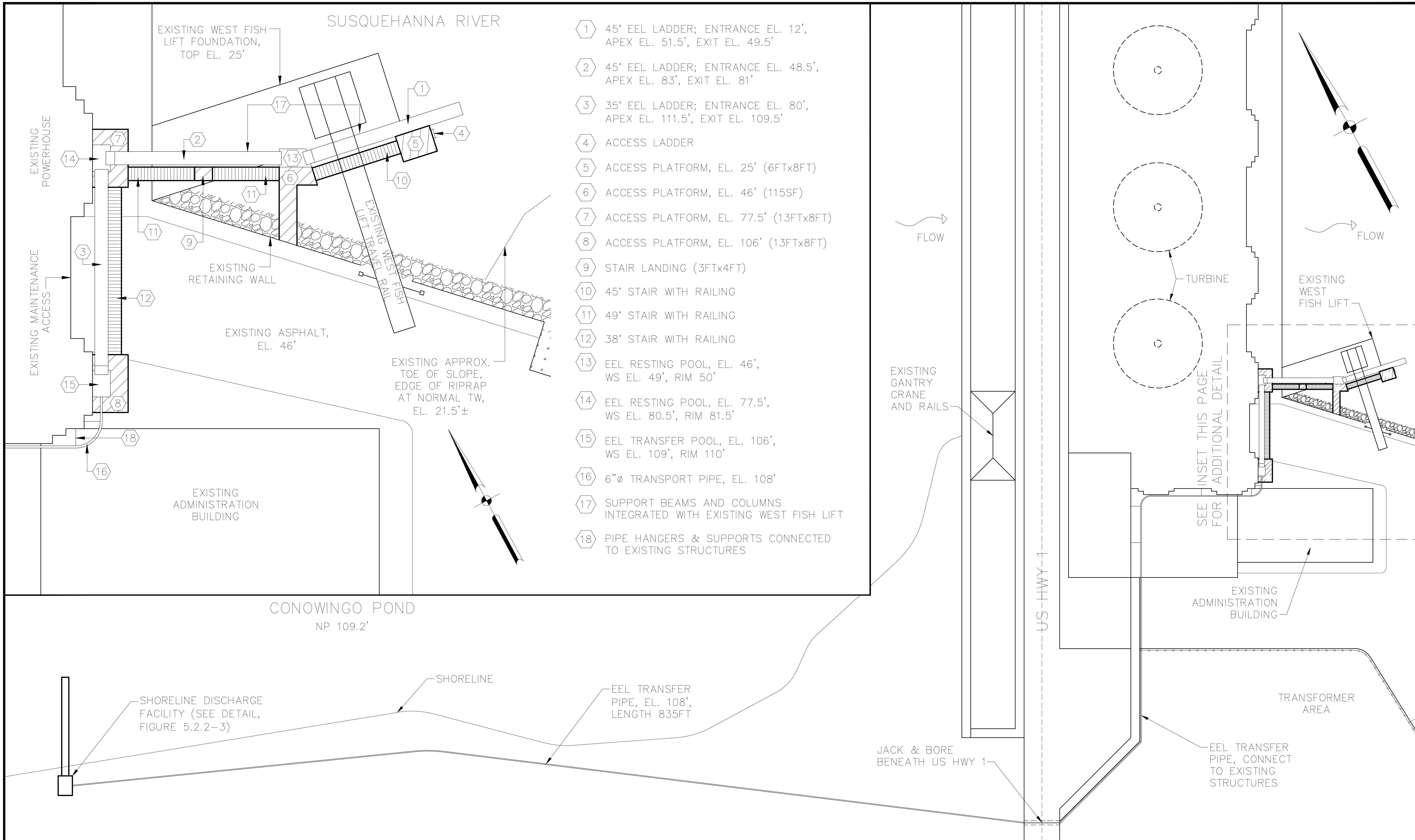
CONOWINGO RELICENSING

EEL PASSAGE DETAILS,
1 OF 2

DATE AUGUST 2012

FIGURE NO: 5.2.1-3



NO.	DATE	ISSUED FOR	BY

DESIGNED
DRAWN
CHECKED
SECT.CHIEF
PROJ.ENGR.

25' 0 25' 50'
SCALE: 1" = 50'
10' 0 10' 20'
SCALE: 1" = 20' (INSET)

GOMEZ AND SULLIVAN Engineers, P.C.
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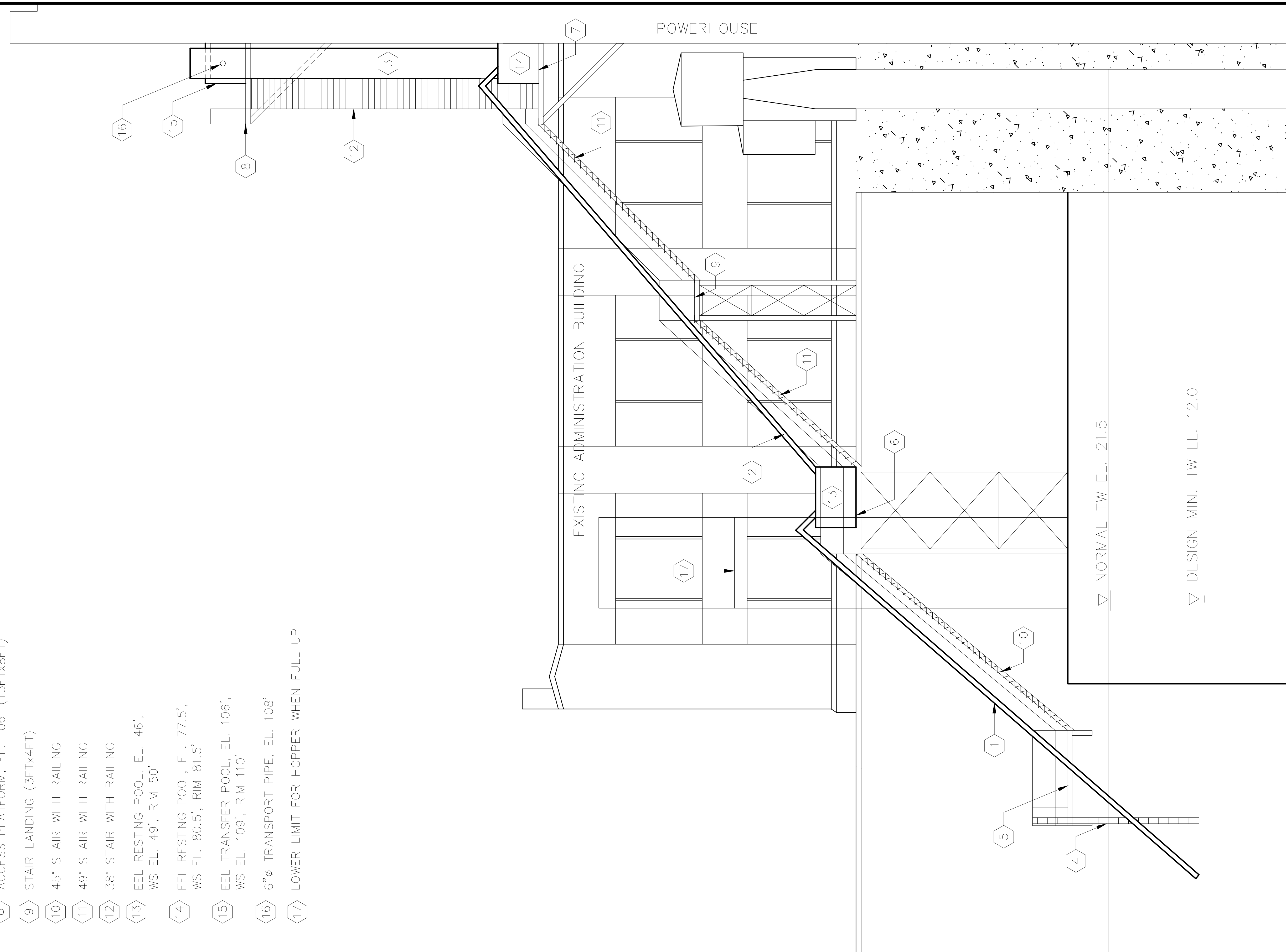
CONOWINGO RELICENSING
UPSTREAM ALTERNATIVES
WEST BANK, OPTION 2
EEL LADDER, PIPE TO WEST SHORE – PLAN

DATE AUGUST 2012
FIGURE NO: 5.2.2-1



1. 45° EEL LADDER; ENTRANCE EL. 12', APEX EL. 51.5', EXIT EL. 49.5'
2. 45° EEL LADDER; ENTRANCE EL. 48.5', APEX EL. 83', EXIT EL. 81'
3. 35° EEL LADDER; ENTRANCE EL. 80', APEX EL. 111.5', EXIT EL. 109.5'
4. ACCESS LADDER
5. ACCESS PLATFORM, EL. 25' (6FTx8FT)
6. ACCESS PLATFORM, EL. 46' (115SF)
7. ACCESS PLATFORM, EL. 77.5' (13FTx8FT)
8. ACCESS PLATFORM, EL. 106' (13FTx8FT)
9. STAIR LANDING (3FTx4FT)
10. 45° STAIR WITH RAILING
11. 49° STAIR WITH RAILING
12. 38° STAIR WITH RAILING
13. EEL RESTING POOL, EL. 46', WS EL. 49', RIM 50'
14. EEL RESTING POOL, EL. 77.5', WS EL. 80.5', RIM 81.5'
15. EEL TRANSFER POOL, EL. 106', WS EL. 109', RIM 110'
16. 6"ø TRANSPORT PIPE, EL. 108'
17. LOWER LIMIT FOR HOPPER WHEN FULL UP

NO.	DATE	ISSUED FOR	BY

DESIGNED
DRAWN
CHECKED
SECT.CHIEF
PROJ.ENGR.

5' 0 5' 10'
SCALE: 1" = 10'

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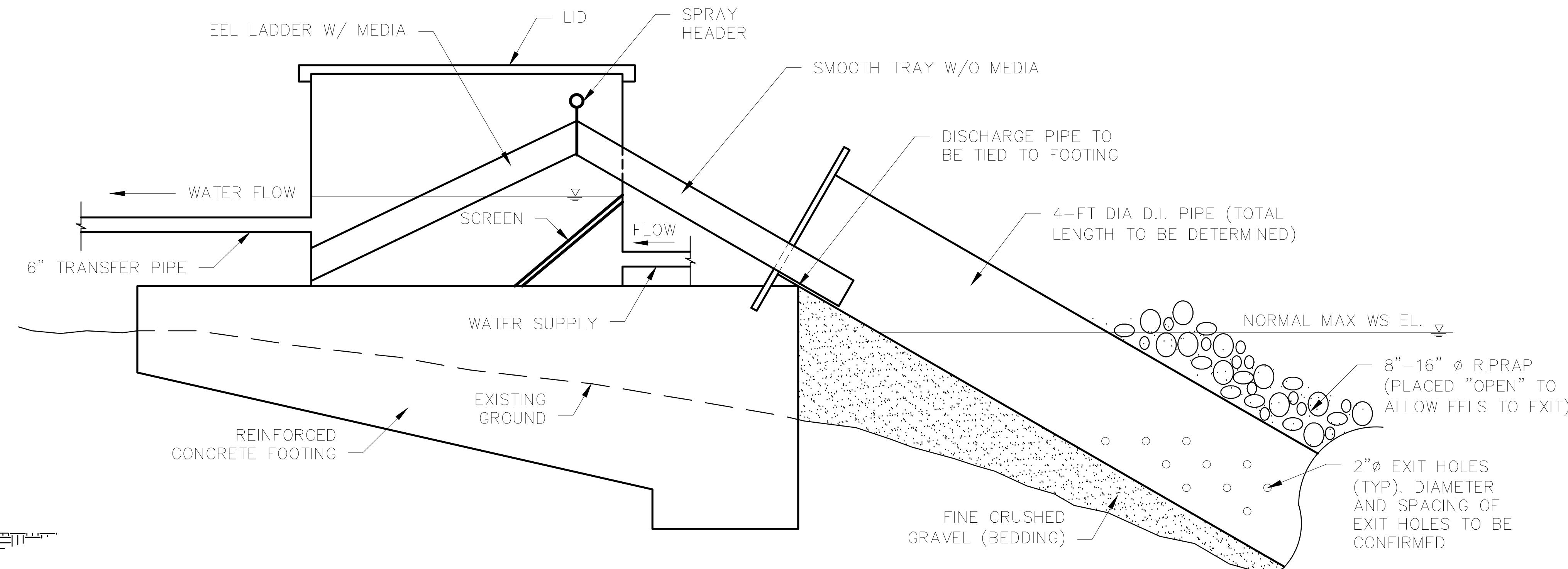
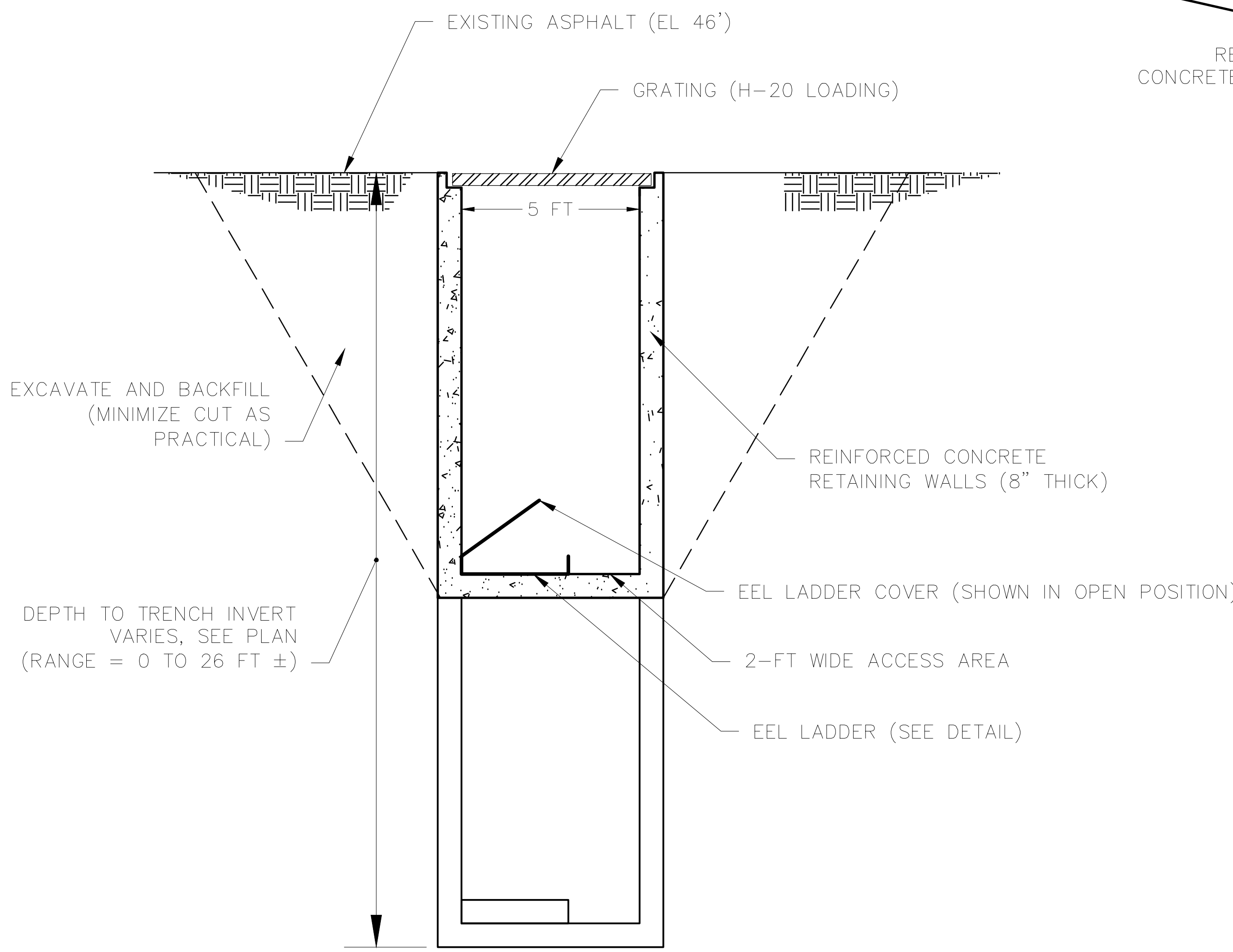
CONOWINGO RELICENSING
UPSTREAM ALTERNATIVES
WEST BANK, OPTION 2
EEL LADDER,
PIPE TO WEST SHORE – ELEVATION

DATE AUGUST 2012
FIGURE NO: 5.2.2-2



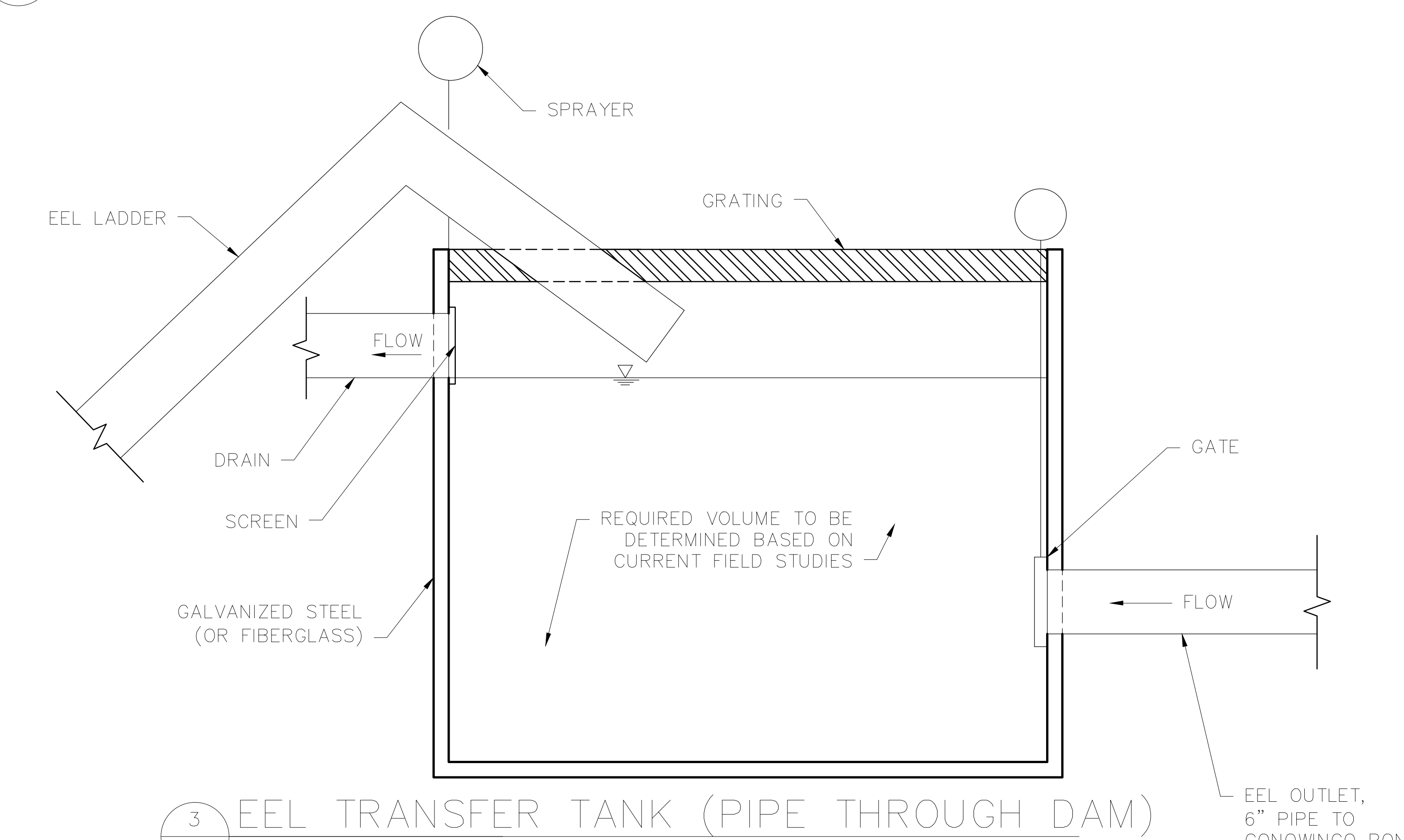
2 (4.2.2-3) SHORELINE DISCHARGE FACILITY PROFILE

Scale: NOT TO SCALE



1 (4.2.2-3) BURIED EEL LADDER SECTION (TYPICAL)

Scale: 1" = 5'



3 (4.2.2-3) EEL TRANSFER TANK (PIPE THROUGH DAM)

Scale: NOT TO SCALE

NO.	DATE	ISSUED FOR	BY

DESIGNED
DRAWN
CHECKED
SECT.CHIEF
PROJ.ENGR.

SCALE: AS SHOWN
2.5' 0 2.5' 5'
SCALE: 1" = 5'

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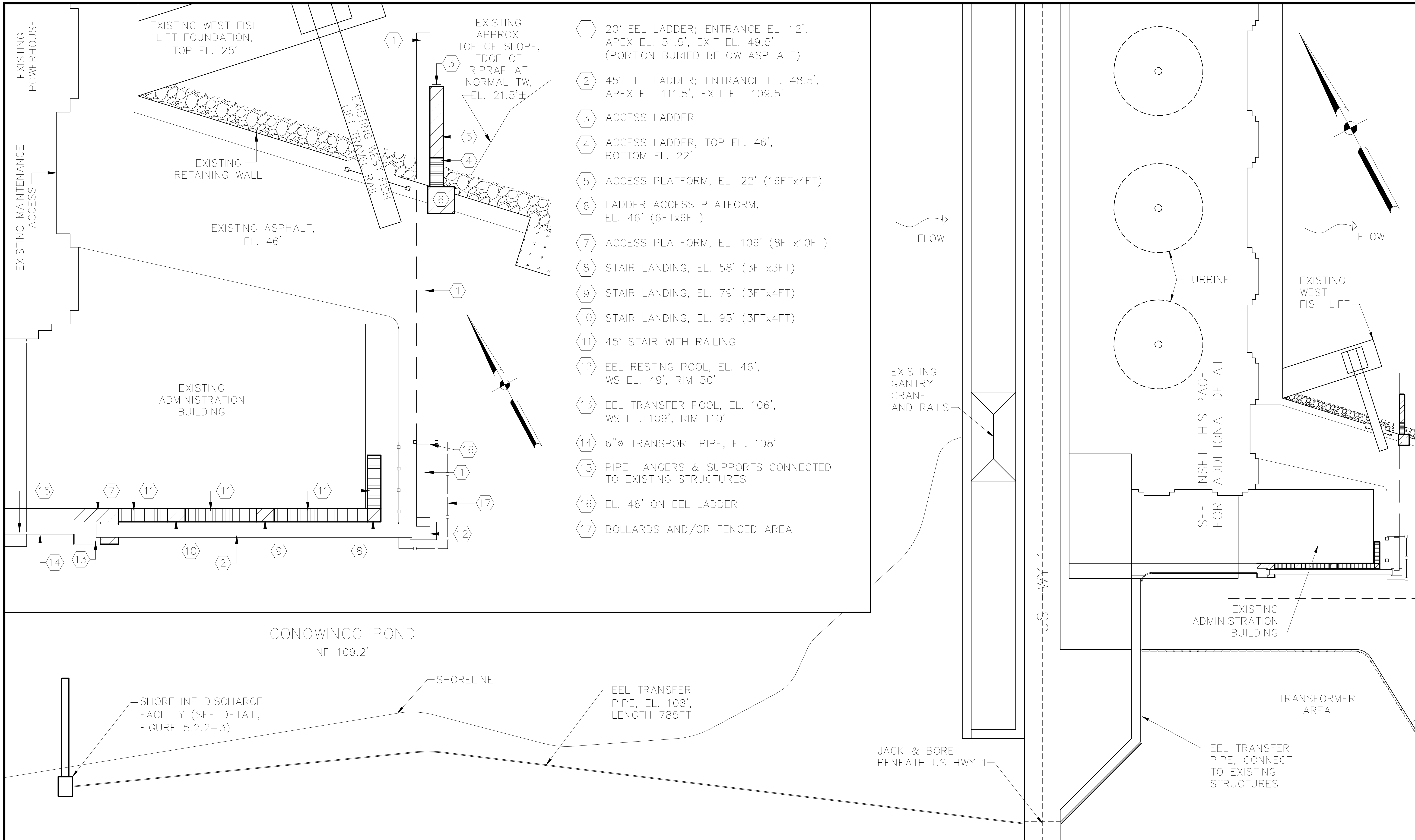
CONOWINGO RELICENSING

EEL PASSAGE DETAILS, 2 OF 2

DATE AUGUST 2012

FIGURE NO: 5.2.2-3



NO.	DATE	ISSUED FOR	BY

DESIGNED
DRAWN
CHECKED
SECT.CHIEF
PROJ.ENGR.

25' 0 25' 50' SCALE: 1" = 50'

10' 0 10' 20' SCALE: 1" = 20' (INSET)

GOMEZ AND SULLIVAN Engineers, P.C.
288 Genesee Street Utica, NY 13502 (315) 724-4860
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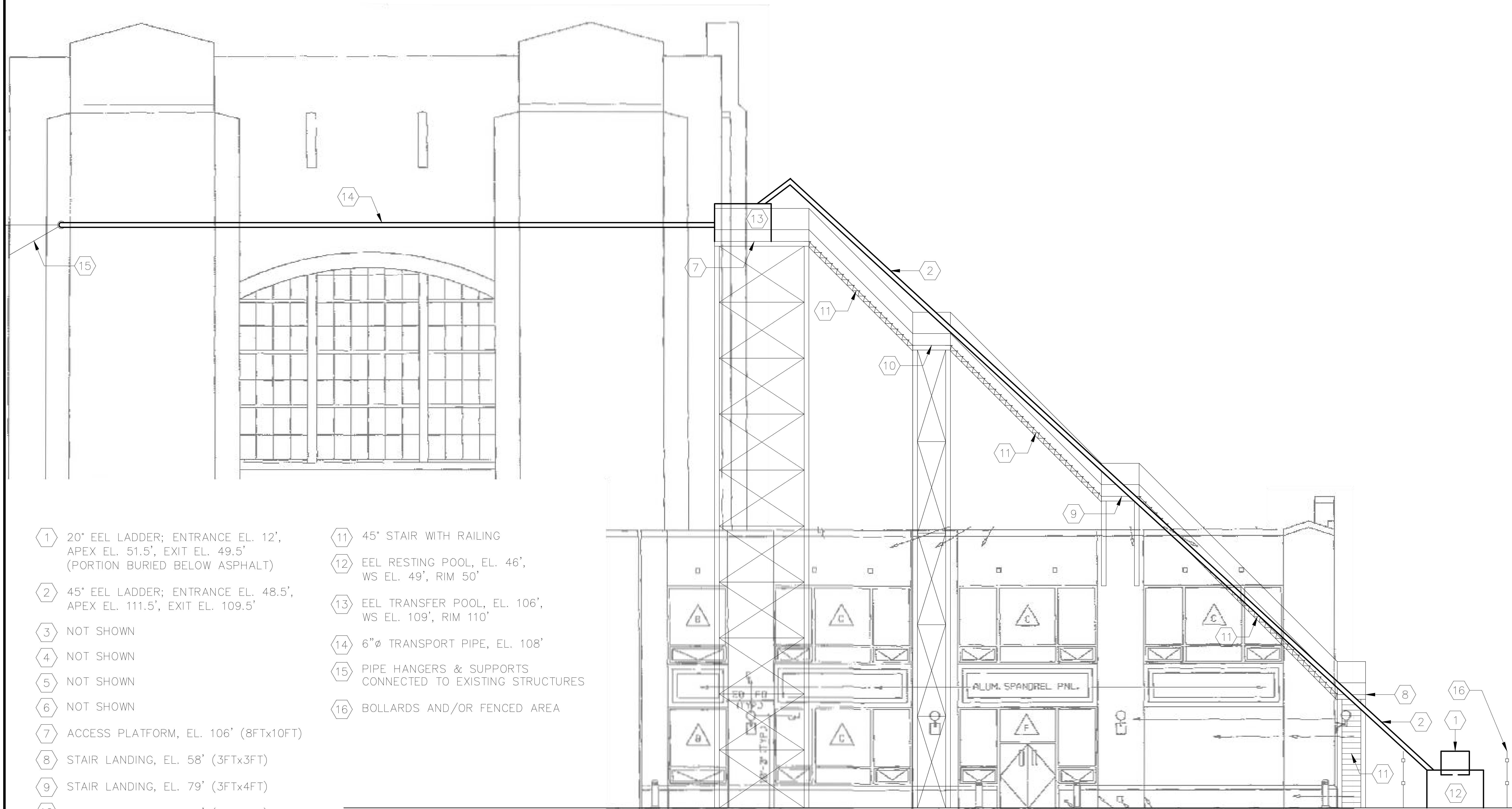
CONOWINGO RELICENSING
UPSTREAM ALTERNATIVES
WEST BANK, OPTION 3,
BURIED EEL LADDER,
PIPE TO WEST SHORE – PLAN

DATE AUGUST 2012

FIGURE NO: 5.2.3-1



1. 20° EEL LADDER; ENTRANCE EL. 12', APEX EL. 51.5', EXIT EL. 49.5' (PORTION BURIED BELOW ASPHALT)
2. 45° EEL LADDER; ENTRANCE EL. 48.5', APEX EL. 111.5', EXIT EL. 109.5'
3. NOT SHOWN
4. NOT SHOWN
5. NOT SHOWN
6. NOT SHOWN
7. ACCESS PLATFORM, EL. 106' (8FTx10FT)
8. STAIR LANDING, EL. 58' (3FTx3FT)
9. STAIR LANDING, EL. 79' (3FTx4FT)
10. STAIR LANDING, EL. 95' (3FTx4FT)
11. 45° STAIR WITH RAILING
12. EEL RESTING POOL, EL. 46', WS EL. 49', RIM 50'
13. EEL TRANSFER POOL, EL. 106', WS EL. 109', RIM 110'
14. 6"ø TRANSPORT PIPE, EL. 108'
15. PIPE HANGERS & SUPPORTS CONNECTED TO EXISTING STRUCTURES
16. BOLLARDS AND/OR FENCED AREA

NO.	DATE	ISSUED FOR	BY

DESIGNED
DRAWN
CHECKED
SECT.CHIEF
PROJ.ENGR.

