NORMANSKILL PROJECT
FERC NO. 2955
Draft
2019 Relicensing Study Report

Downstream Fish Passage and Protection Study

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1 INTRODUCTION

1.1 Background

The Normanskill Project (the Project) is located on the Normans Kill in the Town of Guilderland, NY. The Project was built at an existing water supply dam that was constructed in 1915. The dam impounds the Watervliet Reservoir, which has a surface area of 430 acres and a usable storage capacity of 1,290 acre-feet at normal pool elevation of 262 feet. It is the sole source of drinking water for the City of Watervliet (the City) and is the primary water source for the Town of Guilderland.

The City is currently performing studies to support its licensing process according to study plans developed in consultation with representatives of the New York State Department of Environmental Conservation (NYSDEC), the U.S. Fish and Wildlife Service (USFWS), the Town of Guilderland, and the City. Following a March 27, 2018 Study Plan meeting, the City submitted a Study Plan to the agencies on May 30, 2018 which included a Downstream Fish Passage and Protection Study.

This study report provides information and results pertaining to the Downstream Fish Passage and Protection Study conducted at the Normanskill Project in 2019.

1.2 Goals and Objectives

The goals of this study were to:

- Evaluate if additional intake protection is necessary at the Project, and, if so, determine which protection measures are appropriate and feasible.

- Evaluate the need and alternatives for downstream fish passage at the Project.

Objectives include:

- Collect site-specific physical information including the hydro intake location and dimensions, trashrack spacing, and velocities near the intake to document existing conditions[1].

- Gather and review scientific literature for species of interest relative to physiology, behavior, life history and habitat preferences in the context of downstream passage and turbine entrainment mortality.

- Assess the potential for entrainment and impingement, and estimate turbine passage survival rates for target species, including, but not limited to American Eel, Largemouth Bass, Chain Pickerel, and White Crappie.

[1] Intake velocities have not been collected as of May 2019 as the Project has been unable to operate at the full hydraulic capacity of 240 cfs due to an electrical problem that is expected to be fixed later in 2019.

1.3 Resource Management Goals

The NYSDEC manages the Normans Kill in the Project area as a warmwater fishery. They noted that Largemouth Bass, Chain Pickerel, and White Crappie are game species known to be present in the area. American Eel is also known to be present both downstream of the Project and in the reservoir.

2 PROJECT LOCATION, FACILITIES, AND OPERATIONS

2.1 Project Location

The Normanskill Hydroelectric Project is located on the Normans Kill in the Town of Guilderland in Albany County, New York. The Normans Kill flows over 45 miles through the Capital District of New York State to its confluence with the Hudson River. The Project is located approximately 22.4 river miles upstream of the mouth, with a watershed encompassing approximately 113 square miles. The Project dam is located within a moderately deep ravine of the Normanskill. Immediately downstream of the dam, the ravine is traversed by two active railroad trestles and an Albany County highway bridge on French's Mill Road that has been closed to traffic.

2.2 Project Facilities

The FERC Project Boundary for the Normanskill Project encompasses the reservoir, project/dam area, and a short reach downstream on the Normans Kill. The licensed Project works consist of a dam and reservoir, intake, sluiceway, penstock, an underground powerhouse connected to an underground control building via a tunnel, a transmission line, a transformer bank, and appurtenant facilities.

2.2.1 Intake Structure, Penstocks, Powerhouse

The Project is equipped with an intake structure that draws water from near the surface of the dam, at an elevation of 256 feet and above. The intake gate is 15 feet wide and 8 feet tall, extending 2 feet above the top of the flashboards. When the reservoir is at full pond (El. 262) the total area of water at the intake gate is 90 square feet. A photograph of the exposed section of the intake structure is shown in Figure 2.2.1-1. A section view of the intake structure is shown in Figure 2.2.1-2.

Trashracks consisting of two sections are located past the intake gate, each covering half of the 12-foot by 12-foot intake area to prevent large debris from entering the penstock leading to the turbine. Each trashrack section is 6 feet wide by 14 feet high. The extra 2 feet in height allow the trashracks to sit flush on the concrete where they are bolted down, so the total open area at the trashracks is 144 square feet, as shown in Figure 2.2.1-3. The bars have a rack spacing of 2 inches from centerline to centerline, and each bar is ½ inch thick. A sluiceway adjacent to the trashracks allows for removal of debris. Water is conveyed from the intake to the powerhouse via a 900-foot-long, 6-foot-diameter (inner diameter) reinforced concrete penstock buried in the riverbed.

The underground reinforced concrete powerhouse contains a tube-type generating unit with a rated capacity of 1,250 kW at a net head of approximately 66 feet, with a hydraulic capacity of 240 cubic feet per second (cfs). The minimum generation hydraulic capacity is approximately 60 cfs. Table 2.2.1-1 lists the Project turbine characteristics, which are described in detail below. The facility is operated from an underground control building located on the left (north) bank, which is connected to the powerhouse via a tunnel.

The turbine used at the Normanskill Project is a reaction style turbine, meaning that it operates with the runner fully flooded and develops power from the combined action of pressure and moving water. The tube-type turbine is most similar to a Kaplan turbine in that they are both propeller-style turbines with runners having three to six blades. Both tube-type and horizontal Kaplan turbines utilize axial inflow and outflow. The main difference between the two is that Kaplan turbines contain adjustable blades and wicket gates while the tube-type turbine has fixed components. The layout of tube-type turbines is such that there is a bend in the draft tube immediately following the runner so that the runner has a straight line connection to the generator. This configuration is shown in Figure 2.2.1-4 which displays the layout of the Normanskill Project powerhouse.