5' 0 5' 10'
SCALE: 1" = 10'

GOMEZ AND SULLIVAN Engineers, P.C.
288 Genesee Street, Utica, NY 13502, (315) 724-4860
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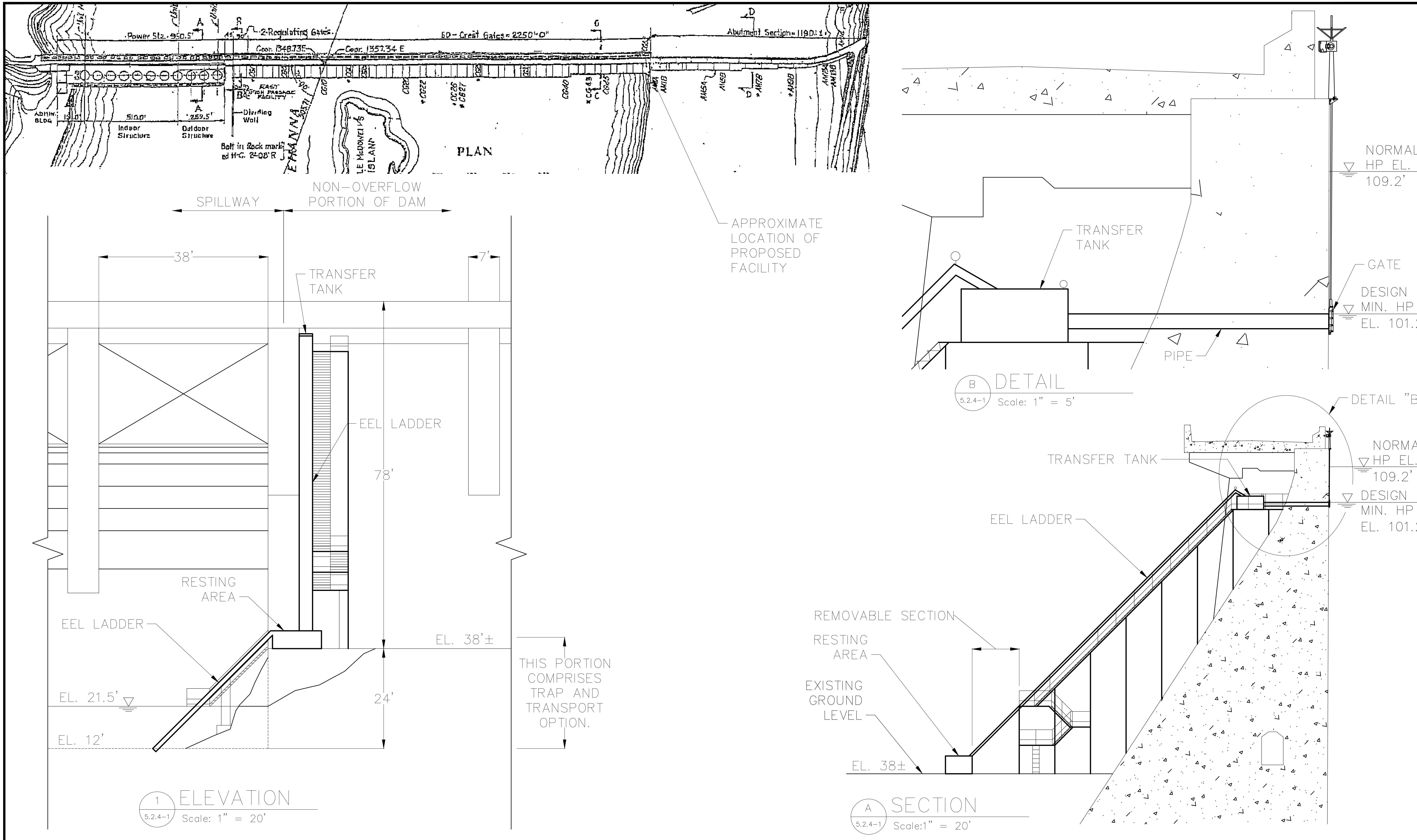
CONOWINGO RELICENSING
UPSTREAM ALTERNATIVES
WEST BANK, OPTION 3,
BURIED EEL LADDER,
PIPE TO WEST SHORE – ELEVATION

DATE AUGUST 2012
FIGURE NO: 5.2.3-2



NO.	DATE	ISSUED FOR	BY

DESIGNED
DRAWN
CHECKED
SECT.CHIEF
PROJ.ENGR.

2.5' 0 2.5' 5'
SCALE: 1" = 5'
10' 0 10' 20'
SCALE: 1" = 20'

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CONOWINGO RELICENSING

EAST EEL LADDER

DATE AUGUST 2012

FIGURE NO: 5.2.4-1

6.0 DOWNSTREAM PASSAGE

This following section of the study is an assessment of potential options for downstream passage of outmigrating adult eels at the Conowingo Project. This assessment is based on biological data on outmigrating adults, downstream passage measures considered at dams on other rivers throughout the world, and laboratory and field research related to potential downstream passage measures.

6.1 Background

The issue of providing downstream passage for adult eels involves very complex eel behavior and biology, engineering, and operational issues. Generally, few solutions have been found that effectively address downstream passage of eels at hydroelectric projects. The complexity of these issues is significantly compounded for a facility as large as Conowingo Dam and a river as large as the Susquehanna.

Given the complexity of potential downstream passage technologies and the uncertainty as to their applicability at Conowingo Dam, Exelon conducted a workshop on October 25 and 26, 2011 to discuss issues related to the downstream passage of adult eels in the Susquehanna River. At the workshop, experts on downstream passage of eels presented information on eel biology and behavior, technologies and approaches proposed for hydro facilities, their potential effectiveness, and the challenges presented for downstream passage of American eel at Conowingo. Presentation material and notes of the workshop are provided in Appendix A and are summarized in Section 6.2.

6.1.1 Downstream Passage Literature

A number of laboratory and field studies have been conducted throughout the world relative to downstream passage of American eel on North American rivers and the closely related European eel (*Anguilla anguilla)* on European rivers. Much of this research has been recently summarized in a report prepared by the New York Power Authority (NYPA, 2009). The report focused on a large hydroelectric dam on the St. Lawrence River (St. Lawrence Project) and provided a comprehensive assessment of many technologies and approaches associated with downstream passage of adult eels on a large river. A report prepared by EPRI (2010), included an assessment of the implications of downstream passage at Conowingo on the Susquehanna River eel population. These reports, other work referenced in these reports, and information presented at the October workshop provide information needed to consider downstream passage at Conowingo.

6.1.2 Downstream Passage on Susquehanna River

Historically, American eel had access to and occupied much of the Susquehanna River and tributaries, but the watershed today has changed substantially. The construction of dams on the River and its tributaries has limited access to upstream migrating eels and changed the nature of the habitat in the impoundments that were created. Other anthropogenic changes (*e.g.*, habitat modifications, development, water quality impacts) have also affected habitats in the watershed.

Not withstanding the availability of downstream eel passage data at a variety of hydroelectric projects, the use of data at a specific project requires knowledge of the biology and behavior of eels in the specific river as well as information on current and future usage of habitat in that river. For the Susquehanna River, some of this information is available or is being collected, but other information is not known with enough specificity at this time.

USFWS (2012) analyzed silver eel migrations past Conowingo dam in 2011. Based on 88 tagged silver eels released in upper Conowingo Pond above the Muddy Run Pumped Storage Project, 79 eels (89.8%) were detected at receivers downstream of Conowingo Dam. As these eels were detected 14 km below the Dam, USFWS concluded that these 79 eels successfully migrated past the Dam and out of the Susquehanna River. Since spillage occurred for a number of days during which eels were outmigrating, it was not possible to determine whether eels passed the Dam through spillage or turbine passage. The remaining nine eels were not detected below the Dam so it is not known if they remained in the Pond, migrated after the end of the monitoring (late December, did not survive passage through the turbines or over the spillway , or the tags or tag battery failed, or the tags were damaged in turbine or spillway passage.

A downstream-passage program would require information on the timing of migration and its relation to rain, flow, water temperature, lunar cycles, and other potential migratory cues (Appendix A, Haro presentation). It is generally believed that the outmigration of eels occurs primarily at night in fall although the factors initiating migration are not well understood. In some instances, most eels outmigrate in a short period of time although outmigration has also been noted to extend over a three- or four-month period on the St. Lawrence River. The timing of migration may vary within the watershed with eels further upstream in smaller tributaries and lakes moving earlier than eels in the mainstem of a river. Environmental factors can suspend or terminate downstream migration.

Before implementing a program to restore eels to the watershed, it would be prudent to acquire pertinent information about eels in the Susquehanna River. As discussed at the October workshop (Appendix A, Haro presentation), this information includes characteristics of the outmigrating eels (*e.g*., run timing, average size class, number, sex ratio).

6.2 Downstream Passage Options

Numerous options have been considered for the downstream passage of outmigrating eels at hydroelectric facilities. These options can generally be considered as those related to 1) turbine passage, 2) deterring eels from turbines with guidance to a bypass, and 3) trapping and transporting eels past one or more facilities. The advantages and disadvantages associated with these options are discussed below and summarized in Table 6.2-1.

6.2.1 Turbine Passage (Appendix A, Richkus presentation)

The literature revealed some generic statements pertaining to survival rates of adult eels passing through different turbine types and which types of turbines might be more prudent to run during outmigration. Other options portrayed in the literature include the use of "fish-friendly" turbines as well as measures such as facility shutdown during adult migration. These options were discussed during the stakeholder workshop and are summarized below:

Preferential Operation of Francis Turbines: Various studies have estimated the survival of adult eels passing through turbines. Generally, these studies have found somewhat higher survival for large eels that pass through Francis turbines than those that pass through Kaplan turbines. Factors influencing survival include eel size, location of turbine entry, turbine load, and distance between vanes and runner blades.

At Conowingo, preferential operation of Francis units during the period of eel migration could increase the survival of outmigrating eels. Although the timing of eel outmigration has not been definitively established at Conowingo, it is expected to include the period in the fall when juvenile clupeids (American shad and river herrings) are also outmigrating. Studies at Conowingo have demonstrated that juvenile clupeids passing through the Kaplan turbines have better survival (95%) than those passing through the Francis units (89.9%)(Exelon RSP 3.2 Entrainment Study: Estimation of Survival of Juvenile American Shad Passed through Francis Turbines). Preferential operation of the Francis units to maximize survival of adult eels would presumably result in increased mortality of outmigrating juvenile clupeids. In addition, the Francis units are less efficient from an electrical generation perspective than the Kaplan units resulting in reduced power generation with preferential operation of these units.

Fish-Friendly Turbine: Alden Laboratories and the Department of Energy have developed and conducted laboratory tests of a turbine designed to improve the survival of fish passing through a turbine. In the laboratory, this "fish-friendly" turbine has shown turbine survival rates of 94% for adult eels less than 18 inches in length (EPRI 2011a).

At this time, no fish-friendly turbine has been installed at an operating hydroelectric project. A commercial version of the fish-friendly turbine has been designed for an additional unit at a small project in New York. This small unit would not be applicable for Conowingo Dam and could not be used to retrofit an existing Conowingo unit. Installation of a fish-friendly turbine at Conowingo would require a design specific to the Project. A simple retrofit of a new unit is not currently possible and would require substantial modifications to the existing powerhouse, water passages and other infrastructure, which would be accompanied by significant capital expenditures. Additionally, there are still questions as to the efficiency of these turbines to increase fish survival in a practical application and more research is needed before considering the applicability and practicality of this type of turbine at Conowingo.

Project Shutdown: Partial or complete shutdown of the Project during eel outmigration would prevent passage through the turbines and associated mortality. Spillage would provide the avenue for eels to pass the Project. The effectiveness of this option would depend on the ability to predict the timing of outmigration. Attempts to develop accurate models predicting eel migration have not been consistently successful.

Complete shutdown would eliminate turbine mortality but mortality or injury would be expected with passage via the spillway. As juvenile clupeids also outmigrate during fall, complete shutdown would result in them passing the Project through spillage with associated mortality. Complete shutdown would result in an associated loss of energy production.

An alternative to complete shutdown would be partial shutdown during night hours, the period when it is believed that eels migrate. However, studies on the St. Lawrence River show that about 25% of outmigrating eels pass the St. Lawrence Project during daylight hours. If some eels pass the Conowingo Project during daylight hours, these fish would be exposed to turbine impacts. Partial shutdown would also result in an associated loss of energy production. As juvenile clupeids migrate during evening, shutdown at night would result in their passage through spillage with associated mortality.

6.2.2 Deterrence/Guidance and Bypass (Appendix A, Richkus and Amaral presentations)

Methods to guide or deter fish at a facility have been used for juveniles and adults of resident and migratory fish. The deterrence/guidance devices may range from permanent and rigid, made from wood or metal, or temporary and flexible made from netting. A collection facility or bypass is generally associated with deterrence/guidance structures to collect fish for transport or pass fish beyond a barrier. In this case, deterrence/guidance structures are discussed in conjunction with bypass facilities.

There are numerous options for eel passage that employ some method to deter eels from the turbine intakes with guidance to one or more bypasses. The proposed methods for deterrence and guidance can be considered as technologies designed to use either behavioral stimuli to affect eel behavior to deter eels from the turbine intake or structural measures that physically prevent eels from entering the area of the turbine intakes. Typically, the deterrence measures are also designed to attempt to guide eels from the area of the turbines to a bypass for downstream passage. The advantages and disadvantages of these measures are summarized in Table 6.2-1 and discussed in the following sections.

Although deterrence measures are discussed as either behavioral or structural, all behavioral measures with the exception of induced flow require substantial physical structures. For example, components of any behavioral technology deployed upstream of the turbine intakes would require structural elements (*e.g.*, piers, steel members, personnel access, utility services). At large projects, these supporting physical elements can become very expensive to install and maintain. At Conowingo, such a structure could be full depth and 1,000 ft long if it were installed along the face of the turbine intake. Moreover, studies have suggested that behavioral measures are more effective if installed at an angle to the flow; such an installation at Conowingo would result in full-depth structures ranging from 1,350 ft in length (45 degree angle for flow) to 3,600 ft (15 degree angle). Given the debris loading in the river, there would be substantial maintenance effort and cost associated with these structures to ensure that this loading has a minimal effect on the behavioral stimulus.

Various studies have shown that eels in the immediate vicinity of dams exhibit exploratory behavior (NYPA 2009). This behavior has been observed in both laboratory tests and studies of eels in large and small rivers in North America. This behavior was observed at dams with and without physical structures (*e.g.*, bar racks) on the turbine intakes and at dams with no screening of the intakes. The exploratory behavior typically involves vertical movement throughout the water column and horizontal movements across the dam prior to passage.

As deterrence measures are designed to keep eels from passing through turbines, it is necessary to provide an avenue to allow eels to move past the dam. Since eels demonstrate exploratory behavior, it is likely that they can discover an appropriately designed and located bypass especially if the deterrence measure provides some guidance toward the bypass. Given eels' vertical and horizontal movements, more than one bypass may be needed at large dams for timely passage of outmigrants, and these bypasses may need to be located at different elevations in the forebay (*e.g.*, surface, midwater, near bottom). The use of bypasses, typically on small dams, by eels has ranged widely with bypass usage ranging from 12% to 50%.

6.2.2.1 Structural Methods (Appendix A, Richkus and Amaral presentations)

In contrast to measures that attempt to use behavioral stimuli to deter eels from the area of the turbine intakes, structural methods involve a physical barrier to deter fish from entering the area of the turbine intakes. The barrier is typically screens/bars although louvers and wedge-wire screens are alternatives. Barriers may be installed on the face of the power dam perpendicular to flow or at an angle to the flow. Most evaluations of barriers on downstream migrants have been conducted on anadromous species. Louvers have been effective at guiding anadromous species at several sites in the Northeast and on the West Coast.

Observations have shown that outmigrating eels have relatively unique behavior when approaching barriers. Eels typically approach a barrier head first and do not show a response until they physically contact the barrier after which they usually move upstream rapidly. Additionally, eels are sometimes easily impinged with relatively low flows (less that 1 m/s). When the barriers are perpendicular to the flow, eels have been observed to attempt to forcibly pass through the barrier, which often causes injury or impingement. Conversely, eels may be more readily guided along angled barriers. Laboratory studies have demonstrated that a barrier set at 15^o to the flow provided better guidance than a barrier set at 45^o; however, efficiency may vary with approach velocity and bar/louver spacing.

At Conowingo, angled physical barriers across the area of the turbine intakes would be very large. Given the high debris loading in the river, it is quite likely that these permanent structures would have substantial debris management requirements throughout the year. As the structure would be permanent, it is likely that some icing will occur during winter months with associated maintenance requirements. Additionally, debris loading, structure icing, and the presence of the screening will result in head loss and reduced generation.

A permanent physical barrier would affect other anadromous species (American shad, river herring) during multiple life stages. The barrier would affect adults passed upstream by the fish lifts and perhaps delay migration. Additionally, the barrier would affect juveniles as they migrate downstream. For example, it is proposed that outmigrating juvenile clupeids pass through the turbines; the associated survival of this passage is estimated to be 95%, based on preferential Kaplan operation (RMC 1994). If these fish were excluded from the turbine intakes, they would have to pass along the screens/louvers before finding and utilizing a bypass. The associated outmigration and survival rates are unknown and could be less than the rates associated with turbine passage. In addition a physical barrier could result in future upstream passage facilities with a less-than-optimal location and/or design.

6.2.2.2 Induced Flow (Appendix A, Richkus presentation)

The provision of flow to guide fish to a bypass has been considered for downstream passage at hydroelectric projects. These flows are intended to induce outmigrating fish to detect and follow this flow to the bypass rather than enter the area of the turbine intakes. The use of induced flows to guide movement has been investigated for some anadromous fish (*e.g.*, juvenile salmon), but has not been tested for eels. The use of induced flows for guidance has also not been tested on large rivers.

Data from studies involving induced flows have been inconsistent. Haro *et al*. (2000) reported that 10 of 13 (77%) radio-tagged eels passed through turbines rather than over a dam or through a bypass. Shultze (1999) found that eels passed through turbines until 50% of flow passed over the dam. Of 15 eels tracked by Durif *et al*. (2002), 10 eels (67%) passed over the dam, one eel (7%) passed through the turbines, and four eels (26%) used a bottom bypass; these data were collected in relation to a storm event (*i.e*., higher flows). As eels are thought to move downstream with the main flow (*i.e.,* flow through turbines), it is generally felt that the effectiveness of bypass flows is likely limited in the absence of barriers to deter fish from the turbines.

6.2.2.3 Behavioral Methods (Appendix A; Richkus and McGrath presentations)

Behavioral deterrents or attractants use a particular stimulus to elicit an instinctual response in fish to produce movement in a desired direction. Potentially successful behavioral stimuli may vary for a particular species and will likely vary depending on the infrastructure associated with a hydroelectric project. If a behavioral-based technology could be designed for outmigrating eels, it is likely to affect both resident species and outmigrating juvenile clupeids. The effects on these species are unknown, but would need to be considered. The behavioral methods investigated include:

Light: Light has been shown to produce an avoidance response in outmigrating eels. In small streams and rivers in Europe, diversion rates of 66% to 90% have been reported for the European eel. In a study on the St. Lawrence River, eels avoided a 300-ft long, high-intensity light field at night; an avoidance rate of 77.6% was estimated.

Although some studies have demonstrated avoidance of light by eels, other studies report little or no effect under some circumstances. One significant limitation of a light-based deterrence technology is water clarity. For the St. Lawrence River study, water clarity was very high (up to 30 ft) whereas water clarity on the Susquehanna at Conowingo is normally much lower. Habituation may also compromise the effectiveness of a light-based system as eels could be required to consistently avoid light along a long light-field. The effectiveness of a light-based system would be limited to night time. Although it is generally accepted that eel outmigration occurs at night, some movement may occur during daylight hours when a light-based system would be ineffective. On the St. Lawrence River, 25% of outmigrating eels moved downstream during the day; a conceptual model for this system estimated that diversion efficiency of a light-based system could range from 13% (some habituation) to 58.5% (no habituation) (NYPA 2009).

Sound: The use of low-frequency sound (infrasound) for diverting eels has had mixed results. Two studies by Sand *et al.* (2000, 2001) showed that eels responded positively to infrasound (11.8 Hz). The 2000 study was conducted on a small river in Europe and demonstrated potential value for diverting movement of downstream migrating eels. In contrast, current studies at the intake of a Belgium power plant intake have not yielded promising results. It is estimated that the area of effect of infrasound is limited to within approximately two to three meters of the source. Based on the equivocal results of studies to date and the limited area of effect, the potential effectiveness of infrasound for deterring and guiding eels, particularly for a long distance on a large river, is not considered promising.

Air Bubbles and Water Jets: The use of air bubbles and water jets to deter fish from entering areas of power plant intakes has been proposed for many years. No lasting response of eels to air bubbles and water jets has been reported. Eels rapidly habituated to these methods.

Electricity: Eels are very sensitive to electricity. There has been some success in eel diversion on small rivers in Europe with electric fields and screens, but this result has not been found consistently (Hadderingh and Jansen 1990). Although these results suggest the potential for the use of electricity, there are numerous obstacles with implementation of this technology for downstream migrating eels. One particular obstacle is implementing this method in a way that successfully deters and guides eels for a long distance without stunning them and increasing the likelihood of being carried into the area of the turbine intakes. Use of electricity could also have the potential for effects on the safety of humans as well as other fish.

Electromagnetic Fields: Studies in the laboratory have demonstrated that eels can detect and respond to electromagnetic fields, and some research suggests that eel may navigate via electromagnetic fields (NYPA 2009). Beyond these simple responses, little is known about the interaction of electromagnetic fields and eel behavior. Before this technology can be considered as the basis for a potential deterrence and guidance method for downstream migrating eels, extensive basic research would be required to determine the type of electromagnetic field that might affect migrating eel behavior, methods of projecting a field, and quantifying field intensity.

Chemical Attractants and Repellents: Fish are known to detect and respond to a wide range of water-soluble compounds. Laboratory studies demonstrate that some life stages of eels (*e.g.*, elvers) can detect and respond to small concentrations of chemicals. No information is available concerning whether eels at any life stage are repelled by a chemical compound.

There are several obstacles to the use of chemicals to deter outmigrating eels from the area of turbine intakes or to guide/attract them to a downstream bypass. Discharge of any compound – if one were to be found – would be difficult to effectively generate a “chemical barrier” (deterrence) or “chemical field” (guidance) in an environment where the direction of flow would be moving the deterrent/attractant substance downstream, away from the desired location of effect. Potential effects on other species would also have to be considered. In addition, the discharge of any chemical would be subject to regulatory constraints.

6.2.3 Trap and Transport (Appendix A, Richkus presentation)

The trapping and transport of downstream migrating eels is inherently different than the other downstream passage options. First, in the case of Conowingo, the facilities associated with trap and transport would not be located in the immediate vicinity of the Project. Thus, there would be no conflicts with other resources the Project is trying to protect in the vicinity of Conowingo Pond (*e.g.*, American shad). Conflicts with aquatic resources in other areas can be minimized by selecting appropriate locations for release (see Section 5.1.3). Second, trap and transport could allow passage past multiple dams. Finally, while trapping efficiency is unknown, it is known that there is extremely high transport survival for adult eels and that large eels tend to resume migration after release (NYPA 2009).

6.3 Discussion of Downstream Options at Conowingo

Following the presentations on downstream-passage options at the October 2011 eel passage workshop, stakeholders discussed the applicability of these options for the Conowingo Project. These discussions are captured in the meeting minutes (Appendix A) and are summarized below.

The discussion concluded that most of the behavioral-based options were not appropriate or feasible. Fish-friendly turbines, variations of turbine operation, structural deterrence/guidance systems with bypasses, and a trap-and-transport program were discussed in some detail. The discussion highlighted a number of questions and uncertainties related to fish-friendly turbines, variations of turbine operation, and structural deterrence/guidance systems with bypasses. It was suggested that a trap-and-transport program may be the most viable option for the lower Susquehanna River. This program could provide for both the reduction in mortality to outmigrating eels at more than one of the four hydroelectric projects on the lower river thereby increasing adults available to reproduce and providing ecosystem benefits resulting from the presence of eels in the watershed.

The stakeholders discussed elements of a potential trap-and-transport program. It was recognized that collection of eels in the mainstem of the river could be difficult due to the size of the river and associated flows. An ongoing USFWS program moving young eels from below Conowingo Dam to areas upstream of the dam has placed eels into several tributaries rather than the river itself. These locations were judged to be appropriate because there was substantial habitat suitable for eels. The placement of eels in tributaries would facilitate the subsequent collection of outmigrants from these streams as part of a trap-and-transport program. There were a number of locations in various tributaries as well as in the river where eel weirs were historically located. These locations could provide appropriate trapping points for the collection of eels for such a program. The consensus of the stakeholders was that a trap-and-transport program within tributaries would be an appropriate initial step.

It was agreed that this type of approach would likely take the form of a management plan. Initial efforts would be focused on stocking selected tributaries [upstream of York Haven] with upstream migrating eels that were captured at Conowingo Dam. These same tributaries would be targeted for collection of eels migrating downstream in the fall using a structural eel weir (see Figure 6.3-1 for a typical plan and profile). As these initial tributaries become saturated with established populations, the program could be expanded to other suitable tributaries. If the program continues to be successful and the populations thrive, efforts could be shifted to larger tributaries and eventually to the main stem of the river.

Capital costs for the initial phase of collection in two tributaries are presented as Table 6.3-1. This includes material and labor to install the eel weirs plus labor and transport equipment to capture and transfer the eels downstream of the dam.

The USFWS program is currently stocking eels collected from the Conowingo tailrace in Buffalo and Pine Creeks, near Kelly Point, PA and Ansonia, PA, respectively. The cost opinion developed includes capital costs for two eel weirs at these locations and one haul truck, assuming it could be used for both locations. The total capital cost was estimated to be approximately $201,500, which includes a 25% contingency, design, permitting, and construction administration. The annual operations cost was estimated to be approximately $266,000 per year, based on a 10-week season assuming one eel biologist and one eel technician could cover both sites on alternating days. Costs for a driver are also included, assuming one trip every other day. Exelon anticipates that the cost of a trap and transport program would be shared among the licensees of the four dams the eels would be required to pass.

For this initial cost opinion it was assumed that transport trips would occur every other day throughout the season. During the peak of the season there will probably be more frequent trips and at each end of the migration the frequency will likely be lower. An additional week was also assumed at the beginning and end of the season for mobilization/demobilization with two eel biologists and two eel technicians. The pilings and lowest layer of the eel weir are proposed to be left in place during the off season; the remainder of the structure would be removed then reinstalled each season. These values do not include costs to replace materials from deterioration or damage, it is expected that the materials will not last more than a few years.

Design of the weirs will be based on eel weirs successfully operated on other water bodies. This information will reflect both structural measures and operational experience including performance during high-flow events and periods of debris loading. Debris loading is expected to decrease collection efficiency so it will be necessary to periodically remove debris during the period of eel migration. Design will consider periods of high flow when eels are known to migrate; however, it may not be possible to achieve maximum collection efficiency during very high flows. Design issues identified with the initial weirs will be addressed, to the extent practicable, in subsequent weirs.

The discussion of a trap-and-transport program identified information needed to develop this program. In addition to the information identified in Section 6.2, information would be needed on:

- Extent and value of eel habitat upstream of York Haven Dam including tributaries, and
- Identification of areas in tributaries and in the Susquehanna River where eel weirs were used in the past.

TABLE 6.2-1: SUMMARY OF ADVANTAGES AND DISADVANTAGES FOR DOWNSTREAM PASSAGE OPTIONS FOR AMERICAN EEL AT CONOWINGO DAM.