Tube-type turbines are utilized far less often than Kaplan turbines and as a result there has been more research into "fish-friendly" analysis for the latter. Because tube-type and Kaplan turbines share basic design characteristics (i.e. propeller style turbines utilizing axial flow), the turbine survival analysis presented in Section 4.2.3 was completed using a formula developed for a Kaplan turbine.

Table 2.2.1-1: Project Turbine Characteristics

Number of Turbines	1
Turbine Type	Tube-Type Turbine
Total Hydraulic Capacity (cfs)	240
Minimum Hydraulic Capacity (cfs)	60
Total Installed Capacity (kW)	1,250
Average Head (feet)	66
Rated Runner Speed (rpm)	600
Runner Diameter (inches)	45.18
Number of Blades	4
Number of Wicket Gates	16

2.3 Project Operations

The primary use of water at the Project is municipal drinking water, as drawn by the City of Watervliet and the Town of Guilderland. The average daily demand of the reservoir in 2017 for both municipalities combined was 5,057,559 gallons. Generation at the Project is largely based on the water level in the reservoir and inflows. The City manages reservoir operations to maintain water levels between 261 and 261.5 ft. In general, when reservoir levels are greater than or equal to 261 feet, the Project generates. When reservoir levels are lower than 261 feet, generation happens less frequently (only about 8.4% of the time). Occasionally, the City reduces the water level to create storage for an expected runoff event (i.e. significant snowmelt); it is rare for reservoir levels to fall below 260 feet (6.1% of the time). Higher reservoir levels occur during high streamflow events, due to limited storage in the reservoir, and low reservoir levels occur during dry periods. The frequency and duration of generation each year depends on annual hydrologic conditions in the watershed. Table 2.3-1 lists the average number of days per month that the Project did not generate hydropower between January 1995 and December 2018.

Table 2.3-1: Average Number of Days per Month with No Hydropower Generation

Period of Record (1995-2018)

Month	Number of Days with no Generation
January	5.8
February	4.9
March	0.9
April	1.4
May	6.6
June	10.5
July	17.7
August	22.1
September	20.8
October	16.5
November	9.4
December	5.8
Annual	122.3

2.4 Project Hydrology

The Project has a drainage area of 113 square miles. There are no suitable USGS streamflow gages in the vicinity of the Project[2], so 24 years of Watervliet Reservoir water level records and Normanskill Project generation records were used to estimate streamflow at the Project. These records extend from January 1995 to December 2018 and contain readings of reservoir water surface elevation, power generation, and gate position on a 20-minute interval. A turbine-discharge curve was used to determine turbine flow based on generation. The weir equation was used to calculate spill flow that occurred when the reservoir surface exceeded the top of the flashboards. Additional flow downstream of the Project is provided by dam seepage, flashboard leakage, and local runoff. This flow is in the bypass is small (averaged 2 cfs in 2018) and is not related to entrainment. The baseflow in the bypass is described in the Downstream Flow Study Report (GSE 2019).

Table 2.4-1 lists the minimum, maximum, median, and average annual and monthly flows of the Normans Kill at the Project.

Table 2.4-1: Normanskill Project Outflow Statistics (Generation Flow and Total Flow Downstream of the Tailrace), 1995-2018

Month	Flow (cfs)[3]							
	Minimum		Maximum		Median		Average	
	Gen Flow	Total Flow	Gen Flow	Total Flow	Gen Flow	Total Flow	Gen Flow	Total Flow
January	0	0	265	3,694	69	71	89	136
February	0	0	255	3,106	69	69	85	122
March	0	0	261	5,082	165	170	153	321
April	0	0	262	7,476	141	160	135	265
May	0	0	262	4,334	69	69	85	129
June	0	0	302	6,304	0	0	63	119
July	0	0	255	5,340	0	0	32	57
August	0	0	252	11,393	0	0	22	42
September	0	0	257	5,524	0	0	24	35
October	0	0	248	4,815	0	0	46	95
November	0	0	264	2,982	61	76	72	124
December	0	0	260	4,210	78	101	96	159
Annual	0	**0**	302	**11,393**	65	**67**	75	**134**

[2] There is one USGS streamflow gage on the Normans Kill located downstream of the project in Albany (USGS Gage No. 01359528) but over 75% of the period of record from 1979 to 2019 is missing flow data.
[3] Flow downstream of the tailrace includes generation flow and spillage flow. It does not include the bypass base flow. The calculated maximum generation may occasionally exceed the rated capacity of 240 cfs.

2.4.1 Water Velocity Calculations

As described above, the intake gate at the Project is 15 feet wide and 8 feet high. The invert elevation of the intake gate is at El. 256, so when the reservoir is at full pond (El. 262) 6 feet of the intake gate area is below the water surface, making the effective intake area 90 square feet. Based on the total Project hydraulic capacity of 240 cfs, the maximum calculated velocity of water at the intake when the reservoir is at full pond is 2.67 ft/s. When the reservoir elevation is below El. 262 the effective intake area is reduced which increases the intake velocity. At El. 261, the effective intake area is 75 square feet and the maximum calculated velocity of water at the intake is 3.20 ft/s. At El. 260, the effective intake area is 60 square feet and the maximum calculated velocity of water at the intake is 4.00 ft/s. This calculated velocity would theoretically apply to the entire intake gate area during full generation. Figure 2.4.1-1 displays the range of calculated intake velocities at the Project and the annual percentage of time that each velocity occurs. This curve was calculated using generation flows and corresponding reservoir elevations from 1995 through 2018 to account for the variability of the effective intake area. Monthly intake velocity curves are located in Appendix A.

Figure 2.2.1-1: Photograph of the Normanskill Project Intake Structure

View of the intake structure from the top of the dam on river right. The intake gate extends approximately 2 feet above the top of the flashboards.

Figure 2.2.1-2: Section View of Normanskill Project Intake Structure

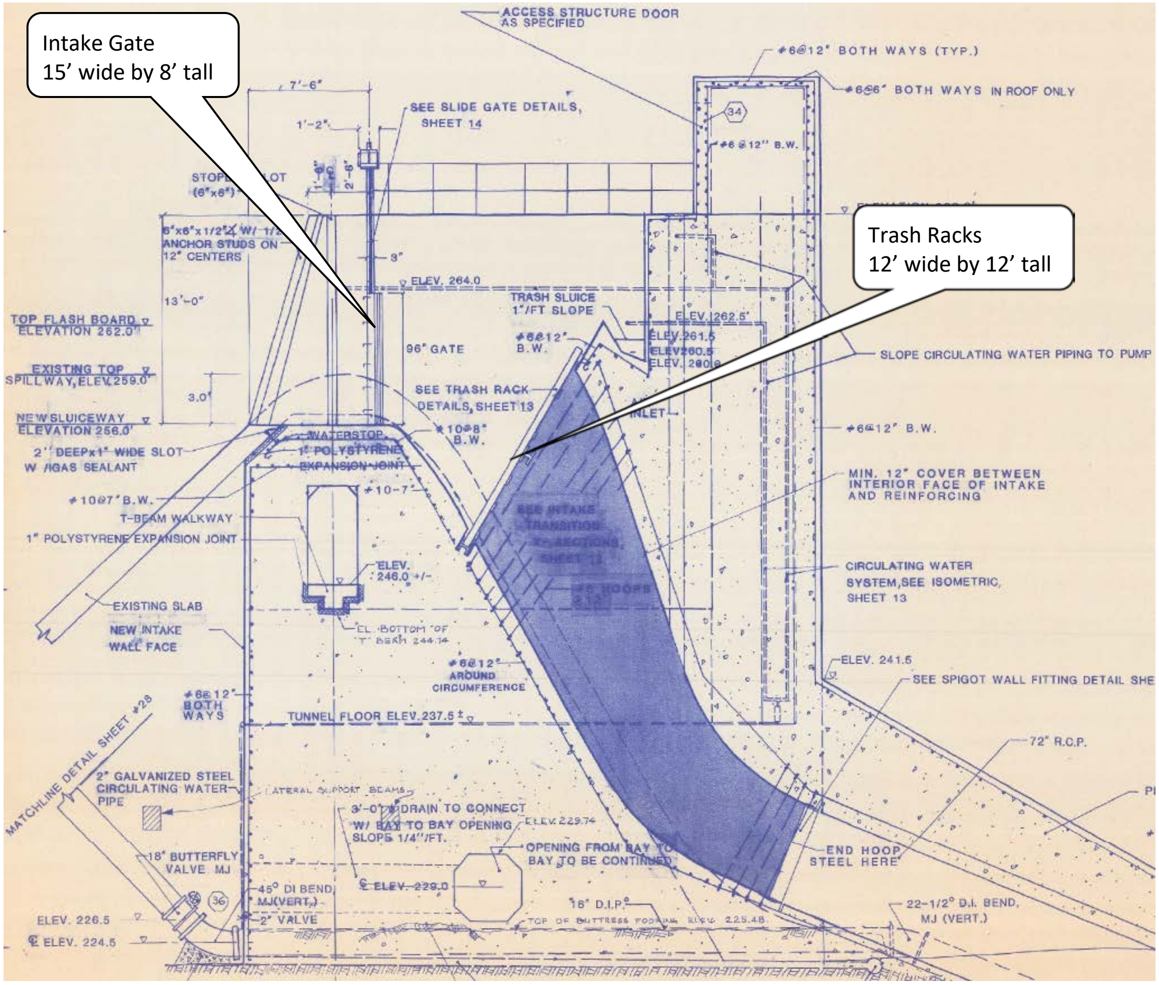


Figure 2.2.1-3: Normanskill Project Trashrack Layout