Passage Method	**Advantage**	**Disadvantage**	**Comment**
Turbine Passage			
Preferential Operation of Francis Turbines	-Better Survival than Kaplan Turbines	-Conflicts with preferential passage of juvenile shad through Kaplan units (95% survival) vs. Francis units (85 - 90%)	-Mortality influenced by eel size, location of turbine entry, turbine load, and distance between vanes and runner blades
Fish-Friendly Turbine	-Lab tests show high survival (94%)	-Existing design for commercial unit not applicable for existing Conowingo units	-No survival data for eels larger than 18 inches
		-Retrofit at Conowingo would require extensive modification to existing water passages at extensive costs	
Project Shutdown	-No turbine mortality	-Loss of energy production	-Passage via spillage with unknown mortality
			-Passage of juvenile clupeids by spillage with unknown mortality
			-Effectiveness depends on ability to predict timing of outmigration
Guidance/Bypass			
Behavioral Methods			
Light	-Some studies show avoidance	-Turbidity limits effectiveness	-Large structure very expensive to install
		-Not effective during daylight	-High costs to operate and maintain
		-Large, full-depth structure required	-Multiple bypasses may be needed
		-Habituation could limit effectiveness	-Unknown effects on other species

		-High potential for debris loading	-Diversion efficiency for large river unknown; estimate for St. Lawrence was 13% to 59%
Sound	-One study showed positive diversion response to infrasound in small river	-Field of effect limited to within two to three meters of source	-Potential effectiveness in large rivers highly uncertain; literature equivocal
		-High potential for debris loading	-Large structure very expensive to install
		-Large, full-depth structure required	-High costs to operate and maintain
		-Habituation could limit effectiveness	-Multiple bypasses may be needed
			-Unknown effects on other species
Air Bubbles/Water Jets	-None	-No lasting response by eels	
		-Rapid habituation	
Electricity	-Eels very sensitive to electricity	-High potential for adverse effects to other species and human safety	-Challenges to install a system that would guide rather than stun eels
	-Some successful diversion using electric fields and screens but results inconsistent	-Large, full-depth structure required	-Multiple bypasses may be needed
Electromagnetic Fields	-Lab studies show eels can detect and respond to fields during some life stages		-Extensive basic research needed to determine potential to be effective guidance mechanism
			-Unknown effects on other species
Chemical Attractants and Repellents	-None	-Chemicals would be difficult to effectively deploy to control movement of outmigrating eels in large river	-Available information insufficient to estimate potential guidance effectiveness
		-Potential regulatory constraints	-Unknown effects on other species
Induced Flow	-None	-In absence of barriers at	-Guidance effectiveness not

		turbines, effectiveness of induced flow likely to be limited	tested in large rivers
			-Inconsistent results in bypass studies
			-Multiple bypasses may be needed
Structural Devices			
Bar Racks/Louvers	-Laboratory studies show angled barriers (screens and louvers) can guide eels	-Eels impinge on screens, often resulting in injury	-Shallow angles (e.g., 15 degrees) more effective than more acute angles (e.g., 45 degrees)
		-Impacts on generation	-High costs to operate and maintain
		-Large, full-depth structure required	-Multiple bypasses may be needed
		-High potential for debris loading	-Large structures may result in lower guidance efficiencies than demonstrated in laboratory tests
		-Screens could affect upstream migrants	
		-Screens could affect outmigrating clupeids	
Trap and Transport			
	-Effective in increasing the number of eels reaching upstream habitats (vs. volitional passage) in systems where eels have to pass multiple projects	-More feasible for small streams than large rivers -Dispersion of young eels from release location could affect percentage of released eels recaptured upon out migration.	-Cost effectiveness depends on ability to predict timing of outmigration
	-Ensures survival of virtually all captured outmigrating eels transported around projects		-Effectiveness in increasing number of successful outmigrants (vs. volitional passage from same areas) depends on ability to capture sufficient percentage of

			outmigrating eels
	-No impact on generation		-Overall effectiveness of program depends on upstream transport to locations that allow for capture of sufficient percentage of outmigrating eels without impacting other aquatic resources

Table 6.3-1. Cost Opinion, Downstream Passage: Trap and Transport with Eel Weir

Item No.	Item	Quantity	Unit	Unit Price	Cost
332	**Reservoirs, Dams, and Waterways**				
	Pilings	480	LF	$32.50	$15,600
	Weir Wall Lumber	760	SF	$5	$3,800
	Fasteners	1	LS	$500	$500
	Screen Slats	250	SF	$7.50	$1,875
	Cross Ties	100	LF	$8	$800
	Collection Trough & Net	1	EA	$500	$500
	Collection Tank	1	EA	$2,500	$2,500
	Rip-Rap	5	CY	$50	$250
	Per Weir Subtotal				$25,825
	Number of Tributaries Being Trapped	2			
	332 Subtotal*				**$52,000**
335	**Miscellaneous Power Plant Equipment**				
	Haul Truck (Assumes 1 can be used for both tribs)	1	EA	$50,000	$50,000
	Transport Tank (1,500 gal)	1	EA	$2,000	$2,000
	Trash Pump	2	EA	$1,500	$3,000
	Dissolved Oxygen Injection System	1	LS	$1,000	$1,000
	Temperature Monitor	1	EA	$500	$500
	335 Subtotal*				**$56,500**

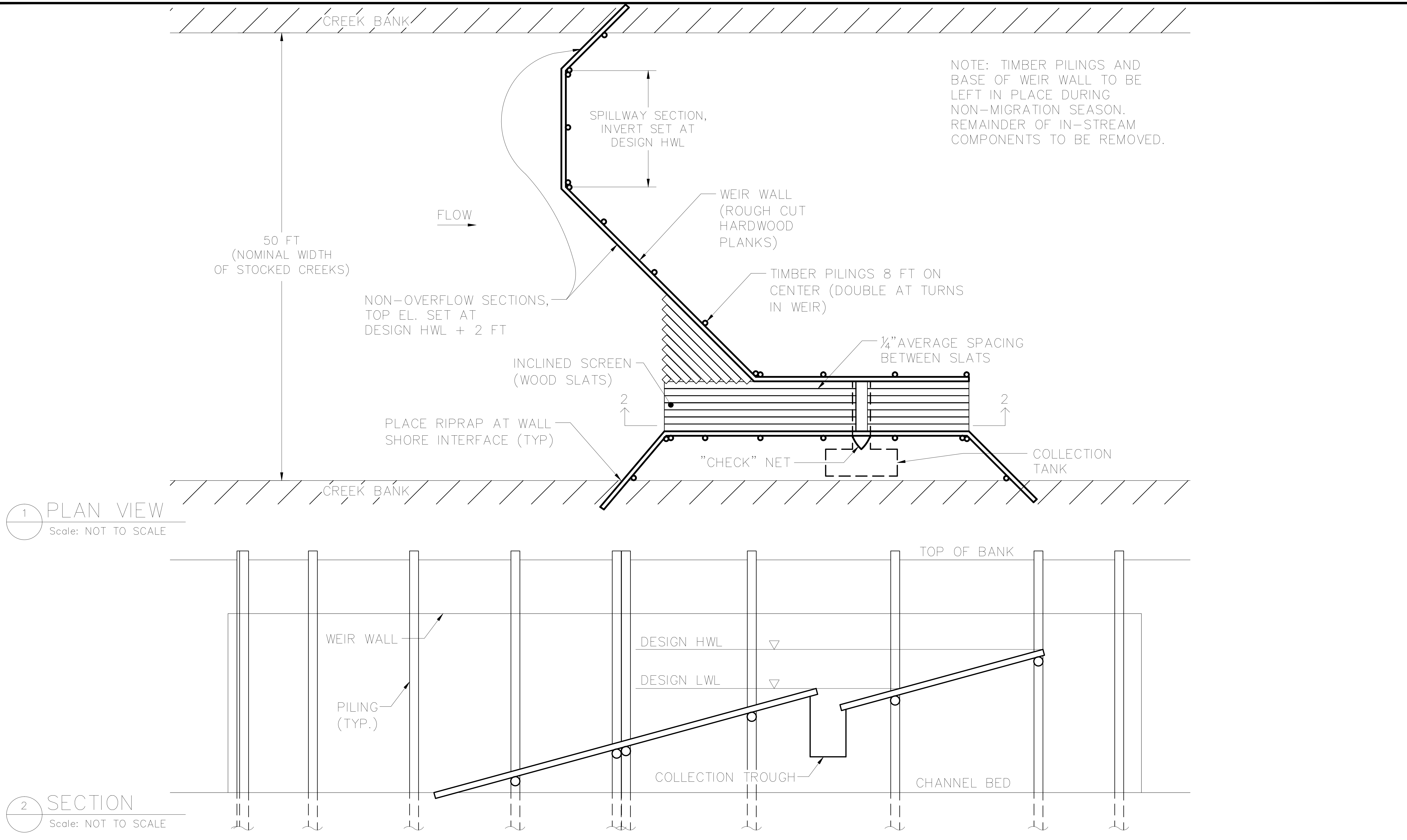
Mobilization/Demobilization (10%)*	**$11,000**
Subtotal Direct Cost	**$119,500**
Contingencies (25%)*	$30,000
Total Direct Cost	**$149,500**
Design (20%)*	$30,000
Permitting (10%)*	$15,000
Construction Administration (5%)*	$7,000
Total	**$201,500**

**Note: Rounded to nearest $1,000*

Item No.	Item	Quantity	Unit	Unit Price	Cost
901	**Annual Operations - Non-Labor**				
	Mileage *(assumes 440 mile round trip, every other day)*	15,000	MI	$0.50	$7,500
	Fuel	5,000	GAL	$5	$25,000
	Salt (Stress Reduction)	5	TON	$500	$2,500
	Tank Refills (Oxygen)	1	LS	$1,000	$1,000
	901 Subtotal*				**$36,000**
902	**Annual Operations - Labor**				
	Eel Biologist *(assumes 10 weeks per year, full time)*	900	HR	$100	$90,000
	Eel Technician *(assumes 10 weeks per year, full time)*	900	HR	$75	$67,500
	Drivers *(assumes 10 weeks per year, half time)*	350	HR	$55	$19,250
	(Bio. & Tech. time also includes 10 days x 2 staff for				
	mob/demob)				
	902 Subtotal*				**$177,000**

Subtotal Annual Operations Cost	**$213,000**
Contingencies (25%)*	$53,000
Annual Operations Total	**$266,000 /YR**

**Note: Rounded to nearest $1,000*



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Exelon.

CONOWINGO RELICENSING

EEL WEIR

DATE AUGUST 2012

FIGURE NO: 6.3-1

7.0 POTENTIAL UPSTREAM AND DOWNSTREAM PASSAGE IMPACTS

In evaluating the impacts of an eel-passage program, one has to consider the expected overall upstream passage efficiency and the expected downstream passage survival. For volitional fish passage, overall upstream passage efficiency is a function of the percentage of fish that enter the fish passage facilities ("discovery rate") and the efficiency of the facility to pass eels that enter it ("in-ramp passage efficiency"). At the 82-ft high Moses-Saunders Power dam on the St. Lawrence River, recapture studies conducted over three years indicated a 38 to 45 percent ramp discovery rate of the tagged eels in the tailrace between the ramps on the American and Canadian sides of the dam. These estimates do not account for potential tagged eel mortality, tag loss or migration to available downstream habitats (*e.g.*, Lake St. Francis) over the three-year period. NYPA's eel passage facility on the American side of the Moses-Saunders dam had an average in-ramp passage efficiency of 86 percent based on five years of study. Based on these two percentages, overall passage efficiency was 33 to 39 percent for eels in the Moses-Saunders Dam tailrace. Little data exist to quantify passage efficiencies for eels that have entered ramps at shorter dams (10 to 40 ft). However, it is expected that shorter ramps at smaller dams and trap-and-transport facilities at larger dams would have a higher in-ramp passage efficiency than fully volitional ramps at larger dams (*e.g.*, the Moses-Saunders Power dam), and this efficiency would likely be approximately 90 to 95 percent (Pers. Communication, D. Desrochers, Aug. 2011). Given a similar ramp discovery rate (38 to 45 percent) as larger facilities; the overall passage efficiency at smaller dams would be 36 to 43 percent, based on 95 percent in-ramp passage efficiency.

Estimates of discovery rate and in-ramp passage efficiency for the eel ladder at the St. Lawrence-FDR Project can be used to assess potential volitional upstream passage on the Susquehanna River. A similar 38 to 45 percent ramp discovery rate at each dam along the Susquehanna may be expected. Different estimates may be used to determine the in-ramp passage efficiency of the lower Susquehanna River's larger dams (Conowingo, Holtwood and Safe Harbor) versus smaller dams (York Haven) or trap-and-transport facilities. Thus, the St. Lawrence overall efficiency estimate can be used to assess a fully volitional system at Conowingo, Holtwood, and Safe Harbor dams because the height of these dams (approximately 90, 55, and 75 ft, respectively) and length of an associated eel ramp would be similar to that at the St. Lawrence Project. However, it may be more appropriate to assume higher in-ramp passage efficiency for the smaller York Haven dam (9 to 17 ft). Table 7-1 illustrates individual dams' discovery rate, in-ramp passage efficiency and overall upstream passage efficiency for volitional upstream passage on the Susquehanna River. As shown in Table 7-1, approximately one-third of the eels in the Conowingo Tailrace would be expected to reach Conowingo Pond, with the remaining two-thirds remaining downstream of Conowingo Dam. As would be expected with any volitional passage, a portion of the migrating eels will become residents in the impoundments through which they pass so that the cumulative passage efficiency from Conowingo tailrace to the York Haven impoundment (1.3 to 2.5 percent) can be estimated as the product of the four dams' upstream passage efficiencies.

In contrast to volitional passage, the overall upstream passage efficiency of the trap-and-transport approach at Conowingo (height of eel ramp to trap equal to 30-38 ft) would be expected to be similar to the overall passage efficiency at a smaller dam (36 to 43 percent, based on a 95 percent in-ramp passage efficiency and a 38 to 45 percent ramp discovery rate). With an expected very low mortality associated with transport, the cumulative efficiency of transported fish upstream of York Haven (or any reasonable distance of transport) would remain constant relative to Conowingo's estimated passage rate.

Upon maturity, eels migrate downstream. If volitional passage was chosen, the eels would have to pass through the four dams' turbines. Survival estimates for downstream turbine passage is a function of turbine type and flow. Table 7-2 illustrates the proportion of flow through the types of turbines (*i.e.*, Francis or Kaplan) at each of the lower Susquehanna hydroelectric projects. Literature reports (EPRI 2011) silver eel mortality at Francis turbines ranges from 9 – 15.8 percent, while mortality at Kaplan turbines is reported to range from 25.2 – 37 percent. Based on the proportion of flow through turbine types at each facility and the range of survival estimates, Table 7-3 illustrates the expected survival of silver eels at each hydroelectric facility.

An alternative to volitional downstream passage would be a downstream trap and transport system where silver eels are trapped via eel weirs at upstream locations (in this case upstream of York Haven) and transported to a location downstream of Conowingo Dam. Eels transported upstream could be released into tributaries, impoundments, and/or the main stem of the river. Release locations would need to be carefully selected so that the collection of downstream migrants does not impact other aquatic resources.

There is very little information on the efficiency of eel-weir type of collection facilities, particularly for a mainstem location on a large river such as the Susquehanna. Based on discussions with Alex Haro of the U.S Geological Survey (USGS) Conte Anadromous Research Laboratory (A. Haro, Personal Communication, January 2012) it appears reasonable to assume trap efficiencies ranging from 50 to 95 percent. Given very low expected transport mortality, we would expect the cumulative trap-and-transport efficiency to also be 50 to 95 percent.

In order to assess the potential number of silver eels available for outmigration to the Sargasso Sea as well as the potential abundance of eels distributed via passage to upstream areas, it was necessary to construct an eel passage survival model for several passage scenarios. For scenarios involving volitional passage, these models include: a) low-end estimates of upstream passage efficiency and downstream survival for volitional passage (Figure 7-1); b) high-end estimates of upstream passage efficiency and downstream survival for volitional passage (Figure 7-2); c) trap-and-transport efficiency to upstream of York Haven with low-end downstream passage survival (Figure 7-3); and d) trap-and-transport efficiency to upstream of York Haven with high-end downstream passage survival (Figure 7-4).

We also evaluated scenarios involving upstream and downstream passage via only trap and transport. Given the lack of downstream trapping efficiency literature and the fact that yellow eels may leave a tributary where stocked prior to outmigration as silver eels, we did a sensitivity analysis with downstream trapping efficiencies of 25, 50, 75 and 95 percent. The analysis results, using low end upstream trap and transport efficiency, are illustrated in Figures 7-5 – 7-7. These scenarios assume low end turbine passage survival rates for outmigrating silver eels not successfully trapped. Figure 7-8 illustrates results for high end upstream trap and transport efficiency, high end downstream survival for outmigrating silver eels not successfully trapped, and a high end (95 percent) downstream trap and transport efficiency.

The scenarios evaluated above allow consideration of various resource management objectives relative to these scenarios. If the sole resource management objective is to provide the most silver eels leaving the Susquehanna River for the journey to the Sargasso Sea, low-end estimates for upstream and downstream volitional passage is estimated to provide a return of 90.0 percent of the eels downstream of Conowingo Dam (Figure 7-1). This scenario has such a high return rate of fish to the Sargasso Sea primarily because a large percentage (67%) of the eels never migrate upstream of Conowingo Dam. For upstream and downstream trap-and transportation options, the number of eels returning to the Sargasso Sea depends on the capture efficiency of the eel-weir structure. The percent of returning eels varies from 81.3 percent at the 25 percent capture rate (Figure 7-5) to over 90 percent for high capture rates (93.8 percent at a 75 percent capture rate and 98.7 percent at a 95 percent capture rate; Figures 7-7 and 7-8).

If the sole resource management objective is to maximize eel abundance upstream of York Haven Dam, this goal would be accomplished with an option involving a trap-and transportation program. Programs involving volitional passage at the four dams result in only 1.3 percent to 2.5 percent of the eels below Conowingo Dam reaching the river above York Haven (Figures 7-1 and 7-2). In contrast, a trap-and-transportation program is estimated to provide for 36 percent to 43 percent of the eels below Conowingo to the river above York Haven (Figures 7-3 through 7-8). The options involving volitional passage will distribute eels in the impoundments behind Conowingo, Holtwood, and Safe Harbor dams in addition to the river above York Haven; a trap-and-transportation program delivering eels to the river above York Haven would not result in eels in the three impoundments in the lower river.

If an upstream and downstream eel-passage program sought to balance the two resource objectives discussed above, an upstream and downstream trap-and-transport program would be the best approach. It is estimated that upstream transport would provide far more eels upstream of York Haven (36 to 43 percent) than a volitional program (1.3 to 2.5 percent). Although the number of silver eels provided for transportation to the river below Conowingo Dam to begin the journey to the Sargasso Sea is dependent on the capture rate, the lower capture rates of the eel weir (25 and 50 percent) provide a number of silver eels (81.3 and 87.5 percent; Figures 7-5 and 7-6, respectively) that is slightly less than provided by the best scenario involving voluntary upstream and downstream passage (90.0 percent; Figure 7-1). At higher eel weir capture rates (75 and 95 percent), the number of silver eels provided (greater than 93.8 percent; Figures 7-7 and 7-8, respectively) would approximate or exceed the number of silver eels provided by the best volitional scenario.

TABLE 7-1: LOWER SUSQUEHANNA RIVER DAMS – POTENTIAL UPSTREAM PASSAGE EFFICIENCY

Dam	Approx. Dam Height (ft)	Low End			High End		
		Discovery Rate	In-Ramp Passage Efficiency	Overall Passage Efficiency	Discovery Rate	In-Ramp Passage Efficiency	Overall Passage Efficiency
Conowingo	90	0.38	0.86	0.33	0.45	0.86	0.39
Holtwood	55	0.38	0.86	0.33	0.45	0.86	0.39
Safe Harbor	75	0.38	0.86	0.33	0.45	0.86	0.39
York Haven	9-17	0.38	0.95	0.36	0.45	0.95	0.43

TABLE 7-2: PROPORTION OF FLOW THRU FRANCIS AND KAPLAN (PROPELLER) TURBINES AT EACH OF THE HYDROELECTRIC FACILITIES ON THE MAINSTEM OF THE SUSQUEHANNA RIVER.

Dam	Proportion of Flow through Turbine Type	
	Francis	Kaplan
York Haven	0.65	0.35
Safe Harbor	0.00	1.00
Holtwood[7]	0.51	0.49
Conowingo	0.55	0.45

TABLE 7-3: LOWER SUSQUEHANNA RIVER HYDROELECTRIC PROJECTS' EXPECTED POWERHOUSE SURVIVAL ESTIMATES FOR OUTMIGRATING SILVER EELS. MODIFIED FROM EPRI (2011).

Turbine Type	Low End		High End	
	Mortality Rate (%)	Source	Mortality Rate (%)	Source
Francis	9.0	RMC (1995)	15.8	Desrochers (1995)
Kaplan	25.2	NA and Skalski (2000); Desrochers (1995)	37.0	NIMO (1995)

Dam	Low-End Powerhouse Survival Rate (%)	High-End Powerhouse Survival Rate (%)
York Haven	80.9	81.1
Safe Harbor	63.0	74.8
Holtwood	77.2	79.6
Conowingo	78.3	79.9

[7] Holtwood's post-expansion setup with two additional Kaplan turbines is used in this analysis.

FIGURE 7-1: FLOW CHART DIAGRAM OUTLINING VOLITIONAL UPSTREAM AND DOWNSTREAM EEL PASSAGE THROUGH THE LOWER SUSQUEHANNA. ASSUMES LOW END UPSTREAM AND DOWNSTREAM PASSAGE RATES.

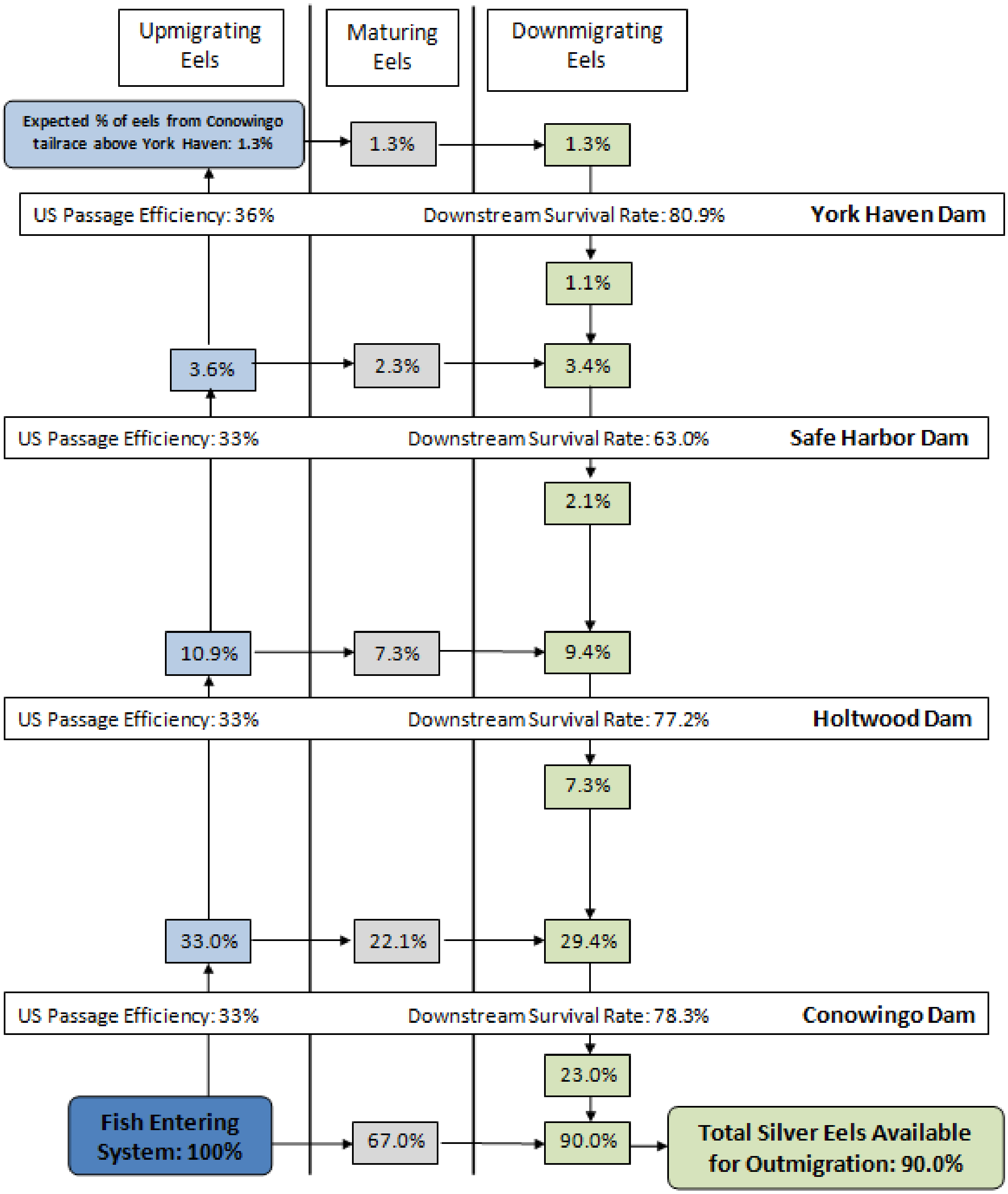


FIGURE 7-2: FLOW CHART DIAGRAM OUTLINING VOLITIONAL UPSTREAM AND DOWNSTREAM EEL PASSAGE THROUGH THE LOWER SUSQUEHANNA. ASSUMES HIGH END UPSTREAM AND DOWNSTREAM PASSAGE RATES.

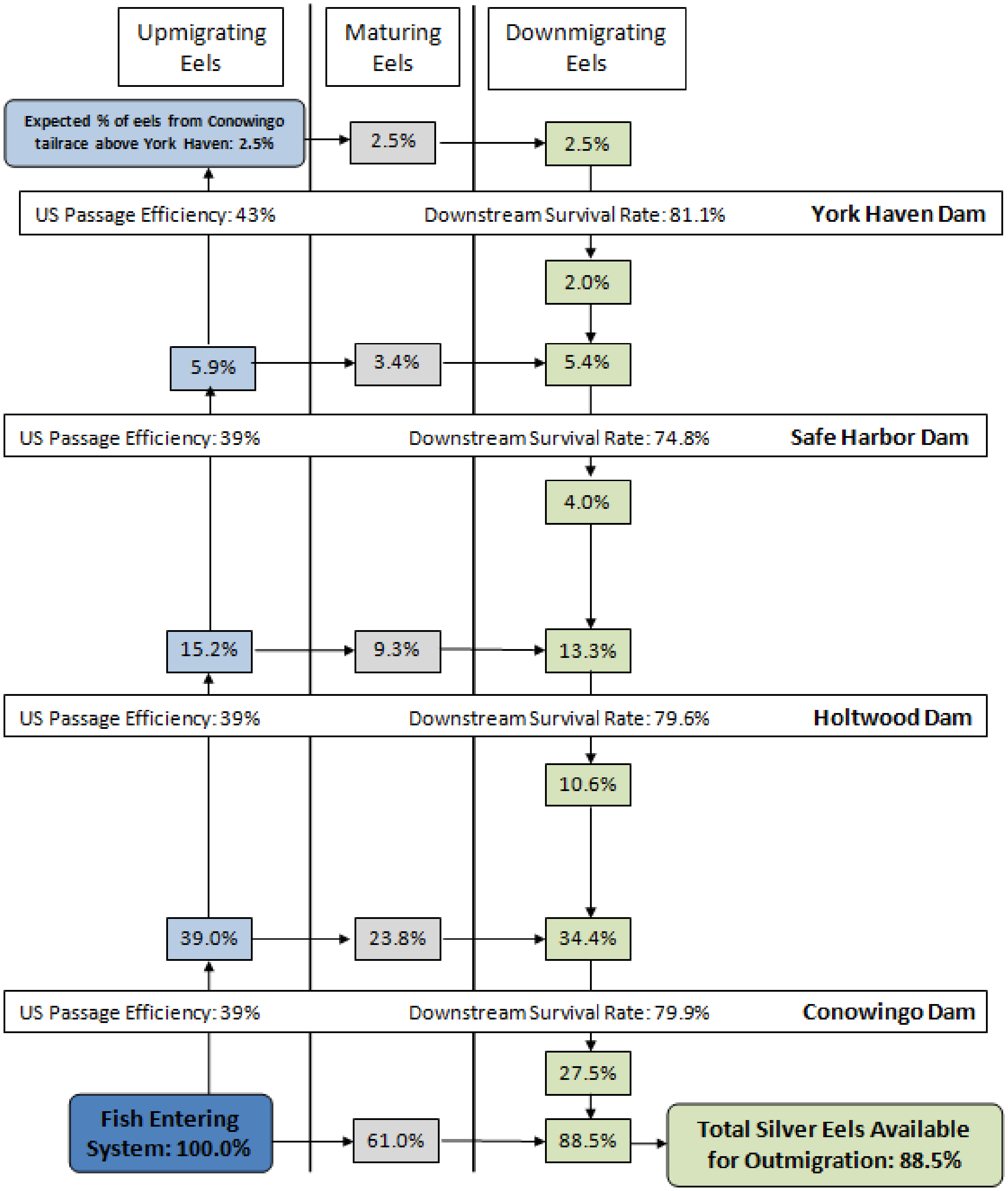


FIGURE 7-3: FLOW CHART DIAGRAM OUTLINING TRAP AND TRUCK UPSTREAM PASSAGE AND VOLITIONAL DOWNSTREAM EEL PASSAGE THROUGH THE LOWER SUSQUEHANNA. ASSUMES LOW END DOWNSTREAM PASSAGE RATES.