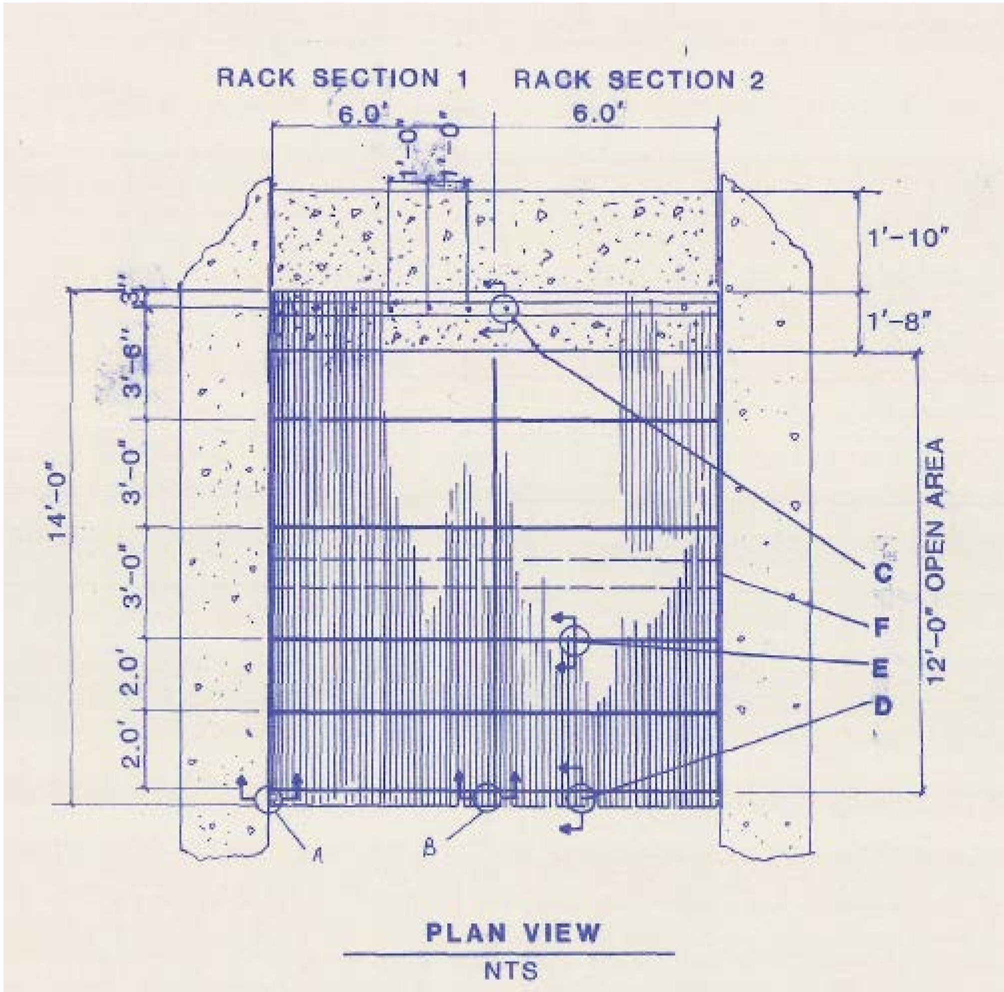


Figure 2.2.1-4: Normanskill Project Powerhouse Layout

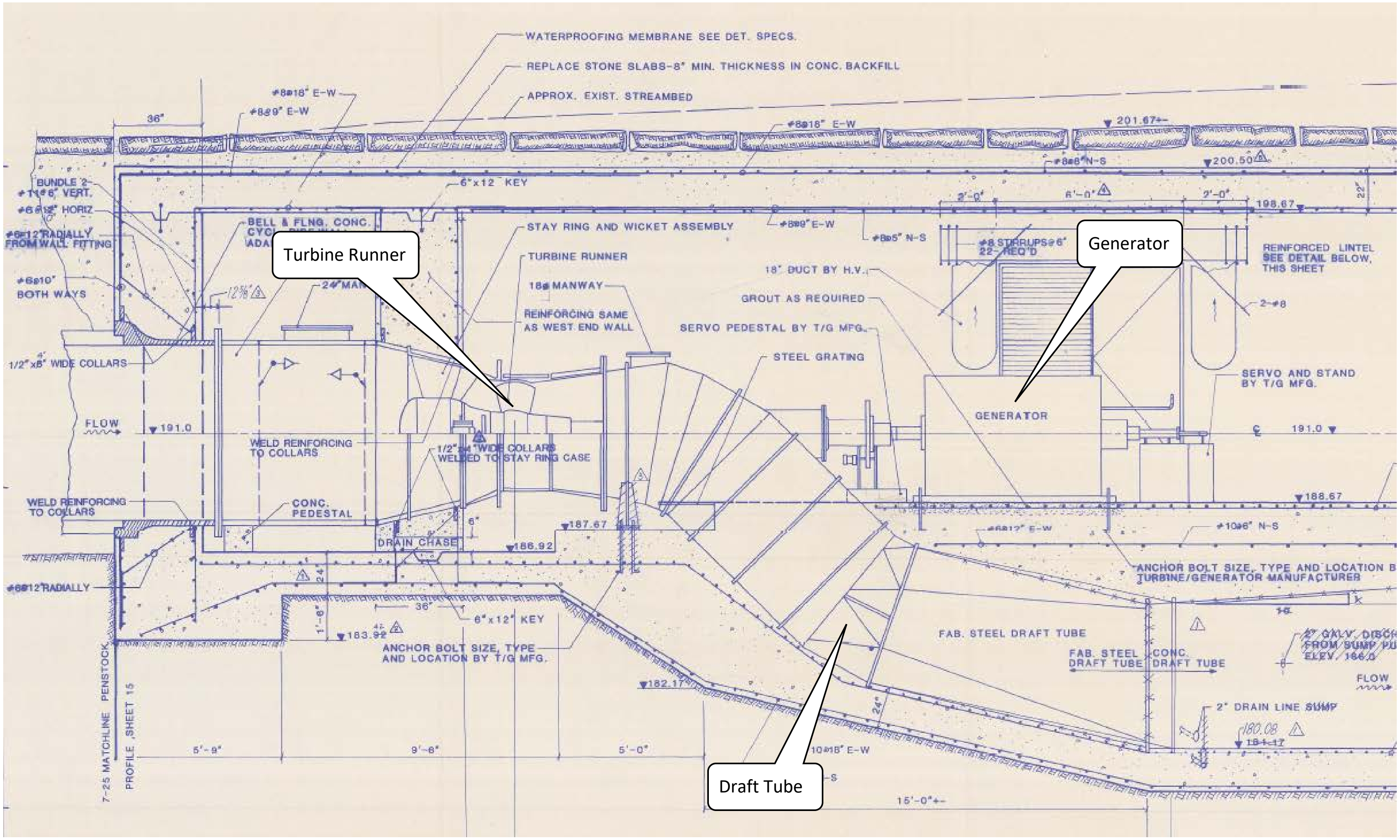
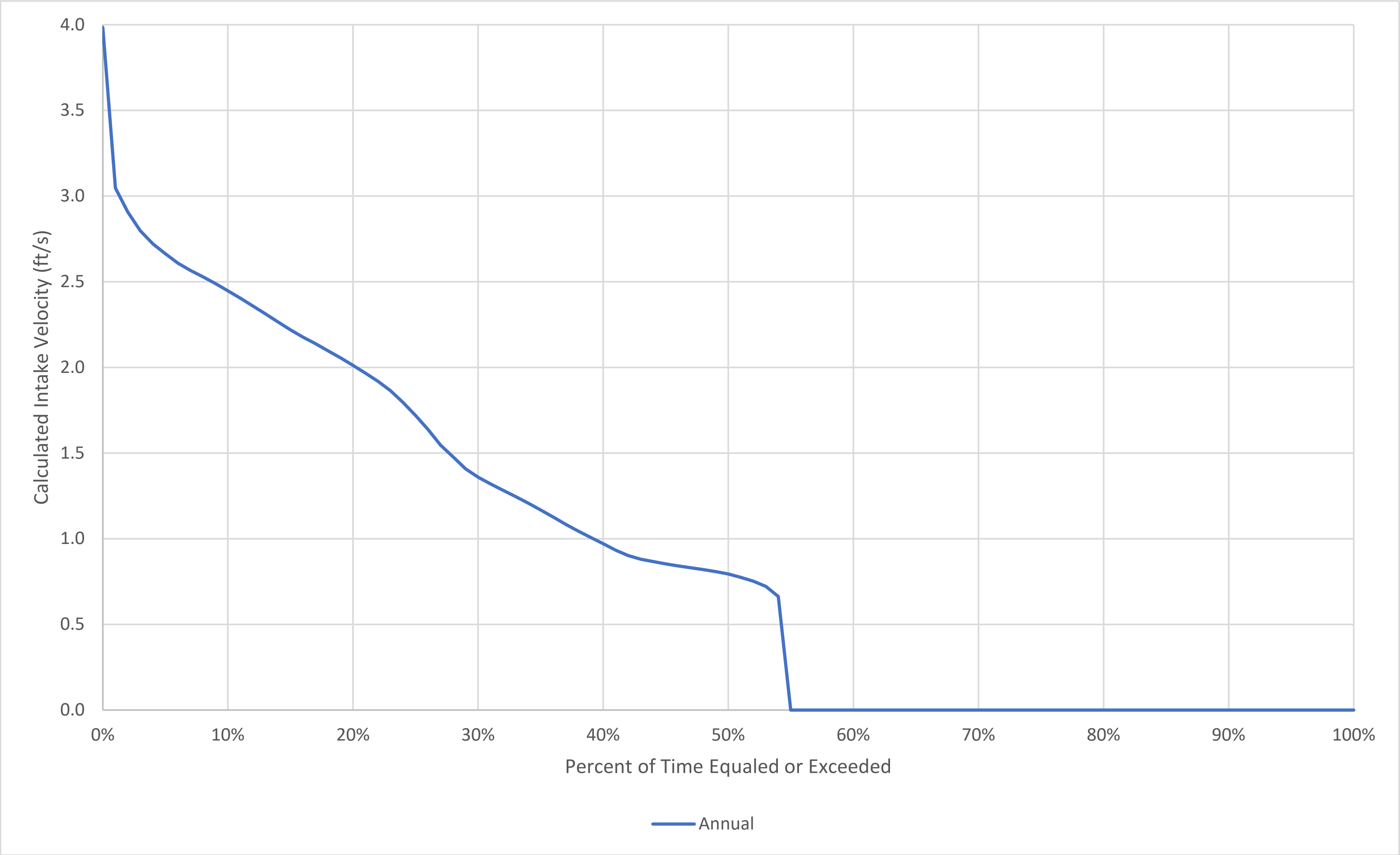


Figure 2.4.1-1: Annual Calculated Intake Velocity Duration Curve (1995-2018)



3 TARGET FISH SPECIES

The target fish species listed in the study plan are American Eel, Chain Pickerel, Largemouth Bass, and White Crappie. These species were included in the study based on the resource management goals listed in the USFWS and NYSDEC study request letters.

3.1 Life History and Habitat Requirements

The life history and habitat preferences and behavior of each target species as it relates to the entrainment analysis at the Project is summarized below and in Table 3.1-1.

3.1.1 American Eel

American Eel is the only representative of the family Anguillidae in North America. It is catadromous, meaning that it spawns in the ocean but spends most of its life in freshwater (Facey and Van Den Avyle 1987). After drifting on ocean currents, eel larvae (leptocephali) develop into juvenile eels (elvers) and migrate inland where they live and grow to maturity (sometimes 15+ years) and are typically referred to as yellow eels. They inhabit a wide variety of habitats, from cold, freshwater streams and lakes to warm, brackish coastal areas. They reside near the bottom, tend to hide in crevices in substrates or available shelter, and are most active during the night (Facey and Van Den Avyle 1987). In the winter, they will lie dormant in the northern latitudes. When they mature into what are commonly called “silver eels”, they develop large eyes, dark fins, a metallic, bronze-black sheen, fatting of the body, thickening of the skin, and additional changes to internal morphology to prepare them for their migration in the open ocean and the Sargasso Sea to spawn (Facey and Van Den Avyle 1987). The spawning migration typically occurs in the late summer or fall in New England and eastern Canada, though out-migration from lakes that are far inland may occur sooner, such as June – August for Lake Champlain (Facey and Van Den Avyle 1987). Migration of eels can be initiated by a wide combination of environmental factors (i.e. changing water temperatures, moon phase, photoperiod, atmospheric pressure, turbidity), though runs with the greatest abundance typically occur during periods of increased discharge and low light conditions (Bruijs and Durif 2009). Emigrating eels are most active at night and may occupy a variety of depths. Haro et al. (2000) monitored eels approaching the Cabot hydroelectric station in Massachusetts. Eels occupied a variety of depths while in the forebay but spent the greater proportion of time at or near the bottom (33 feet), occasionally venturing to the surface. In a test flume under lighted conditions, Adam and Schwevers (1997) and Adam et al. (1997) reported that European eels occupied different water depths depending on flow velocity. At lower velocities (<0.6 ft/s) eels drifted close to the bottom, and at higher velocities (>1.6 ft/s) eels exhibited an active downstream movement generally in the upper two-thirds of the water column.