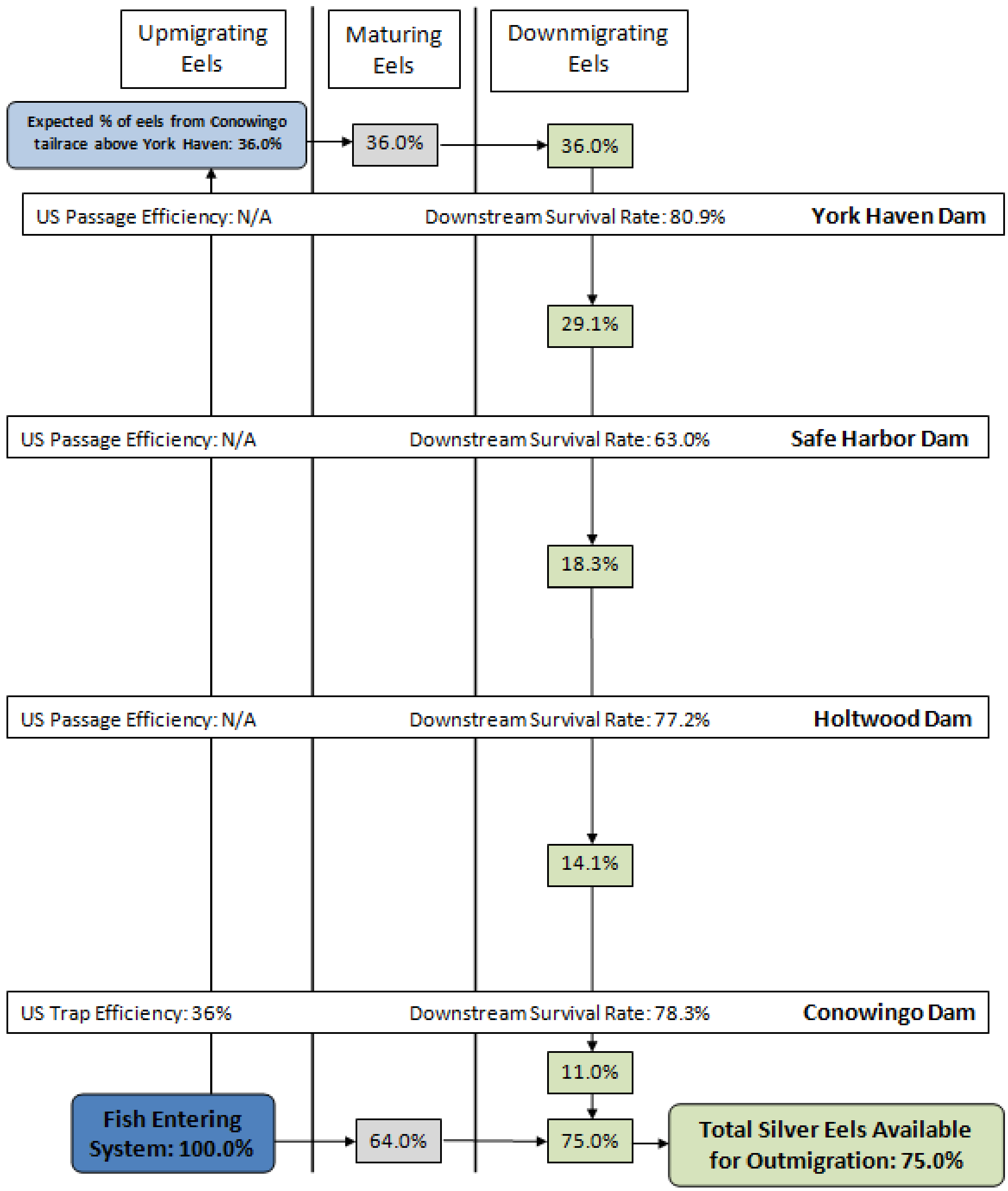


FIGURE 7-4: FLOW CHART DIAGRAM OUTLINING TRAP AND TRUCK UPSTREAM PASSAGE AND VOLITIONAL DOWNSTREAM EEL PASSAGE THROUGH THE LOWER SUSQUEHANNA. ASSUMES HIGH END DOWNSTREAM PASSAGE RATES.

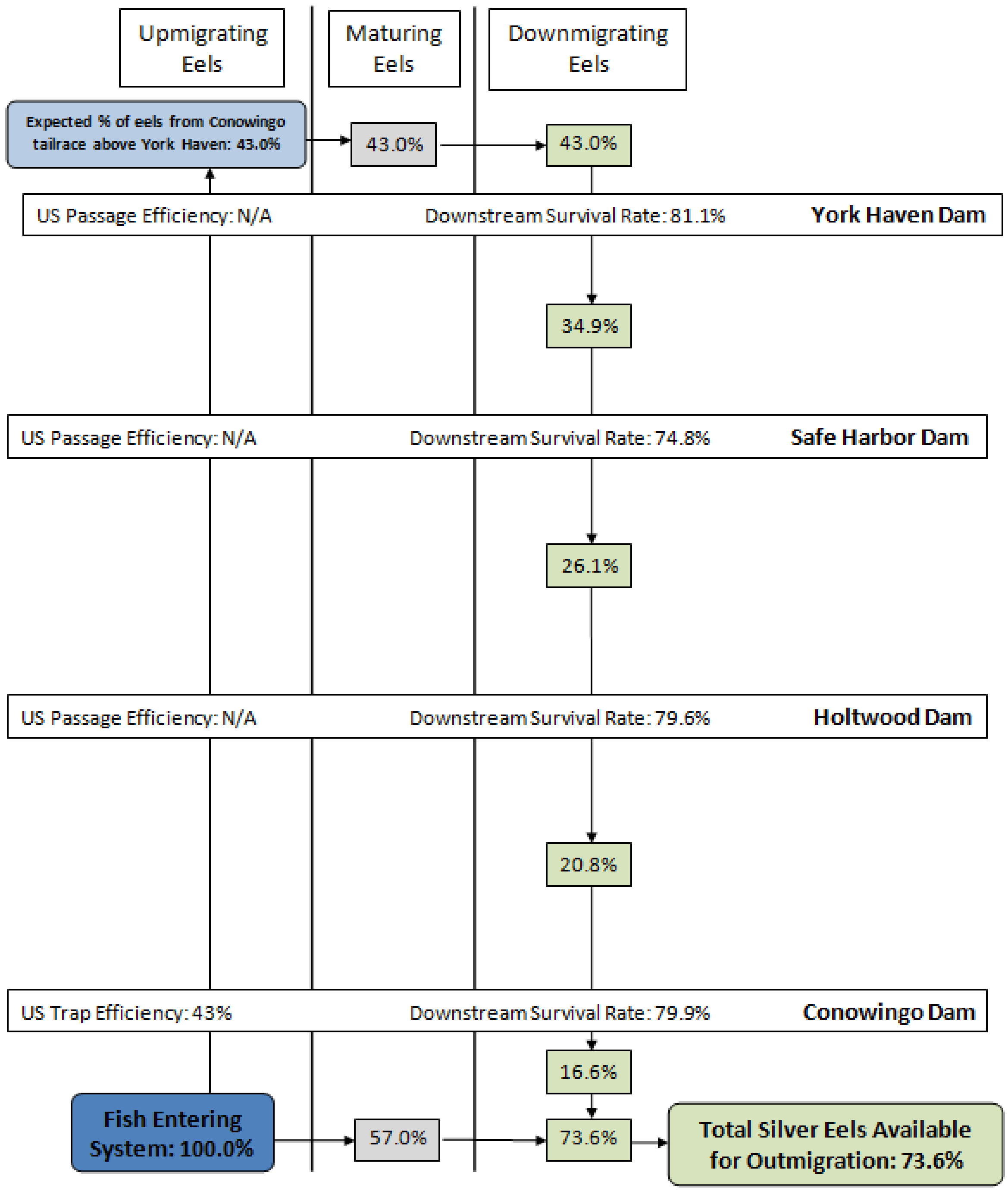


FIGURE 7-5: LOW END UPSTREAM AND DOWNSTREAM TRAP AND TRANSPORT WITH 25% DOWNSTREAM TRAP EFFICIENCY

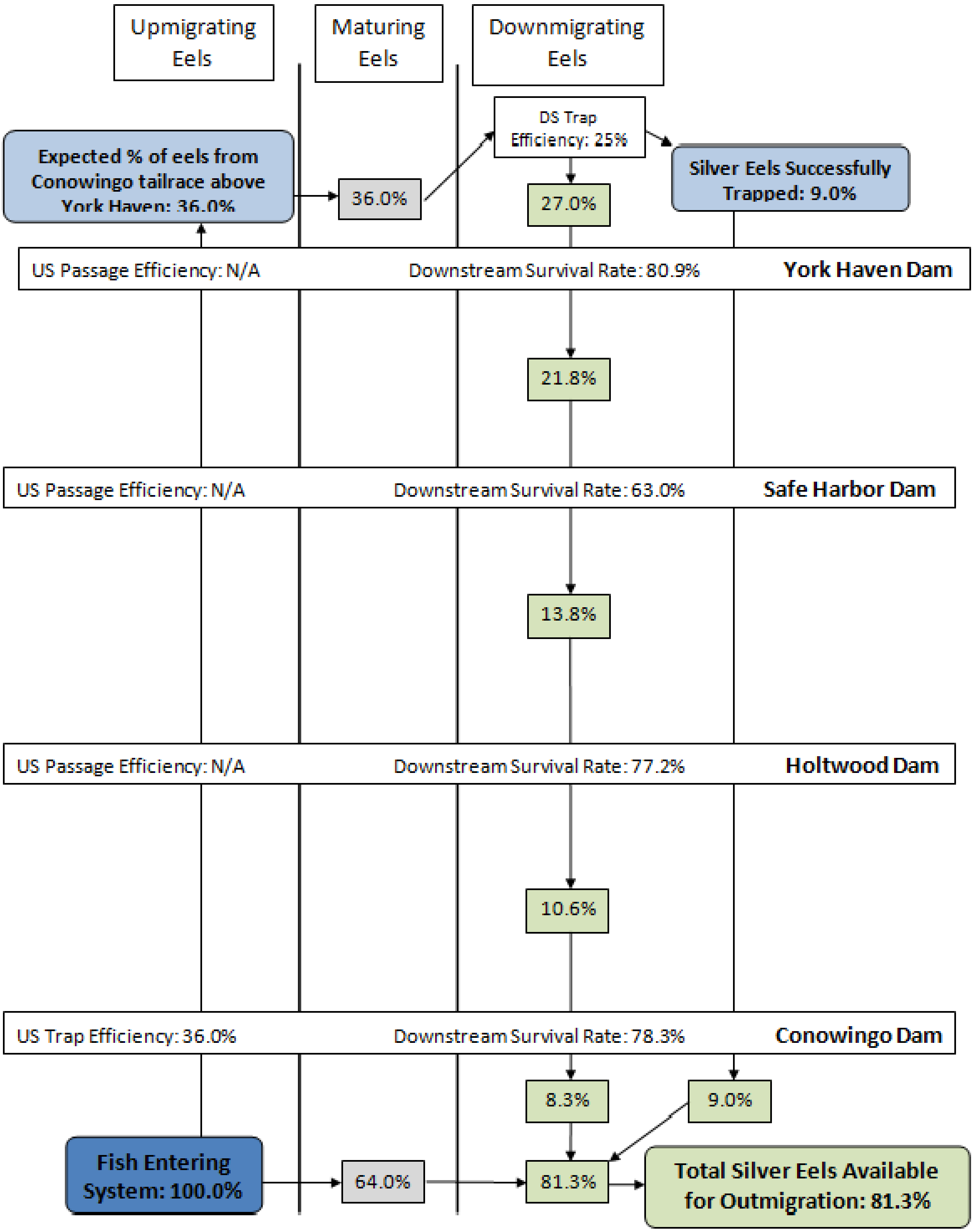


FIGURE 7-6: LOW END UPSTREAM AND DOWNSTREAM TRAP AND TRANSPORT, WITH 50% DOWNSTREAM TRAP EFFICIENCY

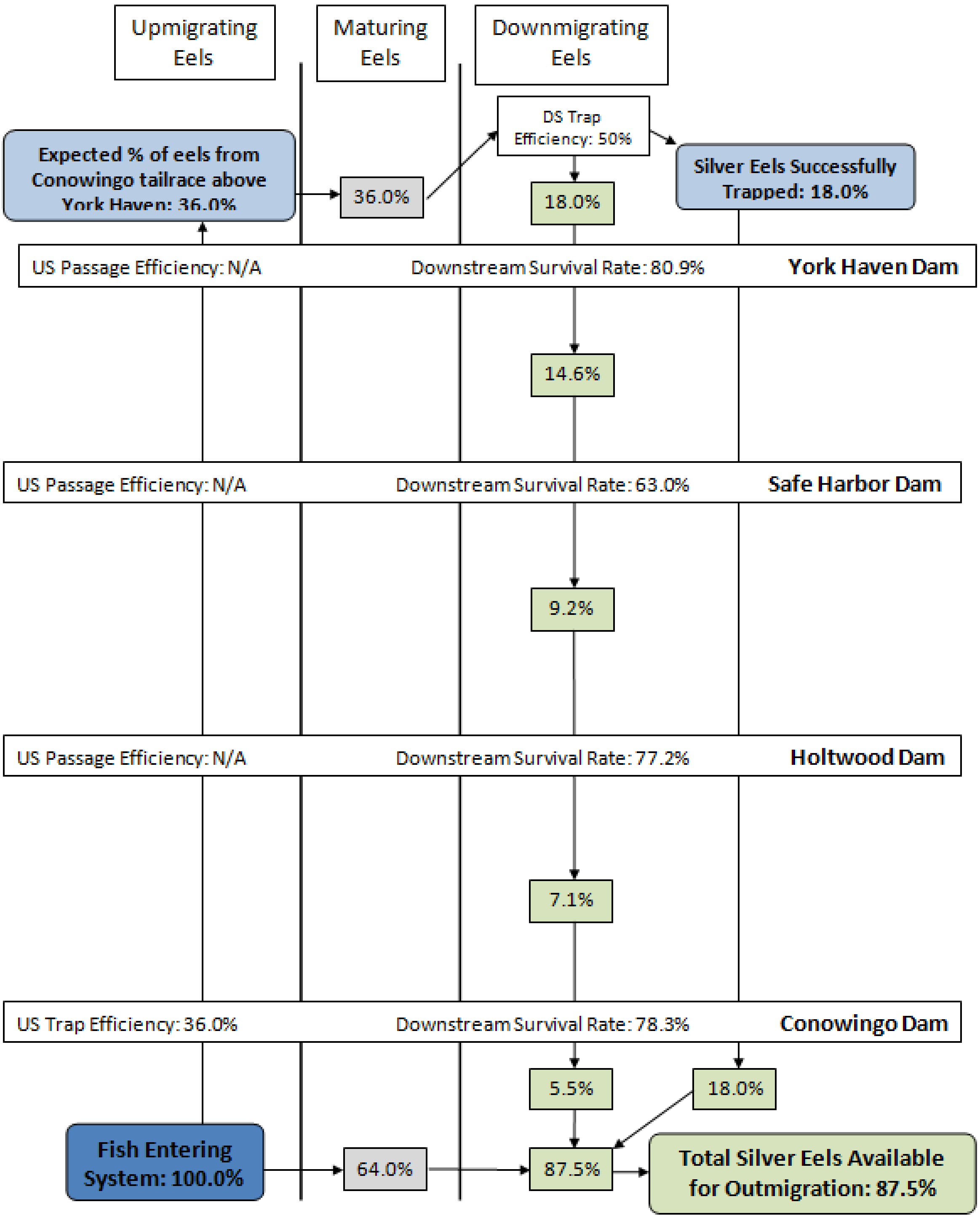


FIGURE 7-7: LOW END UPSTREAM AND DOWNSTREAM TRAP AND TRANSPORT WITH 75% DOWNSTREAM TRAP EFFICIENCY

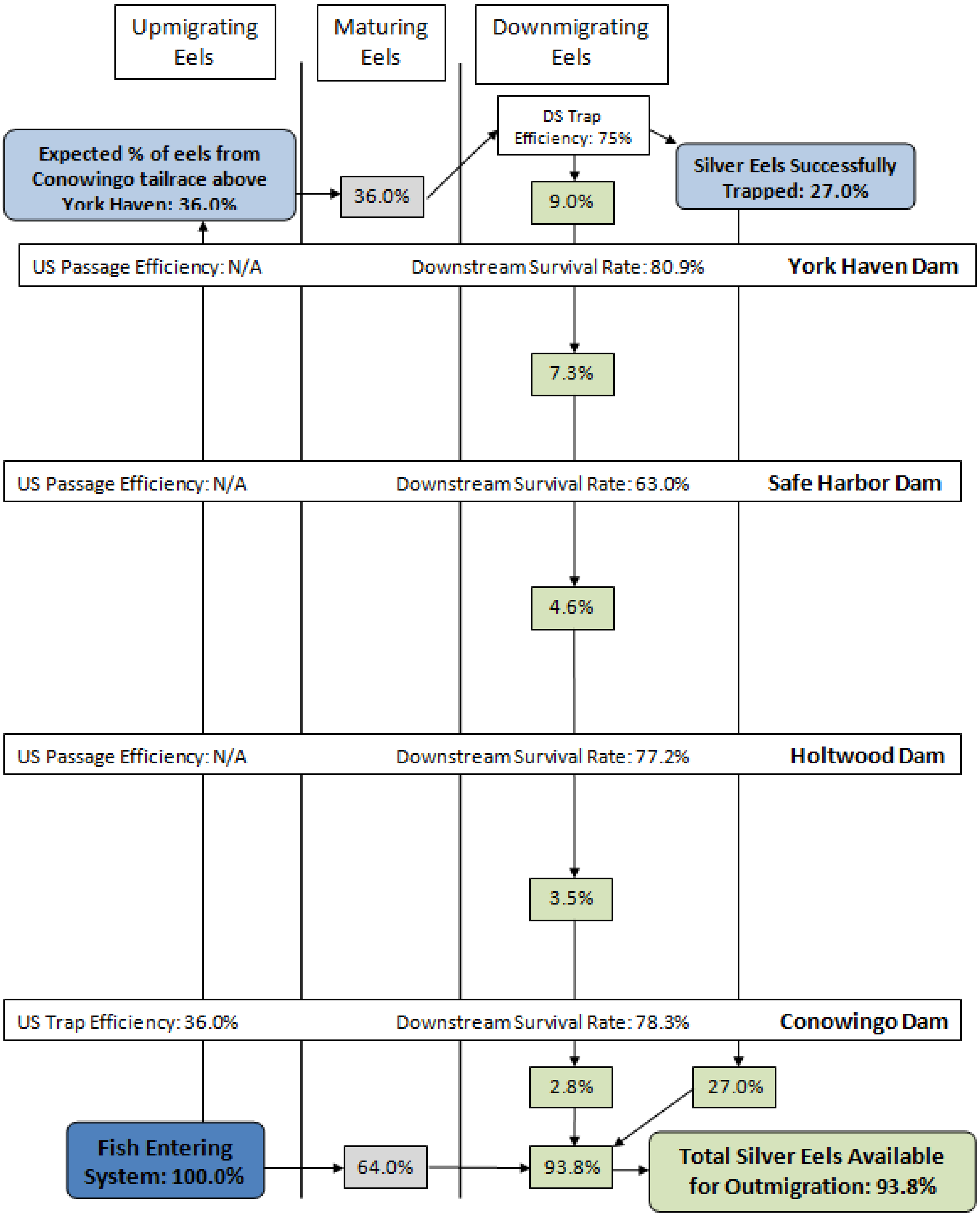
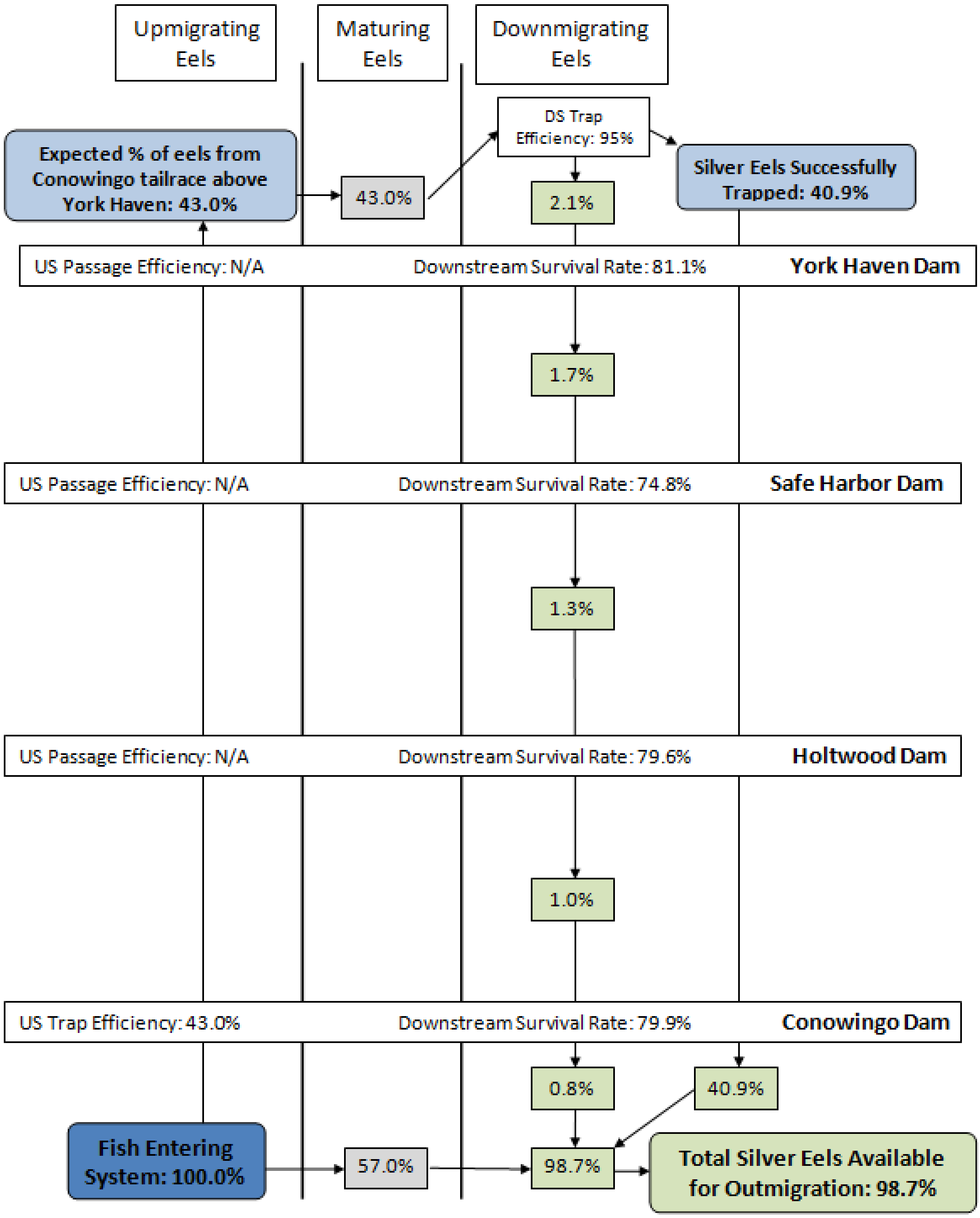


FIGURE 7-8: HIGH END UPSTREAM AND DOWNSTREAM TRAP AND TRANSPORT WITH 95% DOWNSTREAM TRAP EFFICIENCY



8.0 CONCLUSIONS

No range-wide estimate of American eel abundance exists. Such an estimate is hampered by the panmictic nature of the species and the fact that individuals from a single population randomly spread over an extremely large and diverse geographic range in fresh, estuarine and marine waters. Additionally their growth rates and sex ratios vary dependent upon their geographical location and environmental variables further making population estimates very difficult (DOI 2007).

Absent information on range-wide abundance, the DOI has relied on trends in regional indices to draw inferences regarding the status of the overall population. Specifically, the DOI analyzed trends in four glass eel indices and four yellow eel indices across the species range. Of these indices, the DOI found that trends in the glass eel indices were more indicative of the population's reproductive success and hence overall stability than were yellow eel indices (DOI 2007).

Trends in the four glass eel indices analyzed by the DOI showed stable abundance over a 13-15 year period, beginning in 1989. Based on this analysis, the DOI found the species to be stable in its 12-month finding on a petition to list American eel as threatened or endangered (DOI 2007).

DOI did not rely on yellow eel indices to draw conclusions about the overall population abundance, but it did acknowledge that these indices were a good indicator of regional or local conditions. The DOI specifically cited the yellow eel index for the Chesapeake Bay, noting that the trend in this index showed a significant decline (50 percent) over the 1994 to 2004 period. The reasons for this decline in abundance of yellow eels in the Chesapeake Bay are not clear. The potential list of reasons could include local factors (*e.g.*, commercial harvest) or population level factors (*e.g.*, shifting ocean currents and the subsequent dispersal of leptocephali from the Sargasso Sea) or some combination of these or other factors.

At a local level, there are no abundance indices available for the Susquehanna River. The MBSS has compiled eel data in several Chesapeake Bay tributaries, including Deer and Octoraro Creeks, which are tributaries to the Susquehanna with confluences downstream of Conowingo Dam. An analysis of these data (EPRI 2011) indicated that the densities in Deer Creek (0.292-0.347 eels/m^2) and Octoraro Creek (0.347 eels/m^2) were in the middle to lower end of the density estimate range for all Chesapeake Bay tributaries analyzed (total range 0.253-0.975 eels/m^2).

At Conowingo Dam, studies have been conducted by the DOI over the period 2005-present, utilizing a ramp facility located near the WFL. The annual catch at this facility ranged from 19 to 42,059 young eels. The larger catches occurred over the period 2008-2010. The number of yellow eels caught over this period has ranged from 25 to 208. The size range of young eels and yellow eels caught over the period 2005-2010 was 76-195 mm and 256-770 mm, respectively.

Exelon collected eels at two locations in the spillway in 2010 and 2011. Of these locations, the location known as spillbay 50 (extreme eastern side of the spillway) captured slightly more young eels (697) than the EFL spillway ramps (569). The overall size range of the young eels caught by Exelon was 92-188 mm; while the overall size range of yellow eels caught was 300-689 mm.

Based on the study findings to date by the USFWS and Exelon, eel passage facilities were conceptually designed and costed for both the WFL and spillbay 50 locations. Facilities analyzed included both eel ladders and trap-and-transport facilities. As illustrated in Table 8-1, the capital costs for the various alternatives ranged from $622,000 (EFL trap and transport) to $2,230,000 (WFL partially buried eel ramp) with annual O&M costs ranging from $200,000/yr to $585,000/yr. All alternatives considered appear to be technically feasible from an engineering perspective, but additional field biological data are needed before final siting.

From a resource-management perspective, the choice of methods for achieving upstream and downstream passage of American eel depends on the resource goals of an overall program. If the sole resource management objective is to provide the most silver eels leaving the Susquehanna River for the journey to the Sargasso Sea, volitional upstream and downstream passage is estimated to provide the most silver eels downstream of Conowingo Dam. If the sole resource-management objective is to maximize eel abundance upstream of York Haven Dam, this goal would be accomplished with an option involving a trap-and transportation program. If an upstream and downstream eel-passage program sought to balance the two resource objectives discussed above, an upstream and downstream trap-and-transport program would be the best approach. If capture efficiencies for the downstream trap-and-transport program are high (approximately 75% or more), this program would also provide more silver eels leaving the river than the volitional approach. It should be noted that inter-annual variability of glass eels returning to the Susquehanna River make predictions of long-term benefits of any potential program uncertain.

TABLE 8-1: SUMMARY OF UPSTREAM EEL PASSAGE ALTERNATIVES

Alternative	Brief Description	Capital Costs (2011 Dollars)	Annual Operation Costs, if Applicable (2011 Dollars)
West Bank - Trap and Transport	Limited length ramp with collection facility in existing parking lot.	$639,000	$585,000
West Bank - Volitional Passage near West Fish Lift	Full eel ramp with resting pools from tailrace to pond elevation, sited near West Fish Lift superstructure.	$1,695,000	$200,000 per year (assumed personnel cost)
West Bank - Volitional Passage near Administration Building	Full eel ramp with resting pools from tailrace to pond elevation, portion buried beneath parking lot daylighting near Administration Building.	$2,230,000	$200,000 per year (assumed personnel cost)
East Bank - Trap and Transport	Limited length ramp with collection facility in existing access area, below non-overflow section of dam.	$622,000	$585,000
East Bank - Volitional Passage	Full eel ramp with resting pools from tailrace below spillbay 50 to pond, cored through top of dam.	$1,125,000	$200,000 per year (assumed personnel cost)

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APPENDIX A CONOWINGO EEL WORKSHOP MEETING MINUTES AND PRESENTATIONS FROM OCTOBER 25 AND 26

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Via Electronic Filing

November 29, 2011

Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

Re: Conowingo Hydroelectric Project, FERC Project No. 405, Muddy Run Pumped Storage Project, FERC Project No. 2355, Filing of the Meeting Notes Summary

Dear Secretary Bose:

Exelon Corporation, on behalf of its wholly-owned subsidiary, Exelon Generation Company, LLC (Exelon), encloses for filing a Meeting Notes Summary for the relicensing of the Conowingo Hydroelectric Project (Conowingo Project), FERC Project No. 405, and the Muddy Run Pumped Storage Project, FERC Project No. 2355. If you have any questions regarding the above, please do not hesitate to contact Colleen Hicks. Thank you for your assistance in this matter.

Respectfully submitted,

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CC: Distribution List-Attachment I

Conowingo and Muddy Run Project FERC Relicensing
Initial Study Report Meeting
Meeting Notes Summary
October 25-26, 2011

Conowingo Visitors Center
4948 Conowingo Road, Darlington, MD

List of Attendees: See Attachment A

Tuesday, October 25, 2011 (Presentations)

Introductions and Meeting Purpose

Tom Sullivan (Gomez and Sullivan) welcomed the group and introduced the general structure of the two-day meeting. The meeting agenda, the anticipated schedule and the background for the meeting were reviewed. Tom Sullivan mentioned that the agenda would be adjusted slightly as Doug Dixon from EPRI would not be able to attend the meeting and would not be presenting the review of the American eel in the Susquehanna River.

Eel Biology and Downstream Behavior: Alex Haro (USGS) gave a presentation on Eel Biology and Downstream Migratory Behavior (Attachment B).

Radio Telemetry of American Eel at the NYPA Moses-Saunders Hydroelectric Project: Kevin McGrath (Gomez and Sullivan) gave a presentation on a downstream American eel telemetry study conducted at the NYPA St. Lawrence-FDR Power Project (Attachment C).

Evaluation of Bar Racks and Louvers for Protecting Eels at Hydro Intakes: Steve Amaral (Alden Lab) gave a presentation on his research related to bar rack and louver exclusion devices (Attachment D).

Review of Research and Technology on Passage and Protection of Downstream Migrating Eels: Bill Richkus (Versar) gave a presentation on his work related to the evaluation of downstream passage and protection measures for American eel (Attachment E).

Wednesday, October 26, 2011

Introductions and Meeting Purpose

Tom Sullivan (Gomez and Sullivan) opened the meeting and welcomed everyone. Parties introduced themselves and gave their affiliation. Tom Sullivan opened up the discussion by asking if there were any downstream technologies that could be taken off the table as impractical in relation to the Conowingo Hydroelectric Project (Conowingo). Bill Richkus (Versar) recommended that chemical attractants/repellents, sound, and induced flows and bubble curtains could be removed from further consideration as not applicable at Conowingo. Don Pugh (American Rivers) also suggested that lights are not feasible at Conowingo. The discussion then moved to other potential downstream passage measures.

Reducing Turbine Mortality-Steve Minkkinen (USFWS) stated that it would be important to determine the typical nighttime Conowingo operation during the adult eel outmigration season and suggested that selective turbine operation may help reduce turbine mortality. He asked for historical operational data including percentage of time of spill, percentage of time of various flows, and the typical turbine operation combinations used during outmigration.

Steve Amaral (Alden) suggested reducing load would reduce injury and mortality; he also suggested that knowing the difference in mortality rates between the Kaplan and Francis turbines at Conowingo would be helpful. Alex Haro (USGS) asked if there have been any mortality studies for eels on these specific turbines and Tom Sullivan (GSE) indicated there have not been.

Larry Miller (USFWS) asked what the wicket gate spacing is for the Conowingo turbines, and what the hydraulic operation range is for the turbines. Kirk Smith (GSE) indicated that the Kaplans range from approximately 7200 to 9600 cfs. He indicated that the capacities of the Francis turbines are 4200 to 6700 cfs for all units except 2 and 5 and 2000 to 6300 cfs for units 2 and 5.

Larry Miller (USFWS) asked if there is preferential unit operation as part of Conowingo Station operating protocols, and Tom Sullivan (GSE) said that load conditions are input into a computer program that provides the most efficient turbine combination for energy production given the load conditions.

Kevin McGrath (GSE) indicated that there were differences in the mortality rates of eels through Kaplan and Francis turbines in the St. Lawrence River. These differences depended on configuration of the leading edge of the blade, wicket gate spacing, gap distance between the blade and casing, number of blades, and rotational speed. Sheila Eyler (USFWS) indicated that there was no spill mortality on the Shenandoah River projects during her investigations.

The stakeholder group indicated that the potential conflicting needs of downstream migrating juvenile shad should be weighed with the needs of the adult eel when considering any preferential turbine operations.

Fish Friendly Turbines-Steve Amaral (Alden) reviewed the specifications for the School Street Project fish friendly turbine being installed on the Mohawk River, and indicated that it is rated for about 2000 cfs, which may not work well for a project the size of Conowingo. He mentioned that rotational speed, number of blades, design in relation to pressure changes and shear stress as well as a thicker leading edge all make the turbine more fish friendly than traditional turbines. It was mentioned that an approximate 3-50% attraction flow was necessary to draw eels. Alex Haro (USGS) indicated that 3% would not be nearly enough to be effective at Conowingo.

Bypass Facilities-Kevin McCaffrey (GSE) opened the discussion by providing the approximate lengths of diversion structures for a potential bypass facility at Conowingo: a 15° diversion structure would be 3650 feet long; a 30° diversion structure would be 1900 feet long and a 45° diversion structure would be 1350 feet long. Kevin indicated that construction of these types of structures would likely be cost prohibitive. Mike Hendricks (PFBC) asked how this would affect shad migration (upstream and downstream, adult and juvenile) and how would resident fish orient to the structure.

Alex Haro suggested that careful thought be used before a guidance/louver/bar rack system is investigated and that efficiencies of these structures be looked at in detail. Sheila Eyler (USWFS) suggested that Exelon conduct a turbine mortality study at Conowingo before diversion/passage options be considered in great detail.

Alex Haro mentioned that some deep bypass gates have been successful but that there are a lot of unknowns associated with this methodology. He stated that many applications are considering multiple openings as opposed to just one for a deep bypass and that the whole issue is very problematic. He mentioned that it is very important to know how eels approach the dam and potential bypass openings to ensure that they are in the most effective position. It was also discussed that multiple openings may be necessary unless the trash rack spacing is approximately 1-2 inches.

Trap and Transport- Sean Seaman (MDNR) suggested that downstream trap and transport may be the most viable option on the lower Susquehanna River for downstream eel passage. Bill Richkus (Versar) suggested that catching eels upstream of York Haven would be the best location. Mike Hendricks (PFBC) suggested that any trap and transport program must take juvenile shad mortality into account. He also indicated that York Haven Dam would be viable trapping spot for adult eels as well. Jim Spontak suggested starting the trap and transport program within the tributaries, as initial step.

Larry Miller (USFWS) stated that there are ecosystem benefits of eel population growth and not just a benefit to the eel themselves. Michael Helfrich (Riverkeeper) suggested that it would be beneficial to have eels in the lower basin for eastern elliptio propagation. Steve Minkkinen (USFWS) said USFWS is sampling in Buffalo and Pine creeks to evaluate the success of their current upstream trap and transport program.

It was suggested by the stakeholder group that there may potentially be some Endangered Species Act considerations with a trap and transport program, if American eel are eventually listed.

The stakeholder group agreed that a meeting be organized that includes MD, PA, and NY biologists and managers to determine basic management goals and research for a upstream and downstream trap and transport program for eels in the Susquehanna River. Alex Haro (USGS) suggested that some basic information needs be collected before a full fledged program is implemented as there is currently a general lack of information on American eel in the Susquehanna River.

Muddy Run 3.5 – Nearfield Effects of the Muddy Run Project (Doug Royer)

Doug Royer (Normandeau) presented the Nearfield Effects of the Muddy Run Project study report (Attachment F).

Larry Miller (USFWS) suggested that the fish susceptible for entrainment at Muddy Run should be the number of fish that made it to Holtwood as opposed to the total fish in the study or fish that made it to Sicily Island; he suggested this would change the entrainment rate considerably. He also suggested that averaging all fish holding below Sicily Island as a total residence time may mask any operations that cause them to hold longer or pass more quickly.

Bob Sadzinski (MDNR) suggested that a table be developed illustrating the operating conditions that each tagged fish was exposed to during the study, to determine impacts of pumping operation.

Conowingo 3.3 – Biological and Engineering Studies of the American Eel at the Conowingo Project (Chris Avalos, Kevin McCaffrey)

Chris Avalos (Normandeau) presented the 2011 upstream eel sampling study results (Attachment G). Chris indicated that the elvers did not necessarily prefer one substrate over the other. He indicated that attraction flow seemed to be the most important factor and that Akwadrain substrate is much easier to work with than the Enkamat substrate.

Bill Richkus (Versar) asked whether there was a distinct size classification for an elver. Alex Haro (USGS) indicated that there is not and that it has been highly controversial topic in the research community.

Steve Minkkinen (USFWS) said USFWS had good sampling results in 2011 near the tailrace area and that they caught 86,000 eels in their ramp. They have essentially kept the same design for 4 years and have not concentrated on researching different designs. He mentioned that there is a good correlation between the Maryland coastal glass eel surveys and the catch at Conowingo the following year.

Larry Miller (USFWS) indicated that a typical fishway prescription written by the USFWS requires two (2) locations for eel ramps. Steve Minkkinen (USFWS) suggested that the west side of the spillway may have some merit and that the entrance gallery should be as close to shore as possible.

Kevin McCaffrey (GSE) presented the engineering options analyzed for upstream eel passage at Conowingo (Attachment H).

Mike Hendricks (PFBC) indicated that Exelon is greatly overestimating the trucking costs for the eel trap and transport program and that the overall costs could be cut substantially. Ian Park (USFWS) said USFWS transports 8000 eels in approximately 80 gallons of water, and suggested that the trucks costed in trap and transport passage options are unnecessarily large. Steve Minkkinen (USFWS) indicated that the USFWS is more interested in a trap and transport program for upstream eel passage than a fully volitional ramp at this point.

Bob Sadzinski (MDNR) asked that Exelon consider the feasibility of capturing eels in the river on the east side, downstream of the dam, as well as downstream locations on the west side.

Shad Population Model (Steve Leach)

Steve Leach (Normandeau) reviewed the model variables and asked the stakeholder group whether some of the values can be fixed or if ranges can be agreed upon. The current age structure ratios were agreed upon by the stakeholder group. It was determined that NetR will not be a pre-determined range and that ranges should be set for other biological variables and NetR would be back-calculated by matching known conditions.

It was determined that sex ratios should be run at 40 and 60% instead of one set number.

For repeat spawners, it was agreed that a range of 10-30% would be used and then those numbers would be added to the next repeat spawner percentage (i.e., 10% becomes 11% the next year; 30% would become 33% and so on). Some of the stakeholders are currently examining how repeat spawning numbers affect the returning adults (i.e., sensitivity).

The input for spawning below York Haven was discussed. It was suggested to use a percentage of the population up to a cap and until the carrying capacity is reached.

Tom Sullivan concluded the meeting and thanked everyone for their participation.

Exelon Power

Attachment A-List of Attendees

Name	**Affiliation**	**Email Address**	**10/25/2011**	**10/26/2011**
Aaron Henning	SRBC	ahenning@srbc.net	Present	Present
Al Ryan	Exelon	halfred.ryan@exeloncorp.com	Present	Present
Sheila Eyler	USFWS	sheila_eyler@fws.gov	Present	Present
Steve Minkkinen	USFWS	steve_minkkinen@fws.gov	Present	Present
Bill Richkus	Versar	brichkus@versar.com	Present	Present
Ian Park	USFWS	ian_park@fws.gov	Present	Present
Josh Tryninewski	PFBC	jtryninews@pa.gov	Present	Present
Bob Sadzinski	MDNR	bsadzinski@dnr.state.md.us	Present	Present
Colleen Hicks	Exelon	colleen.hicks@exeloncorp.com	Present	Present
Dilip Mathur	Normandeau	dmathur@normandeau.com	Present	Present
Don Capecci	PPL	dcapecci@pplweb.com	Present	Present
Don Pugh	American Rivers	don.pugh@yahoo.com	Present	Present
Gary Lemay	Gomez and Sullivan	glemay@gomezandsullivan.com		Present
Jay Ryan	VNF	jtr@vnf.com	Present	Present
Jim Spontak	PA DEP	jspontak@state.pa.us	Present	Present
Julia Wood	VNF	jsw@vnf.com	Present	Present
Kevin McCaffery	Gomez and Sullivan	kmccaffery@gomezandsullivan.com	Present	Present
Kimberly Long	Exelon	kimberly.long@exeloncorp.com	Present	Present
Kirk Smith	Gomez and Sullivan	ksmith@gomezandsullivan.com	Present	Present
Larry Miller	USFWS	larry_m_miller@fws.gov	Present	Present
Michael Helfrich	Lower Susquehanna Riverkeeper	lowsusriver@hotmail.com	Present	Phone
Alex Haro	USGS	aharo@usgs.gov	Present	Present
Thomas Tatham	Consultant	thomastath@aol.com	Present	Present
Kevin McGrath	Consultant	kjmwp1@gmail.com	Present	Present
Mike Hendricks	PFBC	mihendrick@state.pa.us	Present	Present
Chris Frese	Kleinscmidt	chris.frese@kleinschmidtUSA.com	Present	Present
Ray Bleistine	Normandeau	rbleistine@normandeau.com	Present	Present

Name	Affiliation	Email Address	10/25/2011	10/26/2011
Shawn Seaman	MDNR/PPRP	sseaman@dnr.state.md.us	Present	Present
Steve Leach	Normandeau	sleach@normandeau.com	Present	Present
Steve Shreiner	Versar	sschreiner@gmail.com	Present	Present
Tim Brush	Normandeau	tbrush@normandeau.com	Phone	Phone
Tom Hoffman	Gomez and Sullivan	thoffman@gomezandsullivan.com	Present	Present
Tom Sullivan	Gomez and Sullivan	tsullivan@gomezandsullivan.com	Present	Present
Wade Cope	SRBC	wcope@srbc.net	Present	Present

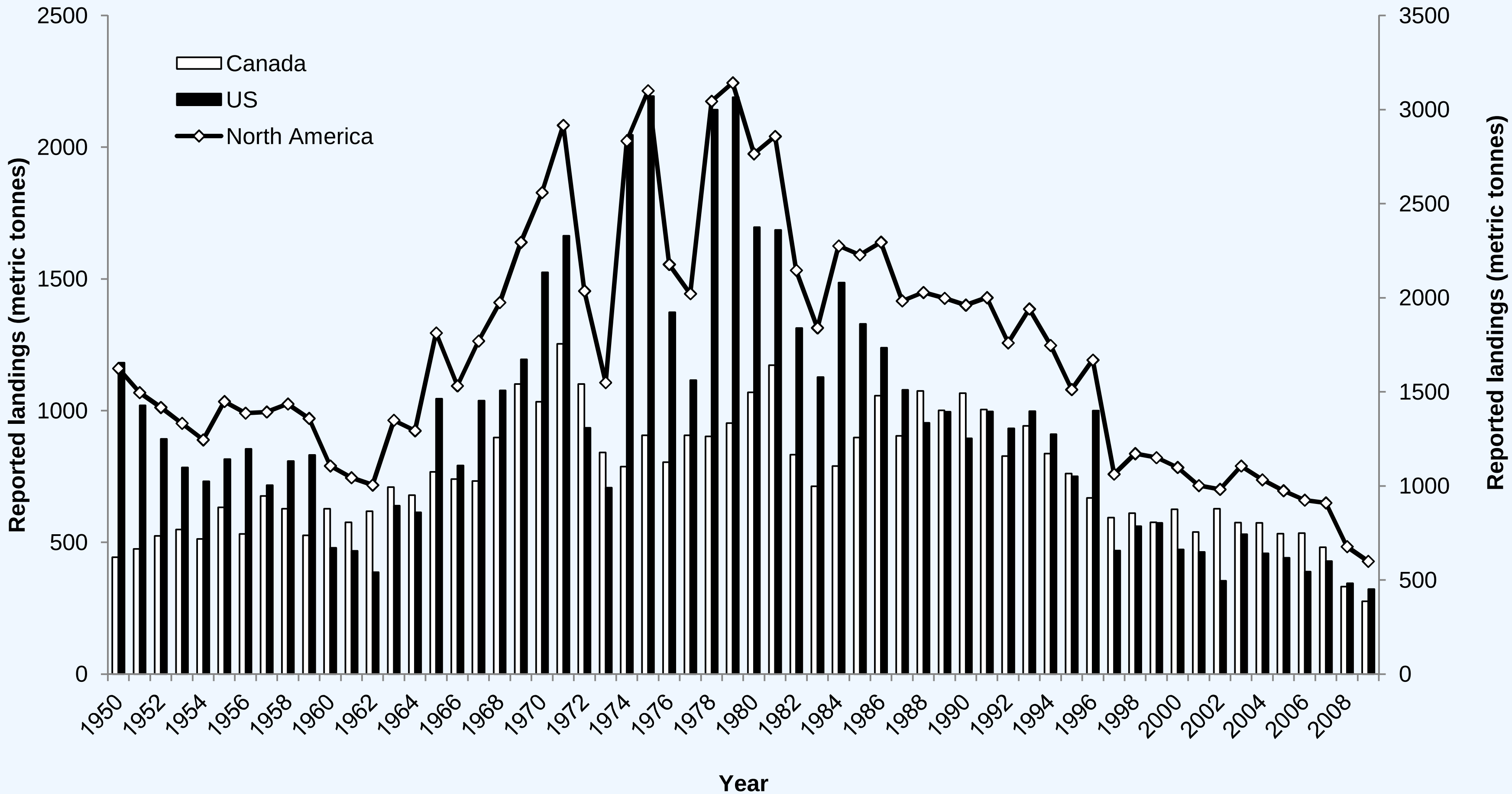
Attachment B-Eel Biology and Downstream Behavior

Eel Biology and Downstream Migratory Behavior

Alex Haro
U.S. Geological Survey
S.O. Conte Anadromous Fish Research Laboratory
Turners Falls, Massachusetts

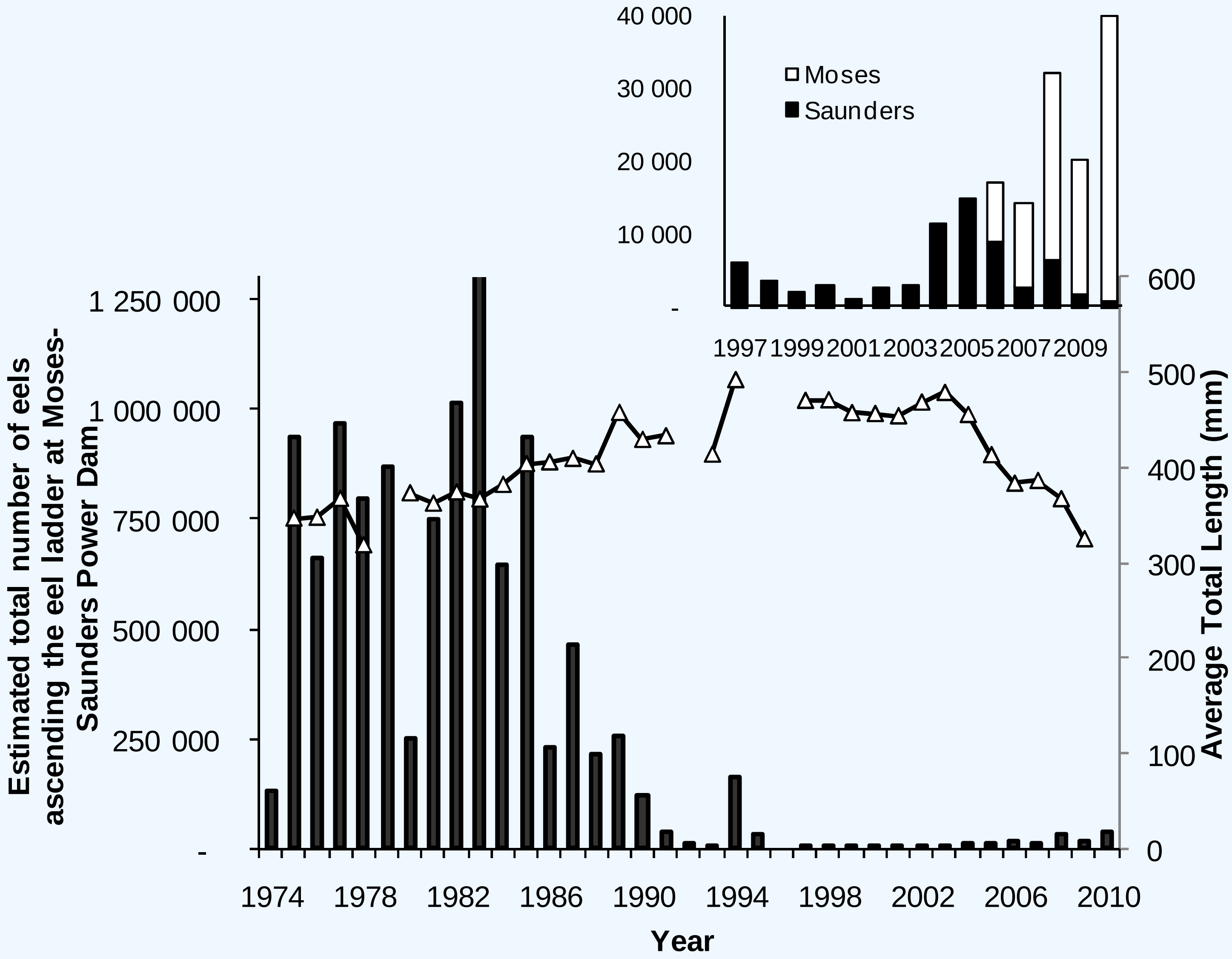
Conowingo/Muddy Run Fish Passage Meeting
October 25-26, 2011
Darlington, MD

Recent decrease in eel population as evidenced by reduction in landings…



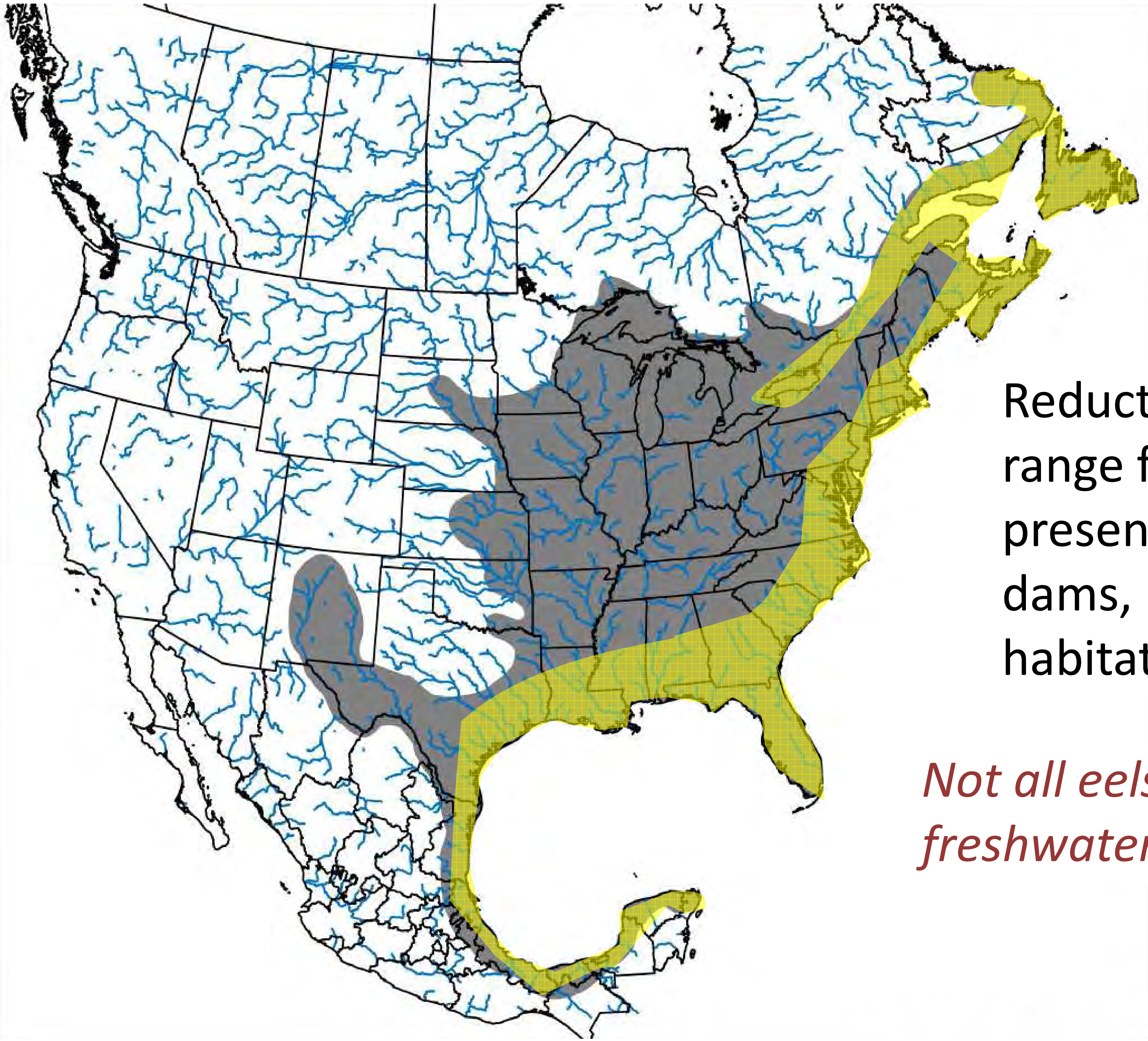
Source: Committee on the Status of Endangered Wildlife in Canada 2006, & V. Tremblay, pers. comm.

…and decrease in recruitment



Source: Committee on the Status of Endangered Wildlife in Canada 2006, & V. Tremblay, pers. comm.

USGS



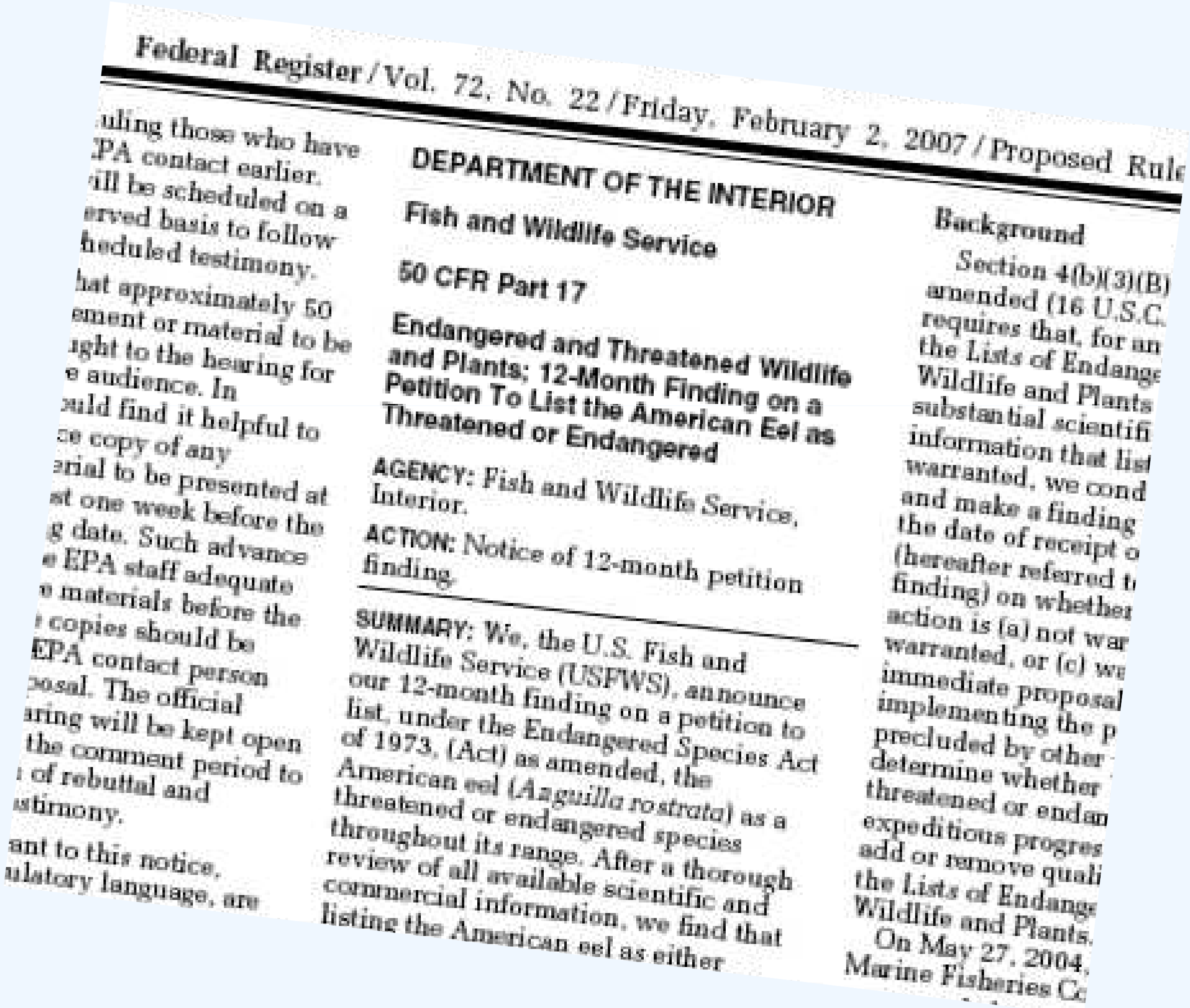
Reduction in range from presence of dams, loss of habitat?

Not all eels enter freshwater

USGS

Petitions to list the American eel as a Federally Endangered Species

- 2004 and 2010
- Not listed as Endangered or Threatened
- No other status assigned


Federal Register / Vol. 72, No. 22 / Friday, February 2, 2007 / Proposed Rule

...uling those who have ...PA contact earlier. ...ill be scheduled on a ...erved basis to follow ...heduled testimony. ...hat approximately 50 ...ement or material to be ...ight to the hearing for ...e audience. In ...uld find it helpful to ...e copy of any ...erial to be presented at ...st one week before the ...g date. Such advance ...e EPA staff adequate ...e materials before the ...copies should be ...EPA contact person ...posal. The official ...aring will be kept open ...the comment period to ...of rebuttal and ...stimony.

...ant to this notice, ...ulatory language, are

DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

50 CFR Part 17

Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition To List the American Eel as Threatened or Endangered

AGENCY: Fish and Wildlife Service, Interior.

ACTION: Notice of 12-month petition finding.