3.1.2 Chain Pickerel

Chain Pickerel can live in a variety of habitats and can tolerate a variety of conditions. They are most often found under cover, such as weed beds, sunken stumps, logs and other aquatic vegetation or natural cover sources. Chain Pickerel are ambush predators; feeding on other fish species, snakes, frogs, and sometimes ducklings (NHFGD, 2019). They spawn in late winter and early spring and may even spawn in the fall. Chain Pickerel sub-adults and adults may be found in deeper portions of lakes and reservoirs at times. Adults often become sedentary in the summer. Chain Pickerel have the ability to tolerate dissolved oxygen levels down to 1 mg/L and warm water temperatures of greater than 30° (NatureServe 2009; Osmond et al. 1995). These fish may also move to deep water during the winter when residing in lakes and reservoirs.

3.1.3 Largemouth Bass

Largemouth Bass are a warmwater, predatory species that prefers lacustrine environments, but also inhabits low-gradient rivers where optimal habitat is characterized by soft bottom, some aquatic vegetation, clear water, and a high percentage of pool and backwater habitat. They spawn in the spring and early summer, at optimal temperatures of 68-70°F over a variety of substrates, but prefer to build nests in gravel, at depths of 0.5-25 ft (Stuber et al. 1982). Adults and juveniles are most abundant in areas with vegetation and other cover (Stuber et al. 1982), preferring areas of low current (velocity < 0.2 ft/s), and velocities greater than 0.66 ft/s are considered unsuitable. Velocities greater than 0.3 ft/s are avoided during spawning/nest building. Fry prefer low velocities and shallow areas with cover such as flooded terrestrial vegetation. Largemouth Bass will sometimes move to deeper water during winter.

3.1.4 White Crappie

White Crappie is native to freshwater lakes and streams from the southern Great Lakes, west to Nebraska, south to Texas, and east to North Carolina, and introduced throughout North America (Scott and Crossman 1973). They are most abundant in lake and reservoirs that are greater than 5 acres (Troutman 1957). White Crappies congregate in areas with submerged trees, stumps, brush, boulders, and aquatic vegetation (Trautman 1957). Fry feed on copepods, rotifers, and algae, juveniles feed on zooplankton and planktonic insects, and adults feed on small fish (Neal 1962). White Crappie spawn from March to July when water temperatures are 16-20°C. Males build and guard nests over multiple substrates in river pools, bays, coves, and littoral areas near vegetation of reservoirs and lakes (Scott and Crossman 1973).

3.2 Swimming Speeds

The swimming speed of fish can be an important factor for escaping and avoiding entrainment and impingement. Swimming speeds can be grouped into three different types based on how energy is supplied to the muscles (Beamish, 1978). Sustained speeds are maintained through aerobic processes, prolonged speeds are maintained through aerobic and anaerobic processes, and burst speeds are maintained primarily through anaerobic processes and result in oxygen debt that must be regained (Beamish, 1978). Sustained speeds can be maintained for long periods without fatigue (Beamish, 1978). Prolonged speeds can typically be maintained anywhere from 15 seconds to 200 minutes until exhaustion, with anaerobic metabolism increasing and the time to exhaustion decreasing with increased speed (Beamish, 1978). Burst speeds are the maximum speeds that can be attained by fish and can only be maintained for short periods (time < 15 seconds) prior to exhaustion (Beamish, 1978). The fish length and corresponding swim speeds for the target species are summarized in Table 3.2-1 below along with the specific literature references.

3.2.1 American Eel

No swim speed estimates were found for yellow or silver American Eel. However, swim speed estimates were found for yellow and silver European eel (*Anguilla anguilla*), a species similar in morphology and behavior to American Eel. Following the test method of Brett (1964), Quintella et al. (2010) tested the prolonged swim speed of 29 yellow eels (14 to 21 inches total length) and 33 silver eels (12.5 to 27.5 inches total length) placed in a swimming tunnel submerged in a fiberglass tank. The water velocity in the swimming tunnel was adjustable from 0 to 4.9 ft/s and water temperature ranged from 61 to 66°F throughout the experiment. Prolonged swim speed for yellow eels was 1.4 ft/s and 2.2 ft/s for silver eels. Applying Bell's percentage calculation[4] and assuming European eel swim speeds are similar to American Eel swim speeds, an estimate of burst swim speed for yellow American Eel is 2.0-2.8 ft/s and 3.1-4.4 ft/s for silver American Eel.

3.2.2 Chain Pickerel

Northern pike was used as a surrogate species for Chain Pickerel due to lack of swim speed data. Beamish (1978) reported burst swimming speeds for adult Northern Pike up to 14.8 ft/s. Reported prolonged speeds for pike are 4.8 ft/s and 6.9 ft/s for 6.5 inch to 14.9 inch fish (Beamish 1978). Using the Bell 1991 Rule, the calculated burst speed of adult Northern pike as 5.52 ft/s to 8.28 ft/s.

Prolonged speeds for juvenile Northern Pike approximately 4.72 inches were reported as 0.62 ft/s to 1.56 ft/s (Peake, 2008). Using the Bell 1991 Rule, the calculated burst speeds for juvenile Northern Pike range from 0.71ft/s to 1.79 ft/s.