SUMMARY: We, the U.S. Fish and Wildlife Service (USFWS), announce our 12-month finding on a petition to list, under the Endangered Species Act of 1973, (Act) as amended, the American eel (*Anguilla rostrata*) as a threatened or endangered species throughout its range. After a thorough review of all available scientific and commercial information, we find that listing the American eel as either

Background

Section 4(b)(3)(B) ... amended (16 U.S.C. ... requires that, for an ... the Lists of Endange... Wildlife and Plants ... substantial scientifi... information that list... warranted, we cond... and make a finding ... the date of receipt o... (hereafter referred t... finding) on whether ... action is (a) not war... warranted, or (c) wa... immediate proposal ... implementing the p... precluded by other ... determine whether ... threatened or endan... expeditious progres... add or remove quali... the Lists of Endange... Wildlife and Plants.

On May 27, 2004, ... Marine Fisheries Co...

Atlantic States Marine Fisheries Commission
Addendum II to the Fishery Management Plan For American Eel (2008)

Recommendations for Federal Energy Regulatory Commission Relicensing

… the Commission requests that member states and jurisdictions request special consideration for American eel in the Federal Energy Regulatory Commission relicensing process. This consideration should include, but not be limited to, ***, improving upstream passage and downstream passage, and collecting data on both means of passage****.*

Recommendations for Improving American Eel Passage at Non-Federally Licensed Dams

Of the 33,663 dams located on the Atlantic and Gulf Coasts that potentially hinder American eel movement, 95% are not licensed by the federal government. Therefore, the states should strive to remove these obstructions where feasible. If removal is not feasible, then ***upstream and downstream passage should be improved*** *to provide access to inland waters for glass eel, elvers, and yellow eel and adequate escapement to the ocean for pre-spawning adult eel consistent with the goal of the FMP.*

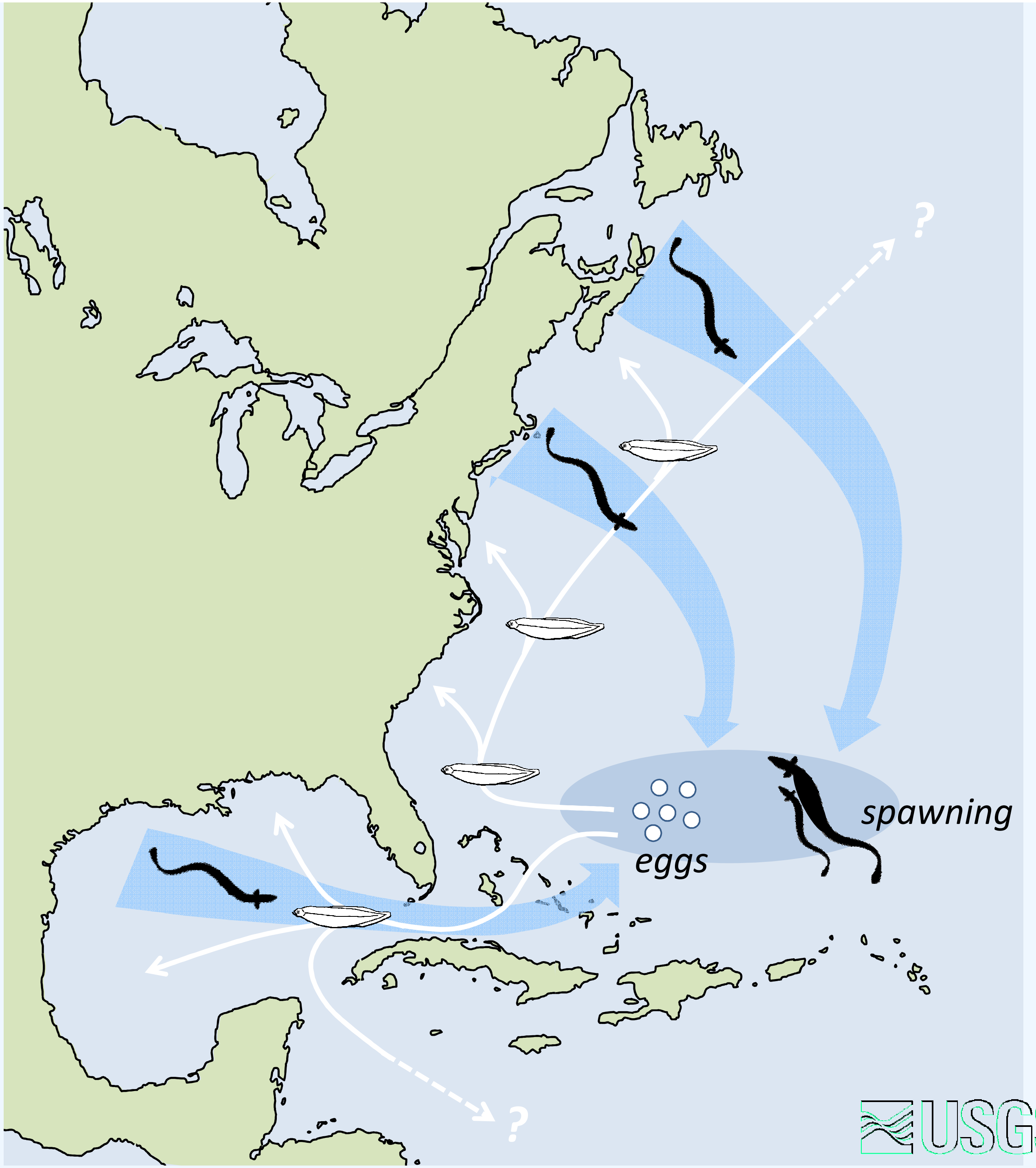
USGS

Canada:

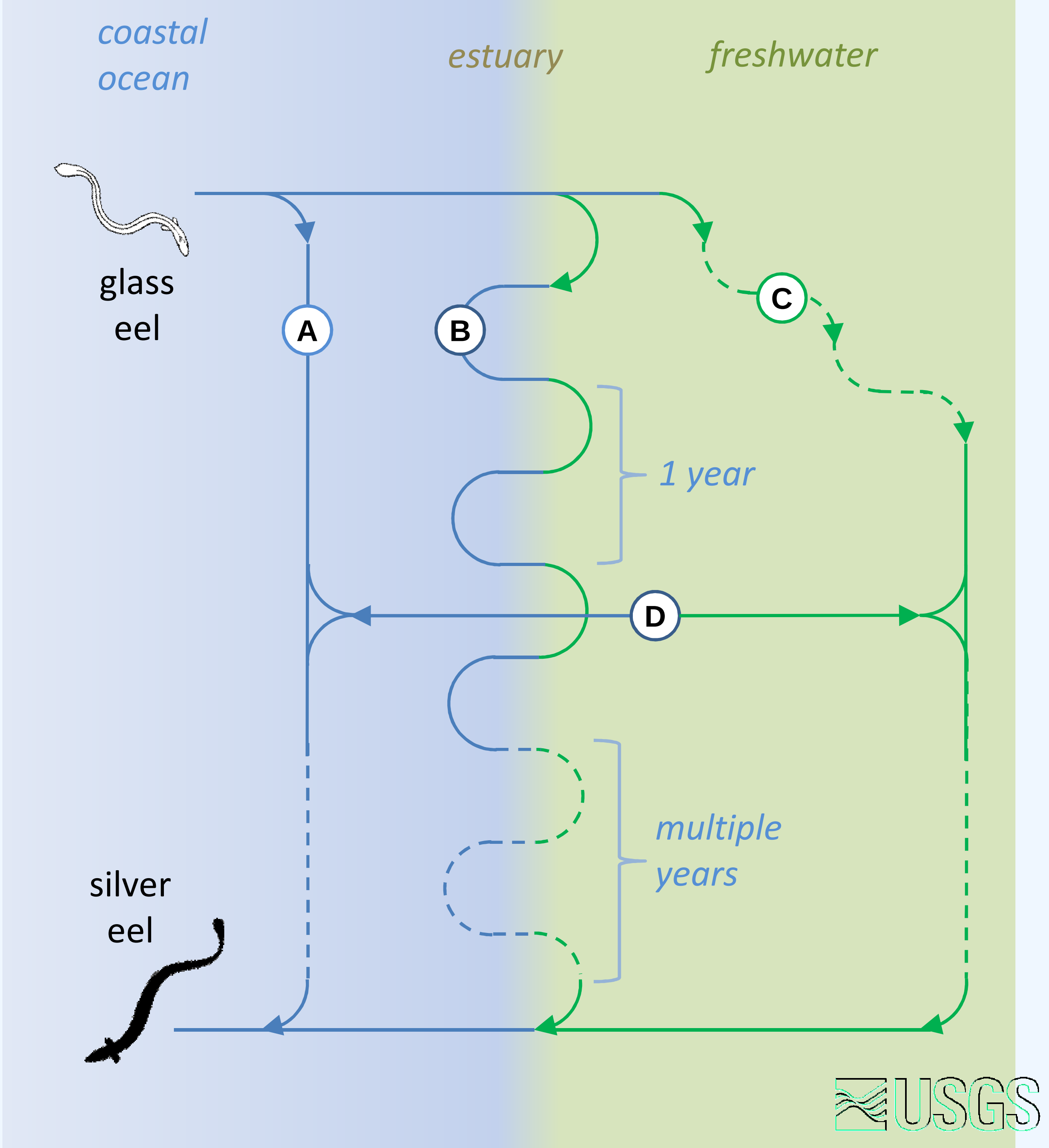
- Designated a *Species of Special Concern* by the Committee on the Status of Endangered Wildlife in Canada in April 2006

- An American eel management plan is being prepared by the Canadian Eel Working Group (CEWG). One of the short-term goals of the plan is to reduce eel mortality by 50% by 2010 through license buybacks. Negotiations are under way with power companies in Ontario and Quebec to develop an overall plan to reduce dam-related mortalities.

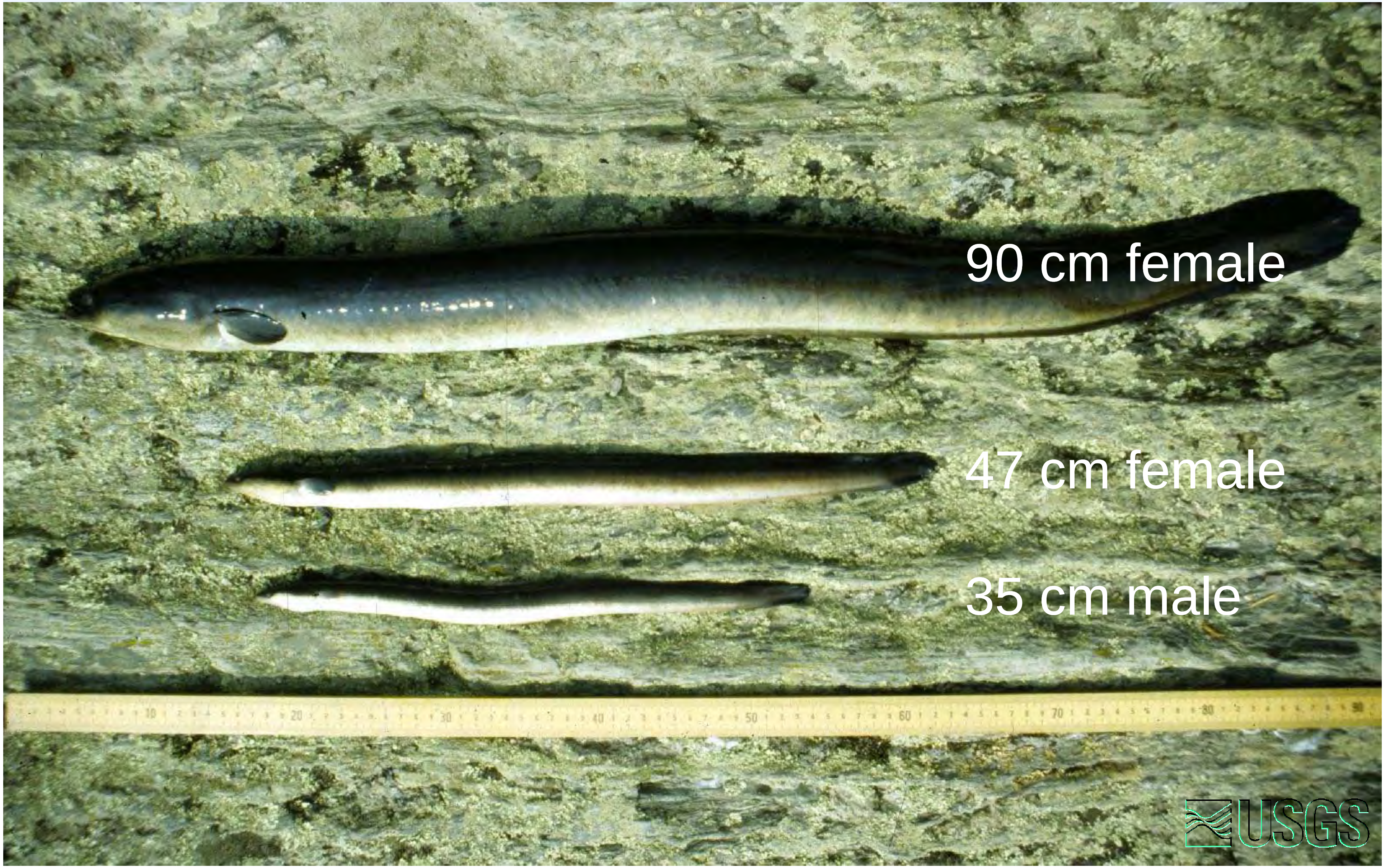
American Eel Life History



Variability in Life History During the Coastal/ Freshwater Growth Phase

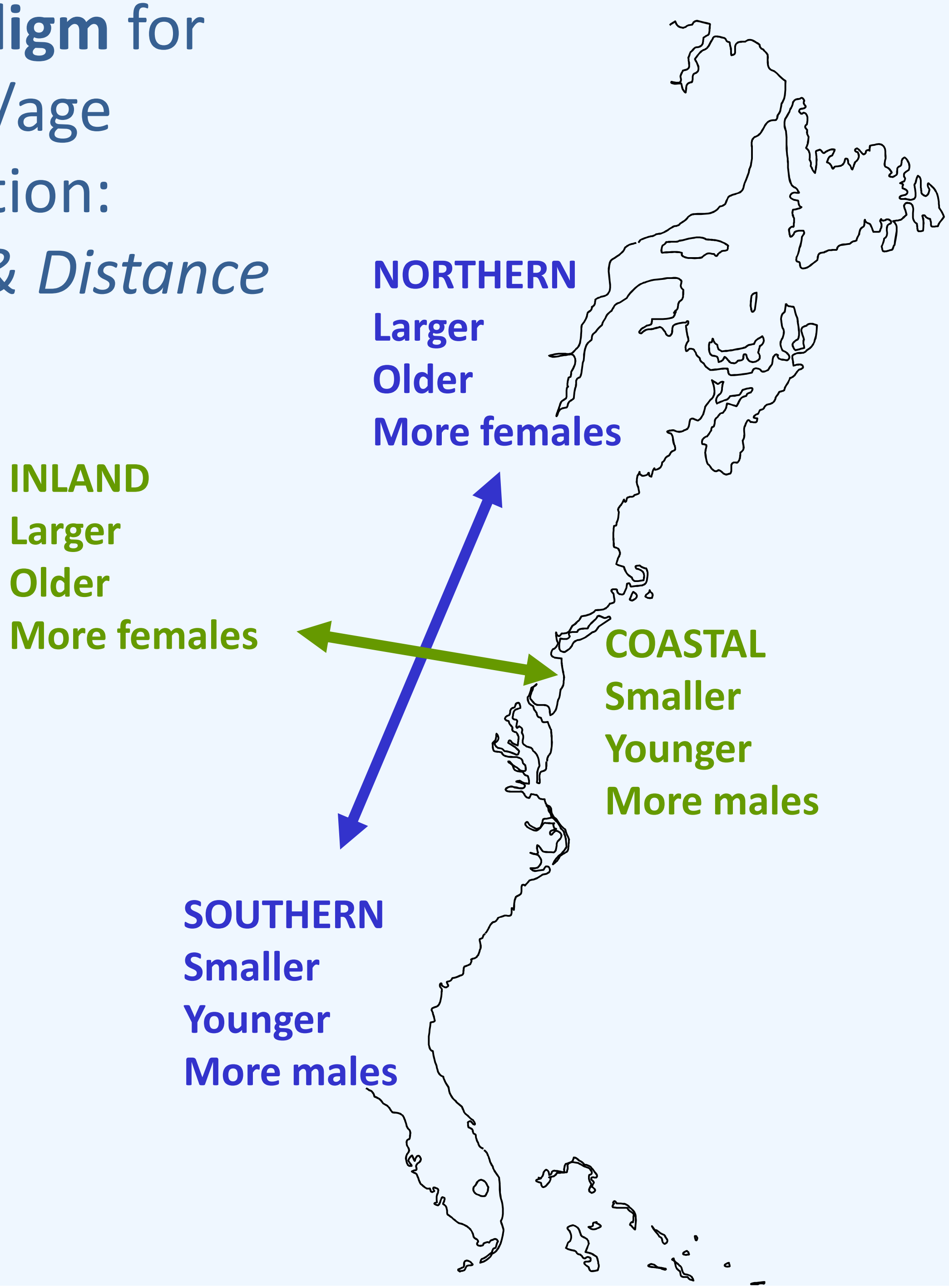


Variability in size, age, and reproductive value of males and females – *all silver-phase, downstream migrants*

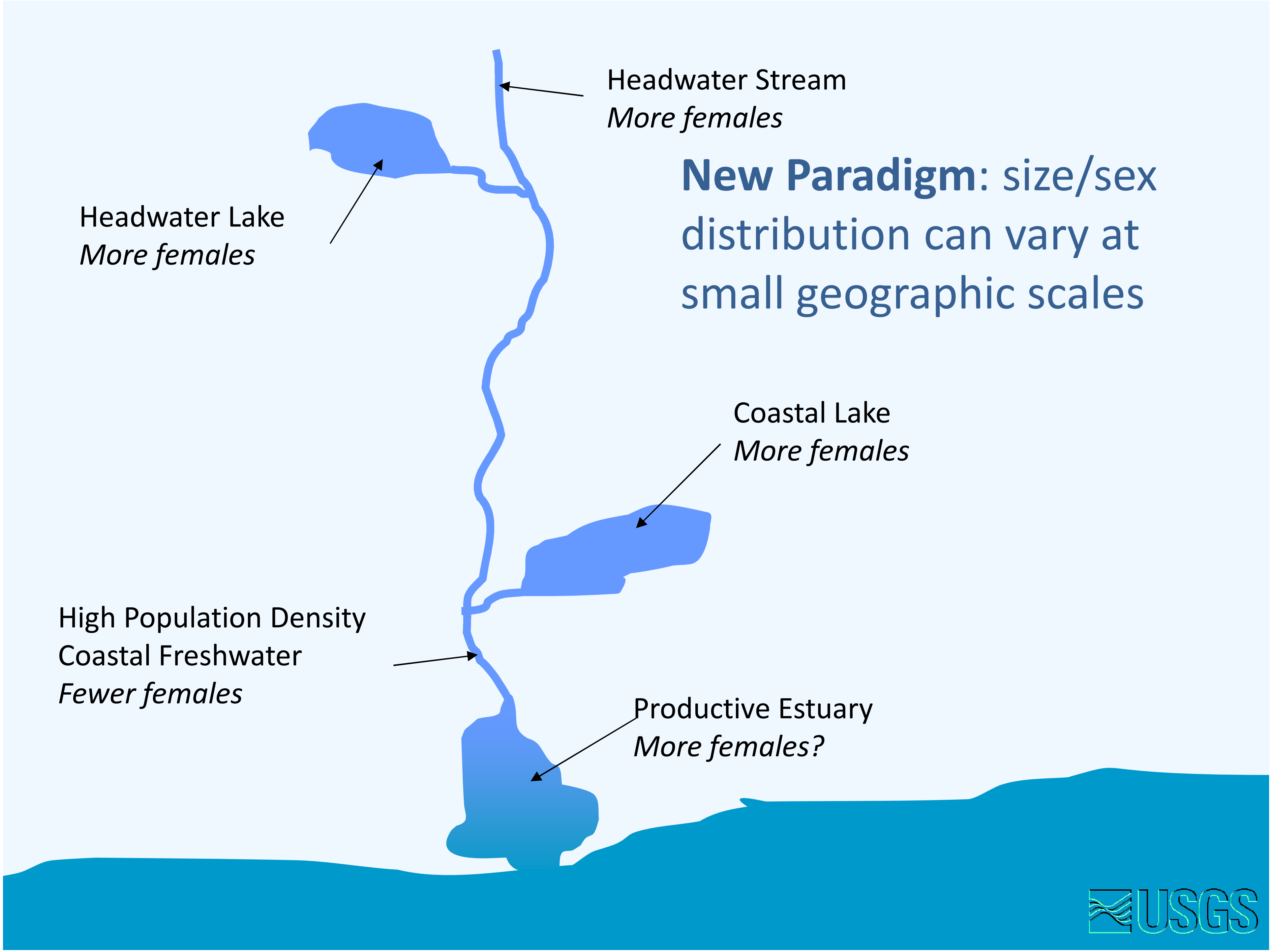


Old Paradigm for sex/size/age distribution:

Latitude & Distance Inland



USGS

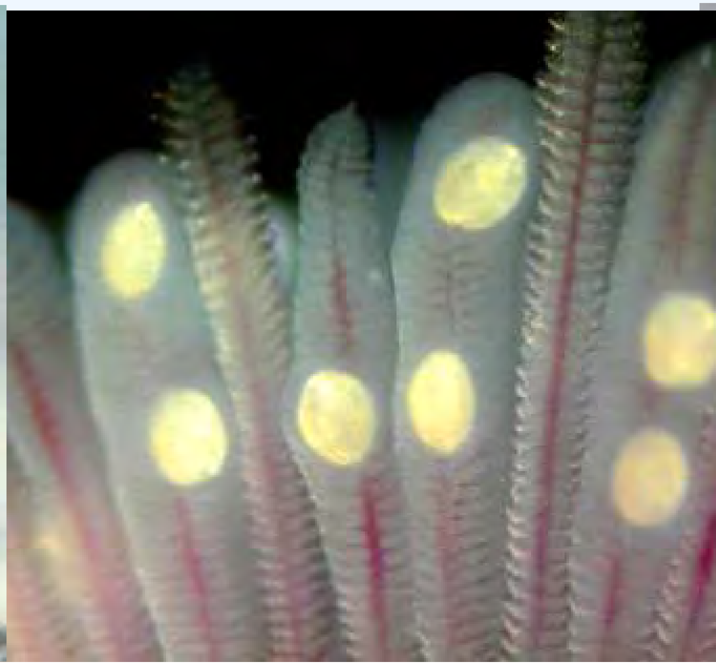

Headwater Stream
More females
New Paradigm: size/sex distribution can vary at small geographic scales
Headwater Lake
More females
Coastal Lake
More females
High Population Density
Coastal Freshwater
Fewer females
Productive Estuary
More females?
USGS

Importance of Environmental Sex Determination in Emigration

- Males: use a *time-minimizing* strategy in emigration (i.e., emigrating at the minimum size required for successful migration to the Sargasso Sea)
- Females: use a *size-maximizing* strategy (e.g., emigrating at older ages and larger sizes to maximize egg production before spawning)
- Females may actually adopt a trade-off between the two strategies which is dependent on environment-specific growth rate (i.e., less favorable growth conditions = migrate at smaller size)

Importance of Eels to Upstream Ecosystems

- Eels occur in virtually all types of freshwater habitats: ecological generalist
- In some habitats, may be the dominant fish species in both numbers and biomass
- Host to several freshwater mussel species, possibly a unique host to some
- Trophic generalist, prey for a variety of other species


Upstream eel passes

•Simple, cheap to construct

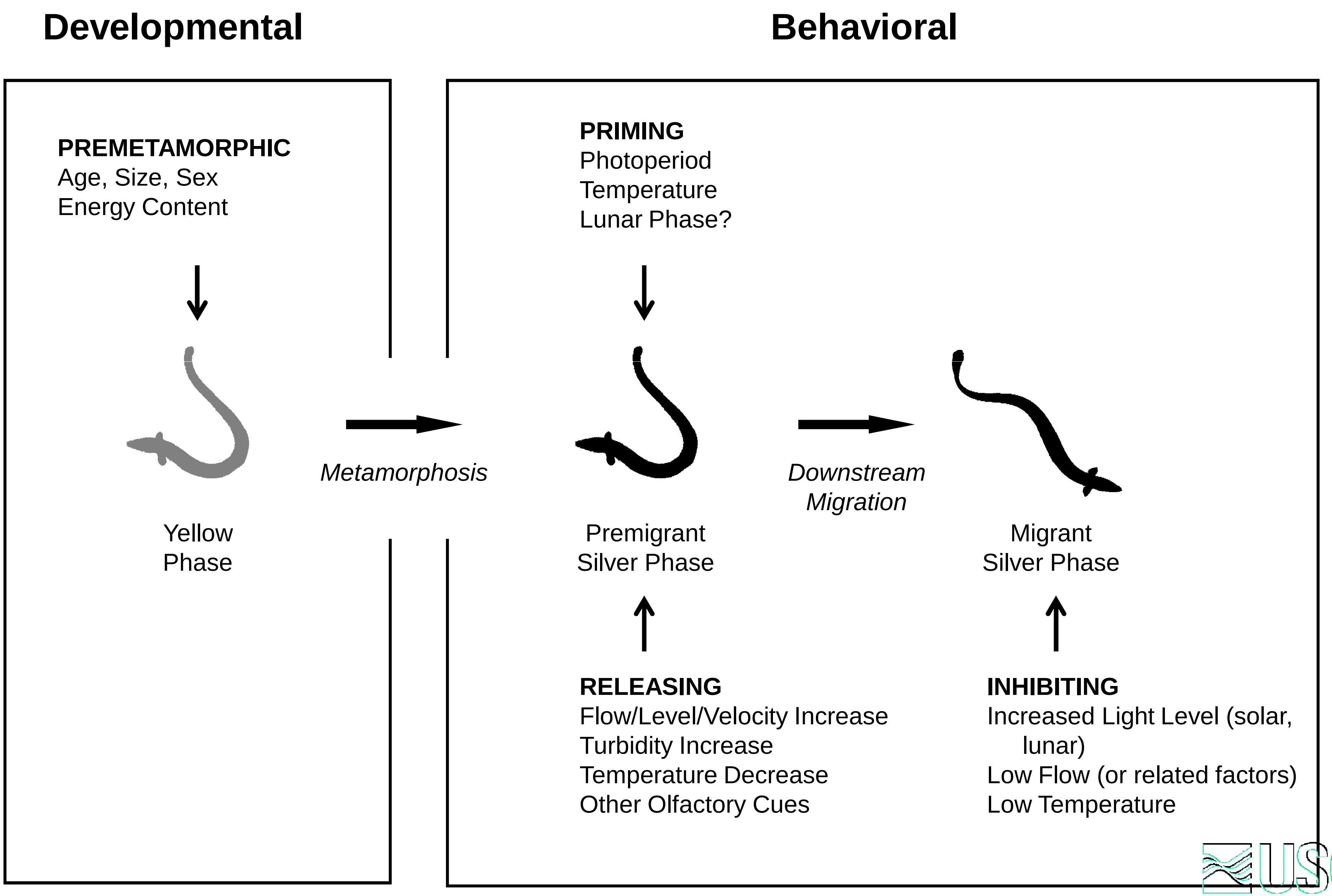
•Can be highly effective

High turbine mortality and injury for eels – 5 to 100%

Downstream Migration: General Behaviors

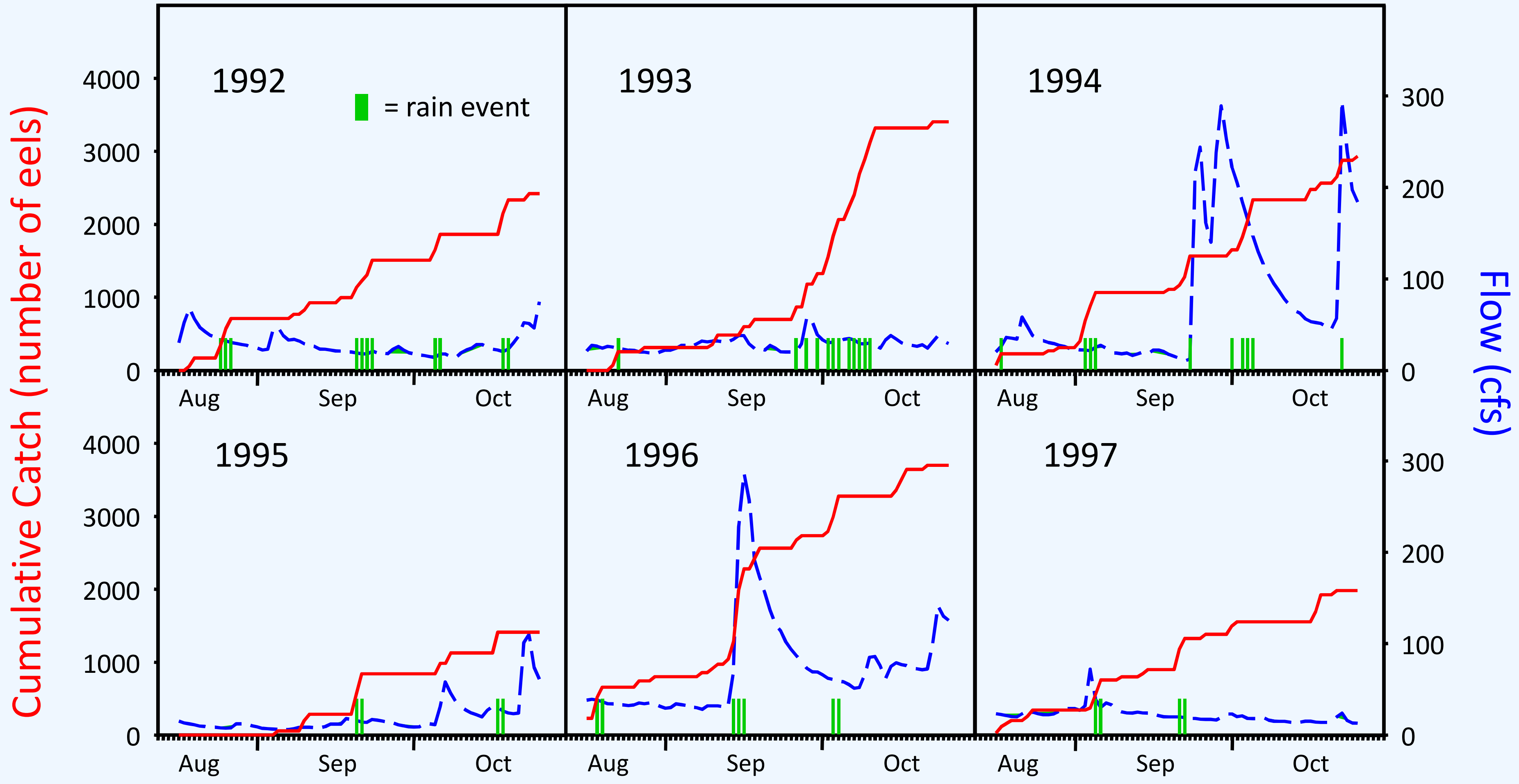
Metamorphosis from territorial, benthic predator to pelagic, riverine and oceanic migrant