3.2.3 Largemouth Bass

Katopodis and Gervais (1991) reported Largemouth Bass 8.8 inch length have a prolonged swim speed of 1.9 ft/s at a temperature of 86°F. Froese and Pauly (2016) documented Largemouth Bass 8.4 inch length have a sustained swim speed of 2.9 ft/s. Therefore, the prolonged swim speed for adult Largemouth Bass is assumed to range from 1.9 to 2.9 ft/s. At present, no information exists for Largemouth Bass burst swim speeds. Largemouth Bass burst swim speeds are calculated using Bell's 1991 rule and range from 2.19 ft/s to 3.48 ft/s.

Juvenile Largemouth Bass ranging in size from 3.0-3.5 inches have a prolonged swim speed of up to 1.6 ft/s (Katopodis and Gervais 1991). Based on sustained swim speed range for juvenile Largemouth Bass, the calculated burst swim speed for juvenile Largemouth Bass is between 1.84 and 1.92 ft/s (Bell 1991).

3.2.4 White Crappie

No swim speed data were found for adult White Crappie. Due to the lack of swim speed data for White and Black Crappie, adult Bluegill swim speed data will be used as a surrogate for adult White Crappie. Adult sustained swim speed was reported at about 1.0 ft/s (Drucker and Lauder 1999; Deng et al. 2004). The burst swim speed of adult Bluegill was estimated at 4.3 ft/s, attained over a 9-second test period using high speed photography (Webb 1978). However, this speed was reported as a final velocity calculated from an acceleration rate and may represent a faster speed than might be estimated by more conventional test methods. Gardner et al. (2006) obtained a critical swim speed (subset of prolonged swim speed) of 1.22 ft/s over a period of 10 minutes. Applying Bell's percent criteria (1991) results in an estimated burst speed for adult Bluegill of 1.4-2.4 ft/s.

Juvenile White Crappie, 2.2 to 3.9 inches had swim speeds of 0.50 and 0.75 ft/s in tests. (Schuler 1968; King 1969). They noted that juvenile White Crappie behavior in the test apparatus suggested poor orientation to current as many fish drifted passively even in low velocities. They also noted that the swimming performance of a 3.1 inch long White Crappie was similar to the swimming performance of a 1.6 inch long Bluegill (Schuler 1968; King 1968). No burst speeds were reported in the study. Using Bell 1991 rule, burst speeds for juvenile White Crappie are between 0.58 and 0.90 ft/s.

[4] The data indicate that a fish's cruising speed level may be 15 to 20% of its darting speed level (Bell 1991).

Table 3.1-1: Life History and Habitat Summary

Target Species	Strategy	Preferred Habitat			Lake Habitat Orientation
		Adult	Juvenile	Spawning	
American Eel	Catadromous	Morph into silver eel phase for migration to ocean	Yellow phase: Wide variety of habitats; cover, substrate crevices, tributary streams	Oceanic	Benthic
Chain Pickerel	Resident	Wide variety of habitats provided cover, such as weed beds, sunken stumps, logs and other aquatic vegetation or natural cover sources is present	Same as adult	Areas with dense vegetation in calm, shallow water	Littoral
Largemouth Bass	Resident	Slow areas with pool/backwater habitat containing soft bottom, aquatic vegetation and cover, and clear water. May move deep in winter	Same as adult	Shallows, backwaters, or tributaries in areas with clean rocky or gravelly substrate	Littoral
White Crappie	Resident	areas with submerged trees, stumps, brush, boulders, and aquatic vegetation	Same as adult	nests over multiple substrates in river pools, bays, coves, and littoral areas near vegetation of reservoirs and lakes	Littoral

Table 3.2-1: Swim Speeds Summary

Fish Species	Fish Size (inches)	Prolonged Speed (ft/s)	Source	Burst Speed (ft/s)	Burst Speed Calculated by GSE using Bell 1991 rule[5]	Source
American Eel	14-21 (yellow)	1.4	Quintella et al. 2010	2.0-2.8	Yes	Bell, 1991
	12.5-27.5 (silver)	2.2	Quintella et al. 2010	3.1-4.4	Yes	Bell, 1991
Chain Pickerel[6]	6.5-14.9	4.8 – 6.9	Beamish 1987	5.5-8.3	Yes	Beamish 1987 and Bell 1991
	4.72	0.62-1.56	Peake 2008	0.71-1.79	Yes	Bell 1991
Largemouth Bass	8.4 – 8.8	1.9 – 2.9	Katopodis and Gervais (1991) Froese and Pauly (2016)	2.2 – 3.5	Yes	Bell 1991
	3.0 – 3.5	1.6	Katopodis and Gervais 1991	1.84 – 1.92	Yes	Bell 1991
White Crappie[7]	2.2 – 3.9	0.50 – 0.75	Schuler 1968; King 1969	0.58 – 0.90	Yes	Bell 1991
	Adult[8]	1.22	Gardner et al. 2006	1.4-2.4	Yes	Bell 1991

[5] The data indicate that a fish's cruising speed level may be 15 to 20% of its darting speed level (Bell 1991).
[6] Northern Pike swim speeds were used to represent Chain Pickerel
[7] Bluegill is a surrogate for adult White Crappie
[8] No numerical size range provided in the literature, just the use of "adult"

4 ENTRAINMENT ASSESSMENT

The potential for entrainment and estimates of survival were developed for the Normanskill Project qualitatively, using a literature-based approach. The entrainment assessment consists of comparing the various characteristics at the Project that could affect entrainment and survival with the behavior, life history and habitat preferences of the target species. Many field entrainment studies were conducted in the United States in the 1990s, as well as numerous studies to specifically estimate turbine passage survival (EPRI 1997). These data and results are useful for identifying common physical, environmental, and biological trends in entrainment that can be applied to this Project and the target species.