Developmental and Behavioral Phases of Metamorphosis and Migration



Commercial weir data form the basis of our knowledge about downstream migration timing

Six Year Catch Dataset from Maine Eel Weir



USGS

Data from European Eel also reflects influence of rain/flow on migration

Vøllestad et al. 1986

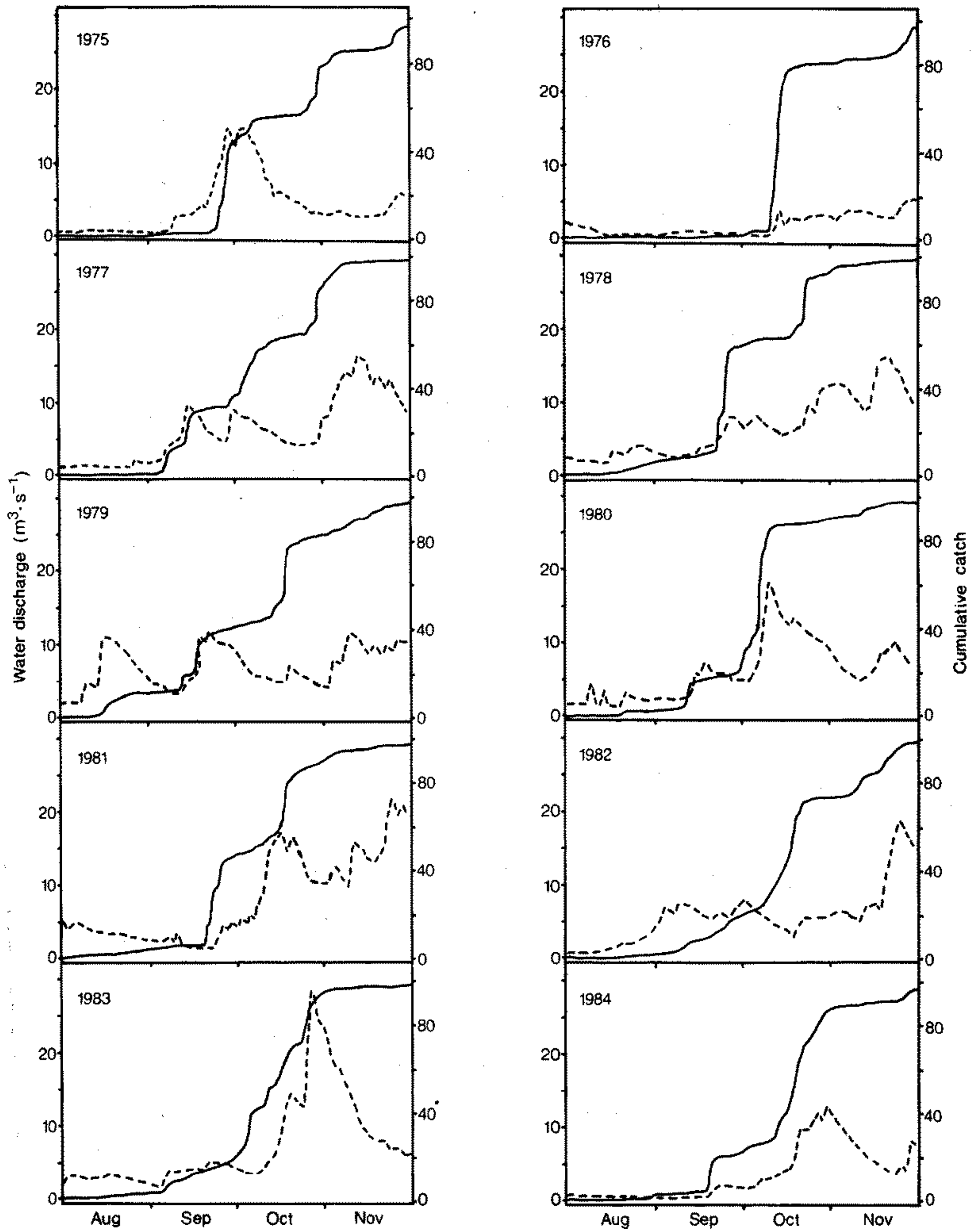
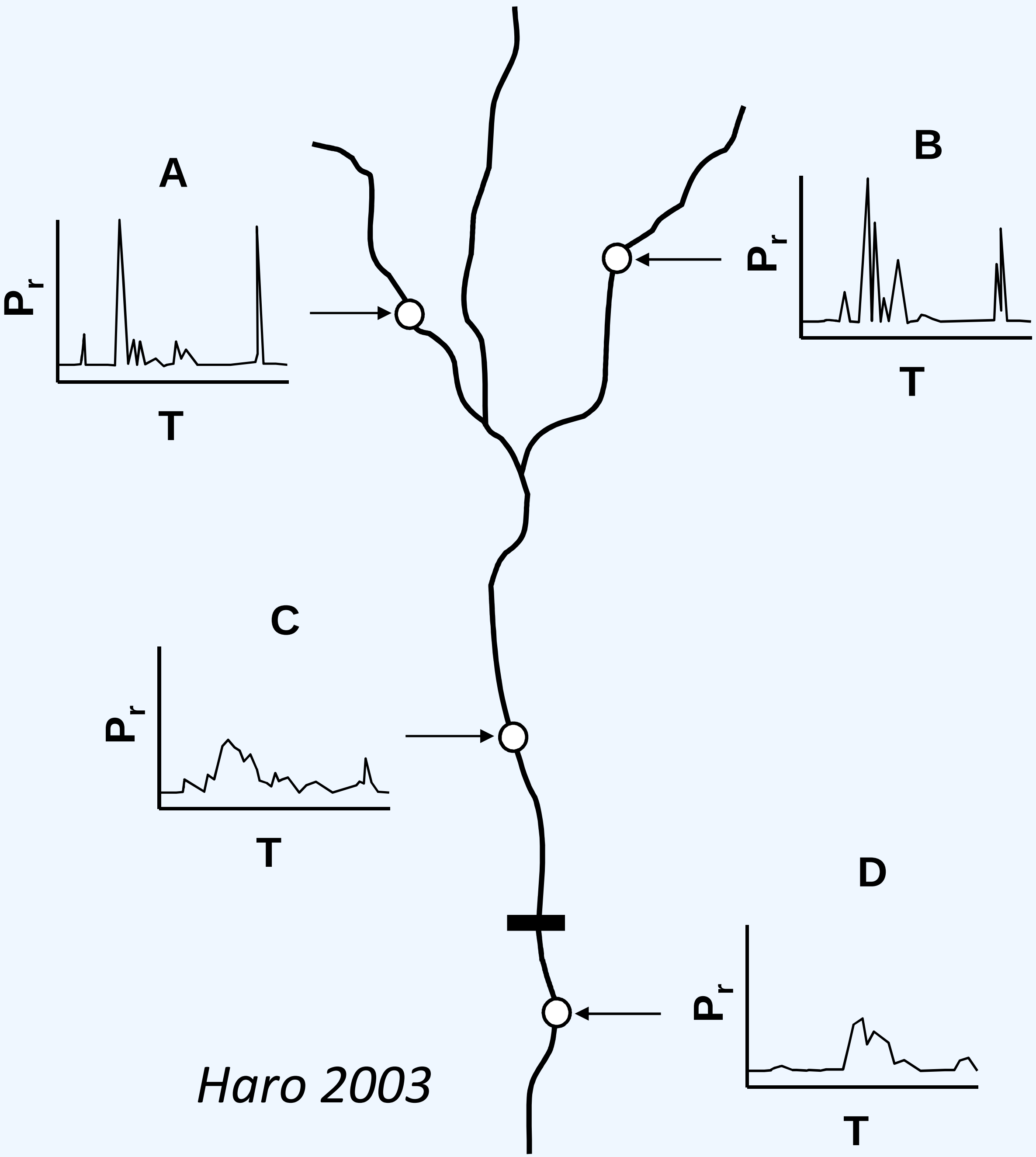


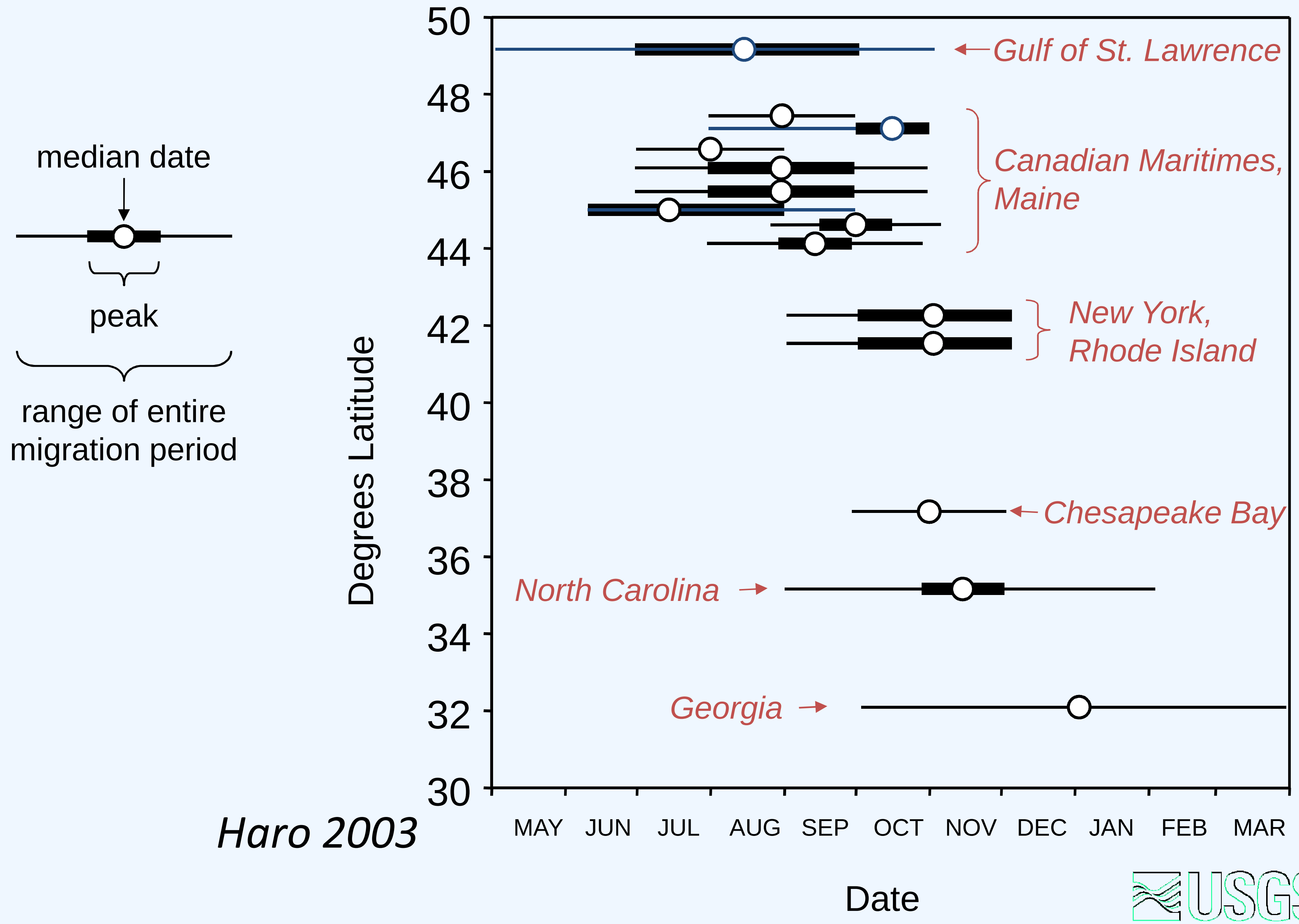
FIG. 1. Cumulative capture of descending silver eels in the fish trap (——) and water discharge (---) in the River Imsa during 1975–84.

Duration and timing of migration may vary in different parts of a watershed



Haro 2003

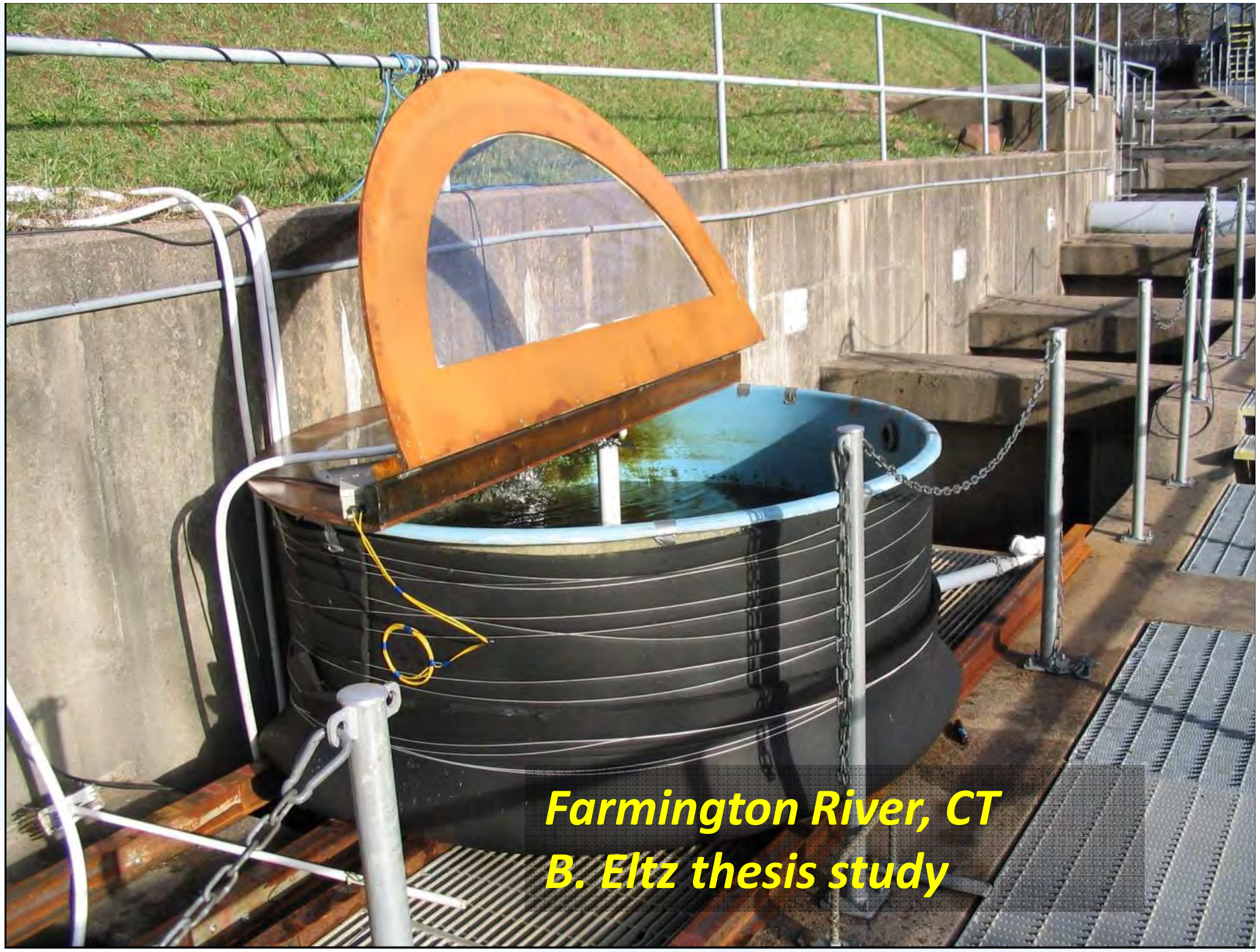
Latitudinal trend in emigration date of American eels

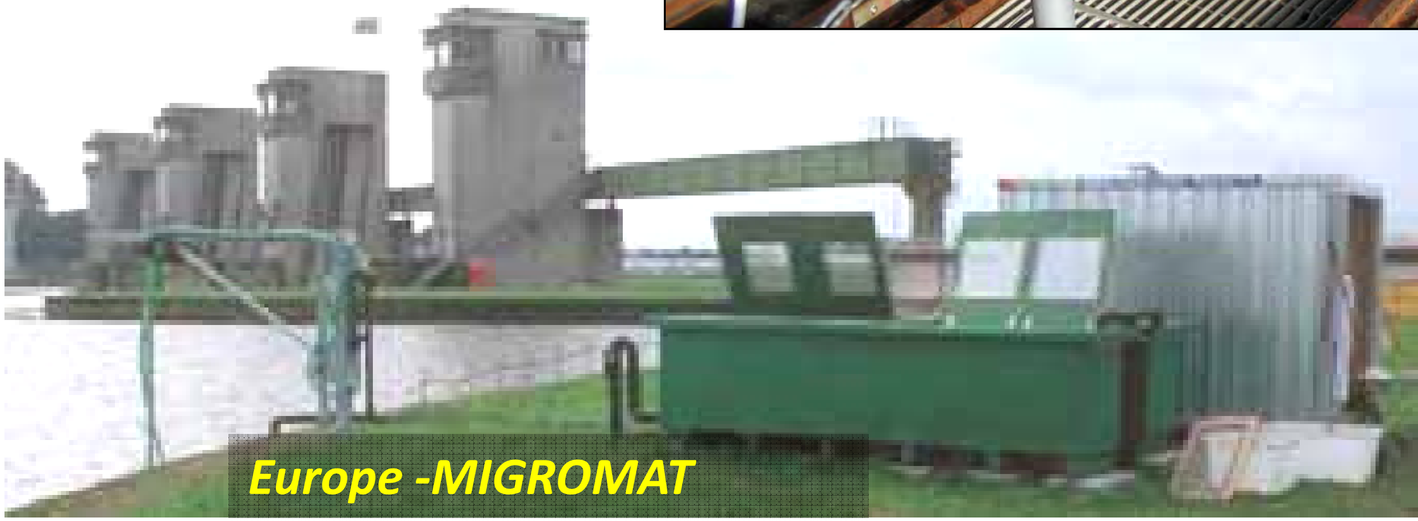


Haro 2003

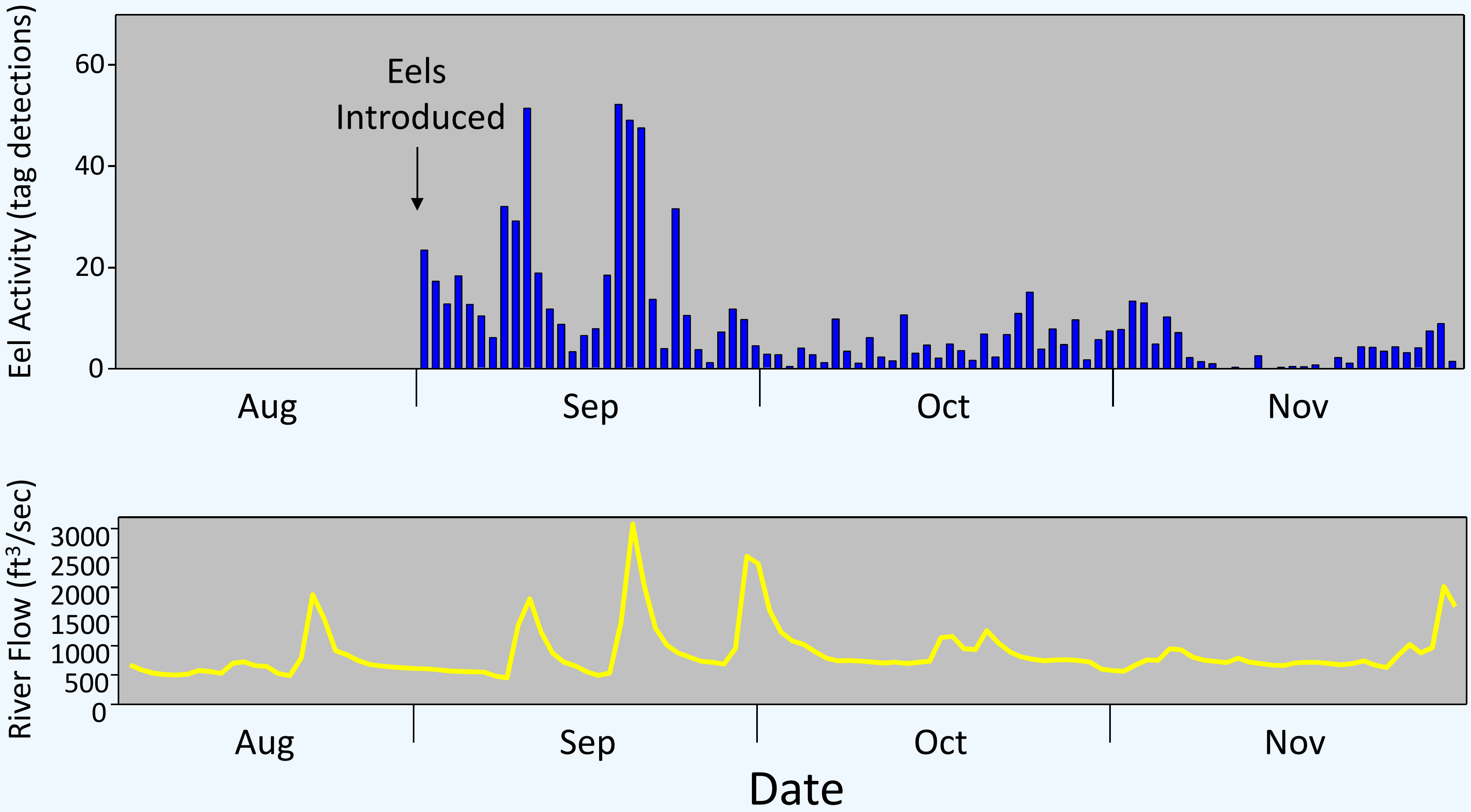
USGS

Migratory Activity & Environmental Cues





Activity monitor data – American silver eels

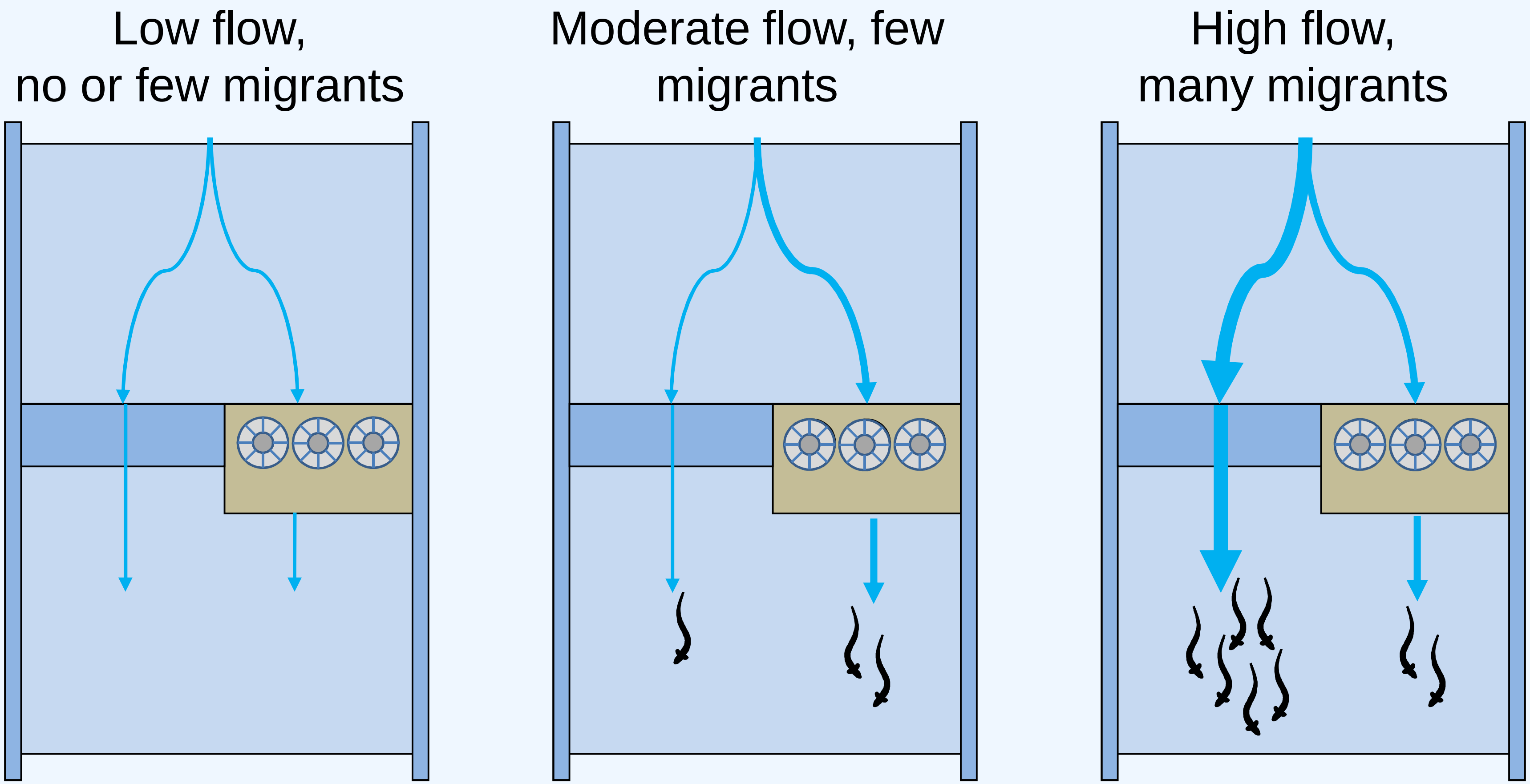


Other Aspects of General Downstream Migratory Behaviors

- Movements primarily at night
- Occupy all depths during migration
- Selective tidal stream transport in tidal reaches
- Tend to follow dominant flows
- Reactive to visual, chemical, and sound stimuli
- Environmental conditions can suspend or terminate downstream migration

Downstream Migration: Dam & Forebay Environments

Relationships of migration timing, flow, and station operation



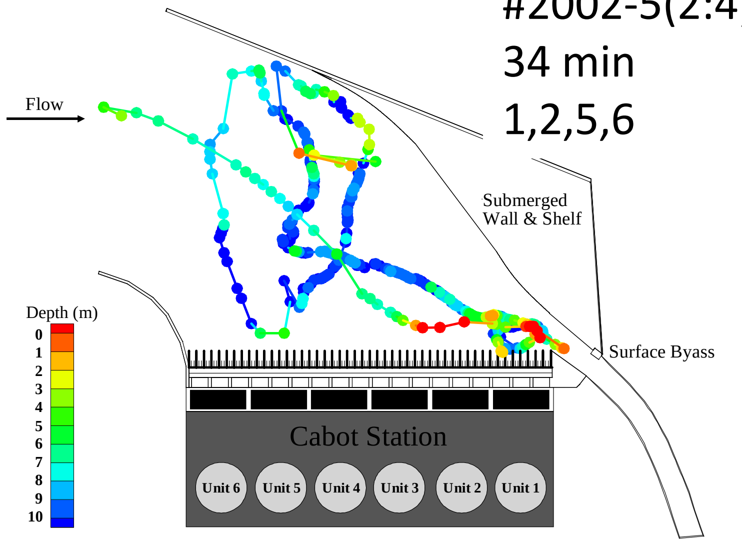
Additional issue of potential spill mortality

USGS

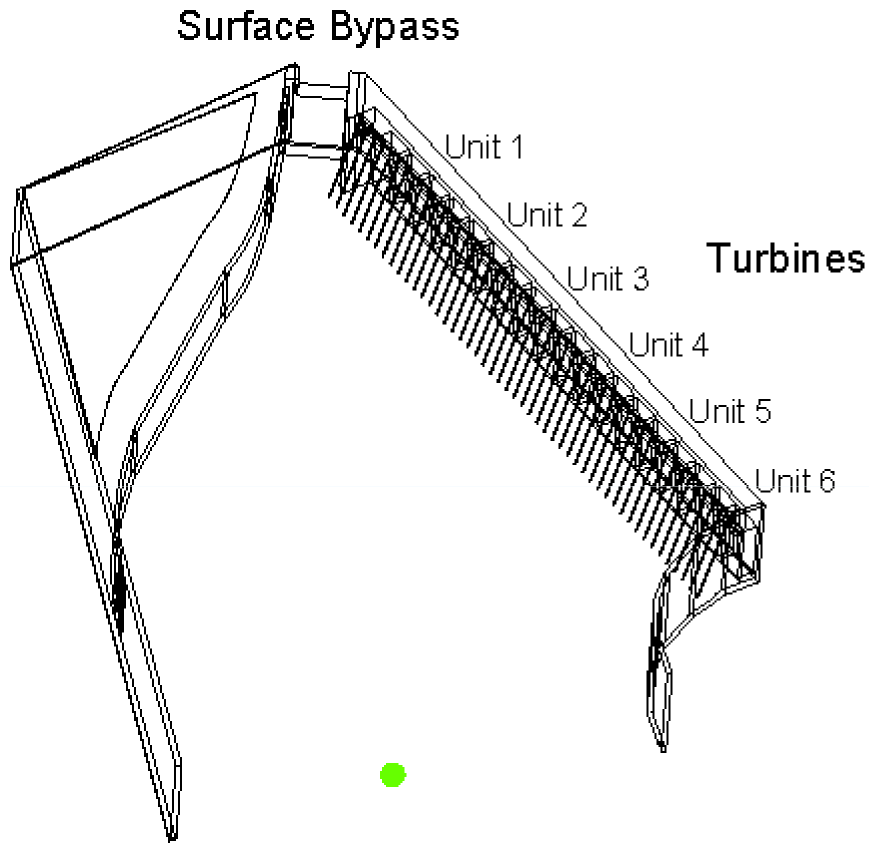
Use of Bypass Structures

Cabot Station (Turners Falls, Connecticut River)
surface bypass entrance

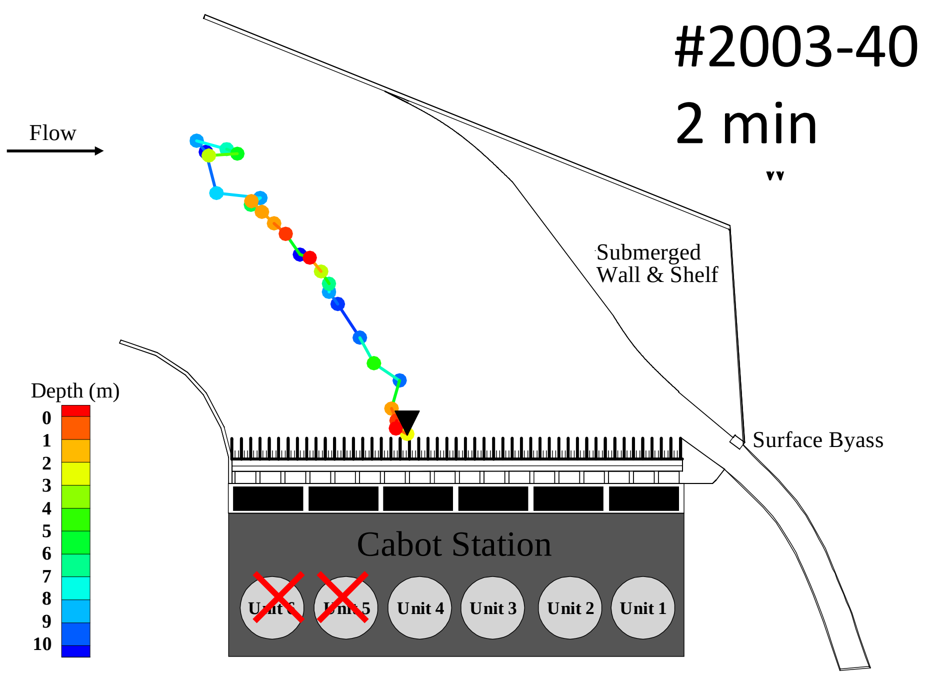
Passage of eels through entrance of Cabot surface bypass



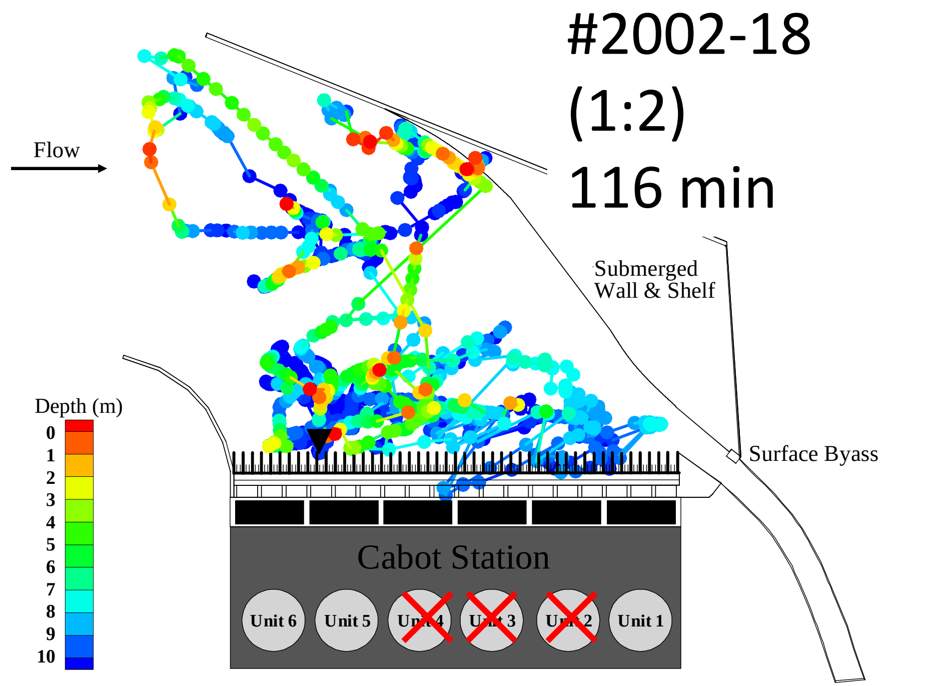
#2002-5(2:4)
34 min
1,2,5,6



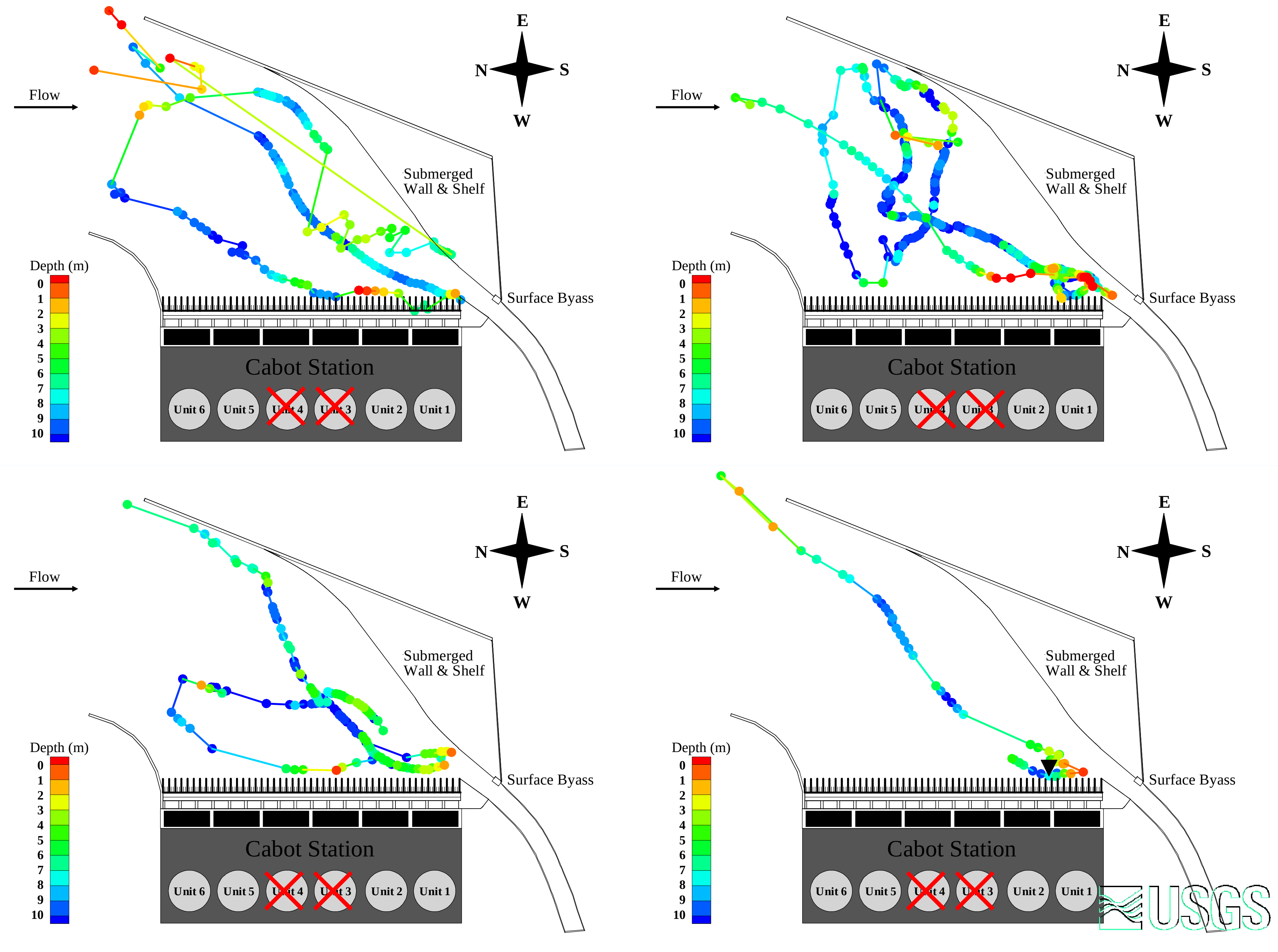
USGS



#2003-40
2 min
Flow
Submerged
Wall & Shelf
Surface Byass
Depth (m)
0
1
2
3
4
5
6
7
8
9
10
Cabot Station
Unit 4
Unit 3
Unit 2
Unit 1

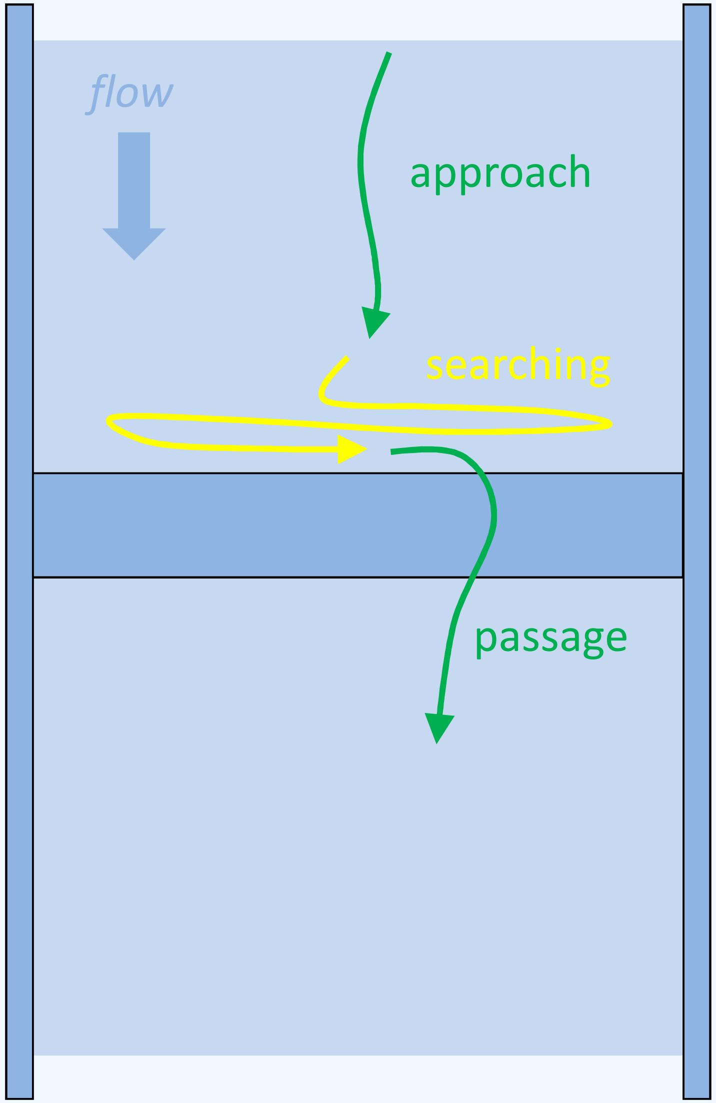


#2002-18
(1:2)
116 min
Flow
Submerged
Wall & Shelf
Surface Byass
Depth (m)
0
1
2
3
4
5
6
7
8
9
10
Cabot Station
Unit 6
Unit 5
Unit 1

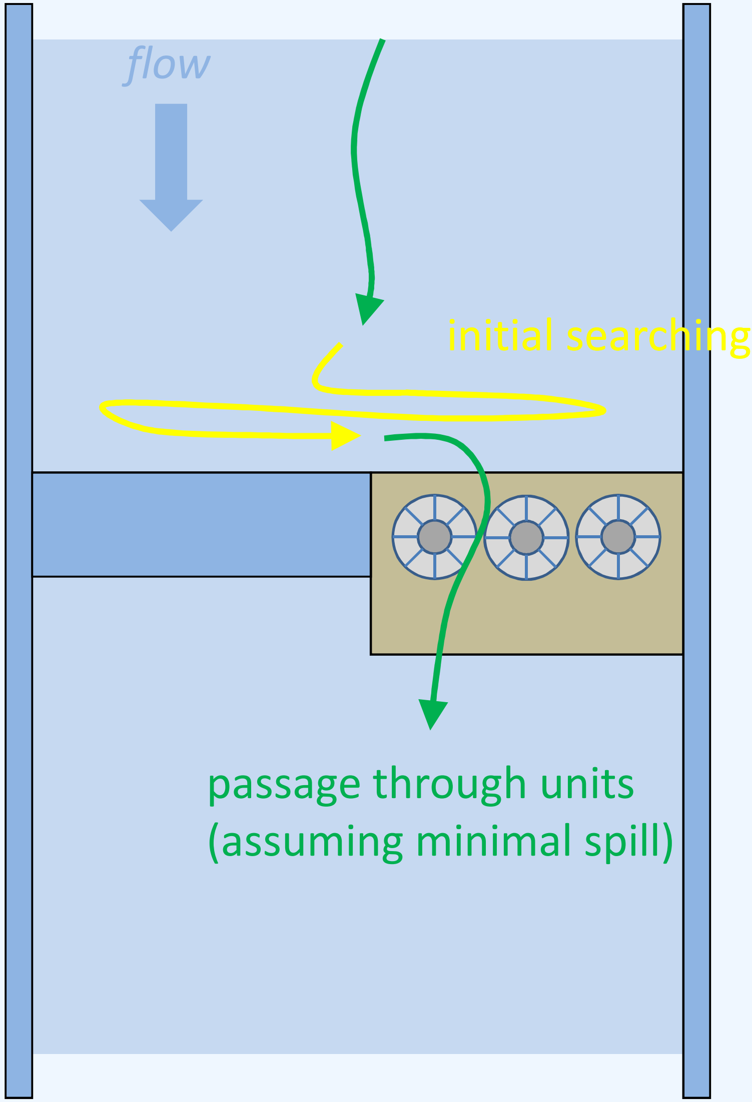

Flow
E
N
S
W
Submerged Wall & Shelf
Surface Byass
Depth (m)
0
1
2
3
4
5
6
7
8
9
10
Cabot Station
Unit 6
Unit 5
Unit 4
Unit 3
Unit 2
Unit 1
USGS

Generalized Behavioral Model of Eel Passage at Dams

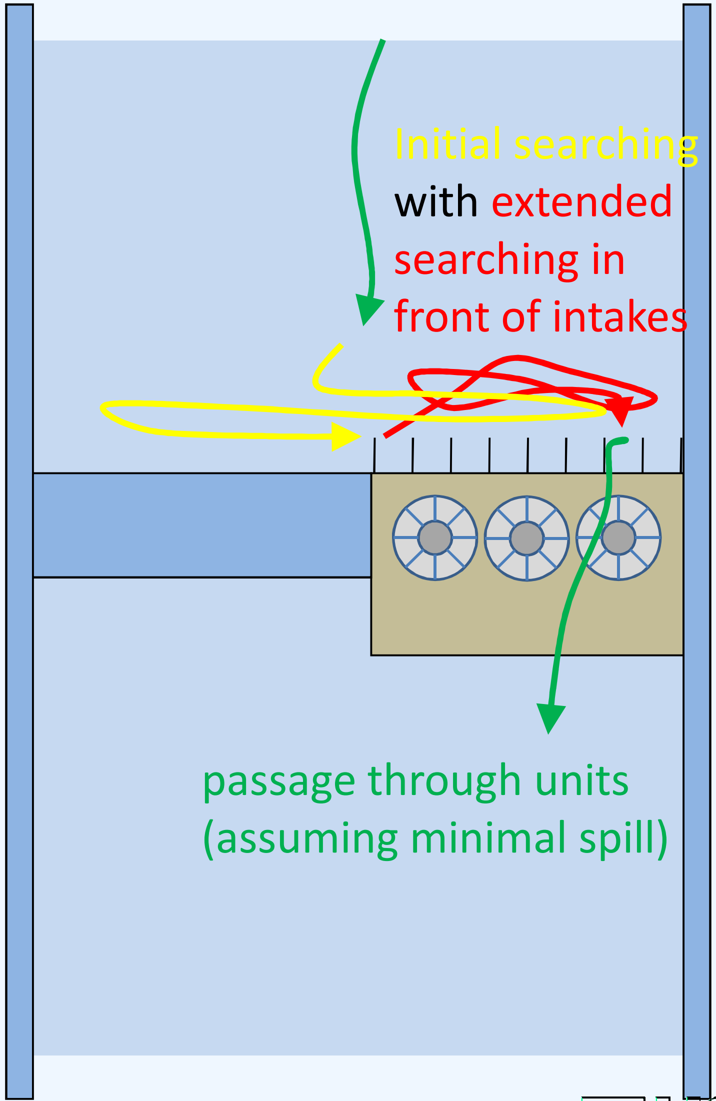
Dam with no hydro



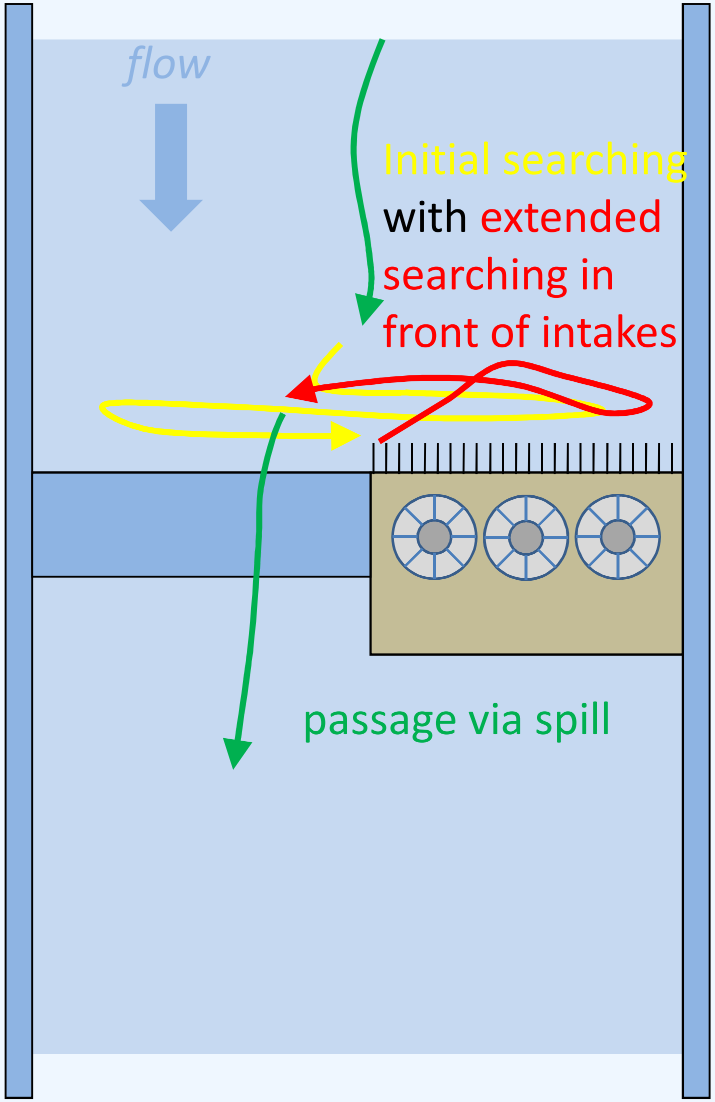
Dam with hydro – *no exclusion*



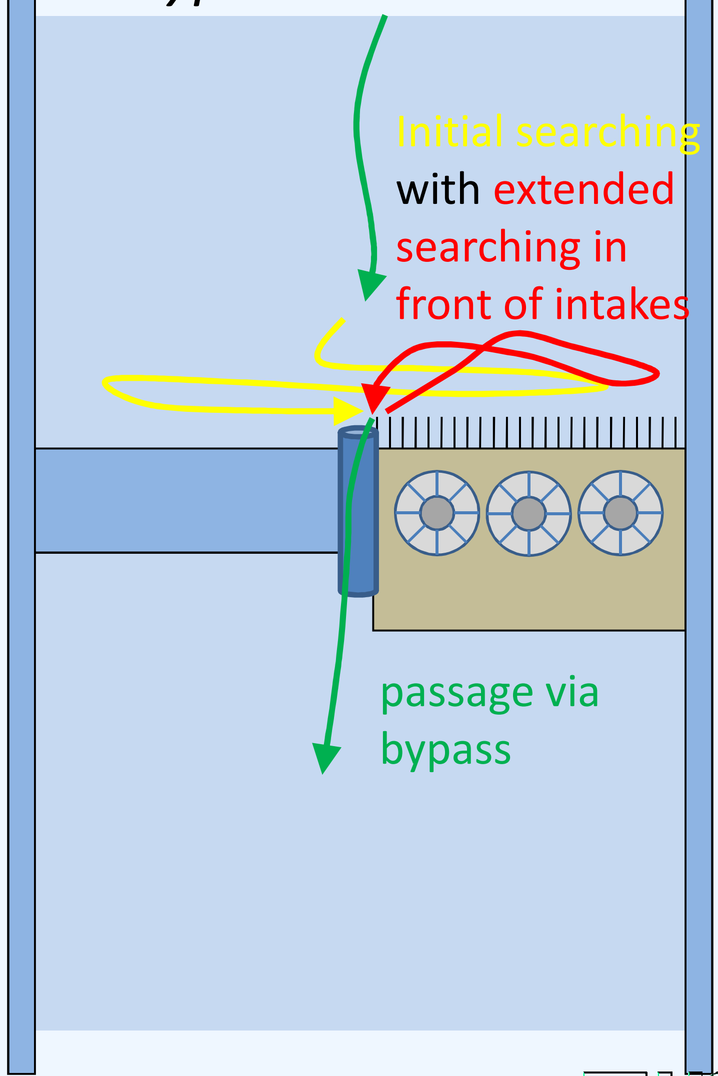
Dam with hydro – *partial exclusion*



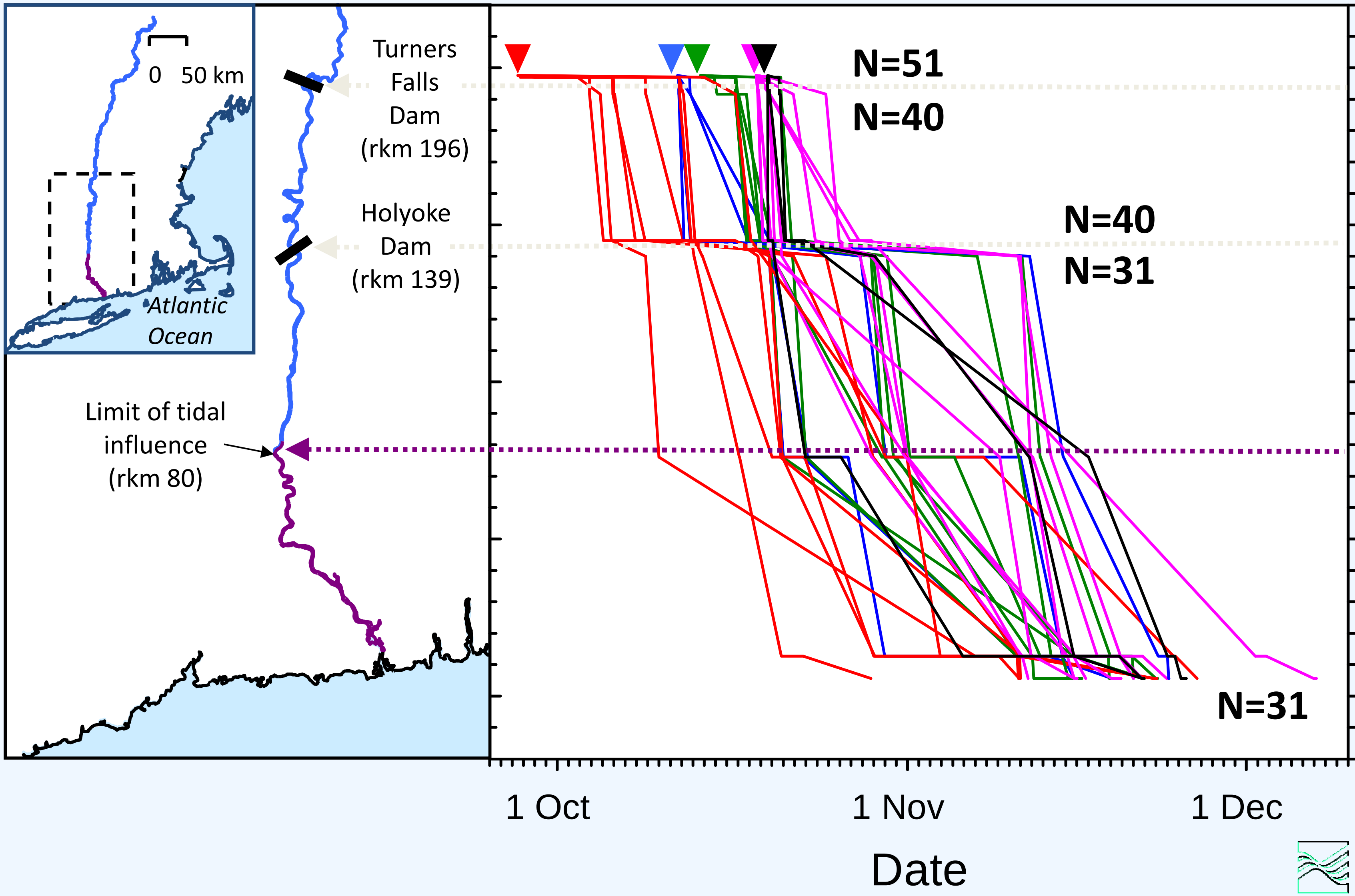
Dam with hydro
– complete exclusion



Dam with hydro
– complete exclusion & bypass



Downstream movement of telemetered silver eels in the Connecticut River – *delays at dams*



USGS

Important Questions Relevant to Eel Biology & Migration for the Susquehannah:

- What is the extent and value of eel habitat upstream of mainstem Susquehannah dams?
- How important are eels to upstream ecosystems?
- What happens to juvenile eels that don't pass upstream of Conowingo Dam?
- What are the current demographics of the eel population throughout the Susquehannah watershed? How do they compare to similar undammed rivers (e.g., Delaware)?
- What are the characteristics of the downstream run of eels in the Susquehannah (timing, numbers, sex ratio), and how do they relate to rain/flows or other potential migratory cues?
- What are the effects of dams on upstream population size, demographics, and escapement of adults?

USGS

Exelon. Power

Attachment C-Radio Telemetry of American Eel at the NYPA Moses-Saunders Hydroelectric Project

AMERICAN EEL TELEMETRY STUDY
ST. LAWRENCE RIVER

ST. LAWRENCE-FDR POWER PROJECT

Summer/Fall, 2000

Presented by Kevin McGrath

Gomez and Sullivan Engineers

kjmwp1@gmail.com

Study supported and conducted by

New York Power Authority

Conowingo Project
Downstream Eel Meeting
October 2011

MAJOR CONTRIBUTORS

Kleinschmidt Assoc.

Planning/Management and Report Preparation

Scott Ault -- Joe Dembeck -- Mike Hreben

Vemco

Telemetry

Fred Voegeli -- Greg McKinnon

Baird Associates

Software Analytical Tools

Kevin MacIntosh -- Derek Williamson -- Don Zimmer

Stantec Consulting (formerly Beak Associates)

Field Management and Report Preparation

David Stanley -- Geoff Burchill

Primary Objective:

To gather information on downstream migrating eel movement patterns above and in the near-vicinity of the Moses-Saunders Power Dam

Secondary Objective:

Determine if eels concentrate in any area which would lend itself to collection or guidance

August 2000 CM 13680001.fh8 (08-17-00)