4.1 Potential for Fish Entrainment

4.1.1 Factors Affecting Entrainment Risk

Multiple factors influence entrainment potential. Typically, the risk of entrainment is based on the probability that an individual will encounter the intake based on habitat and life history traits relative to the location and configuration of the Project. Fish that are not expected to encounter the intake during their life cycle would not be expected to be at high risk for entrainment. Factors that affect the probability of encountering the intake include:

- Movement patterns of fish species. Fish that are sedentary or do not move long distances have a lower probability of encountering the intake compared with fish that tend to travel long distances. Movement patterns often include a seasonal component given the tendency of fish to perform life history functions (i.e. spawning) based on environmental cues that happen at specific times of the year, and potentially a diurnal component (i.e. nocturnal fish species).

- Habitat availability near the intake. The presence of suitable spawning, foraging, or wintering habitat near the intake would encourage fish to reside in the area near the intake. Conversely, if no suitable habitat is present there, the abundance of fish near the intake would be low and few fish would be at risk of encountering the intake.

- Project configuration. The design specifications of the project can influence whether certain fish would be susceptible to entrainment. Examples include trashracks that preclude certain size fish from entering the turbines, location of the intake (i.e. depth, distance from shore), and alternative passage routes.

- Project operations. Hydroelectric generation is not typically constant at a Project, and the amount of generation (and therefore intake flow) can vary by season and time of day. If fish encounter the intake during idle times of non-generation, there would be no entrainment risk at that time. Additionally, operation at partial capacity typically reduces the velocities near the intake and would result in greater chances of fish escaping entrainment.

4.1.2 EPRI Entrainment Data Relevant to the Normanskill Project

In 1997, EPRI compiled entrainment data from 43 hydroelectric sites. All studies in the database utilized full-flow tailrace netting, which according to EPRI is the most preferred entrainment study methodology as opposed to partial-flow tailrace netting, intake gallery netting, and/or hydroacoustics. The species, number, size of entrained fish, sampling period (hours), and turbine hydraulic capacity (cfs) were documented in the database. Information is available for approximately 140 species and 30 species groups.

Sites with similar characteristics and fish assemblages compared to the Project were identified. Criteria used in selection were total hydraulic capacity (capacity < 1,500 cfs), trashrack spacing (gap width > 1.5 and < 3 inches), reservoir area (area >300 and area <1,200 acres) and fish assemblage. Using these criteria, the list of entrainment studies selected for comparison to the Project was narrowed from 43 to five projects (Table 4.1.2-1).

4.1.2.1 Belding Project

The Belding Project is located on the Flat River in Michigan. According to EPRI, the total hydraulic capacity is 416 cfs with trashrack clear spacing of 2 inches. No average velocity at the trashrack is provided in the database.

The study collected 14,421.89 fish (adjusted for collection efficiency[9]) during approximately 3,251.1 hours of sampling from January to December. The dominant species entrained during the study were unidentified Pomoxis[10] species (n[11] = 2,457.84, 17.04%). They were collected from April to November and ranged in size from less than 2 inches to six inches. The majority of Pomoxis spp. were collected in July and were in the less than 2 inch size range.

Of the Normanskill target species, Largemouth Bass (n = 2,174.66, 15.08%) were collected. White Crappie are also a target species, but this specific study did not provide individual data for Black Crappie and White Crappie, instead they were grouped together under unidentified Pomoxis species. Largemouth Bass were collected from January to December. Collected fish ranged in size from less than 2 inches to 15 inches. Sixty percent of Largemouth Bass were collected in July (n = 1,305.1) and were less than 2 inches to 4 inches in length.

4.1.2.2 Caldron Falls Project

The Caldron Falls Project is located at river mile 70 on the Peshtigo River in Wisconsin. According to EPRI, the total hydraulic capacity is 1,300 cfs with trashrack clear spacing of 2 inches. No average velocity at the trashrack is provided in the database.

The study collected 12,298.26 fish (adjusted for collection efficiency) during approximately 2,160 hours of sampling from January to December. The dominant species entrained during the study were Yellow Perch (n=5,107.25) and Black Crappie (n = 3,408.58). The highest entrainment level for Yellow Perch was in April (34.5%). The majority of the Yellow Perch entrained in April were in the 4 to 6 inch size range. The highest entrainment level for Black Crappie was in September and October (48.1%). The majority of the Black Crappie entrained in September and October were in the 2 to 4 inch size range.

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[9] The EPRI database presents the data after it has been adjusted to account for collection efficiency of the sampling gear and other site specific data adjustments that were made for each study; therefore, the number of fish shown may not be a whole number.

[10] Pomoxis is the genus name for both Black and White Crappie species. Collected fish were not identified to species level in some cases.

[11] n= total number of a species collected

Of the Normanskill target species, Largemouth Bass (n = 310.52, 2.52%), and White Crappie (n = 8.17, 0.07%) were collected during the study.

Largemouth Bass were collected from April to August and in October. Collected fish ranged in size from less than 2 inches to 15 inches. Seventy five percent of Largemouth Bass were collected in July and ranged from less than 2 inches to 4 inches in length.

White Crappie were collected in January, May and June. Collected fish ranged in size from less than 2 inches to 8 inches in length. Sixty two percent of White Crappie were collected in June and ranged in size from 2 inches to 8 inches. No fish were collected in the 4 to 6 inch size range.

4.1.2.3 Johnsonville Project

The Johnsonville Project is located at river mile 13.3 on the Hoosic River in New York. The EPRI database lists the total hydraulic capacity as 1,288 cfs with a trashrack clear spacing of 2 inches. An average velocity at the trashrack is not provided.

The study collected 17,153.9 fish (adjusted for collection efficiency) during 1,646.8 hours of study from January to December. The dominant species collected were Black crappie (n = 8,019) and Spottail shiner (n = 3,221.3). Black crappie was collected from February to December and ranged in size from 0 to 15 inches. Black crappie entrainment was highest in August (n = 4,745.8) followed by November (n = 1,604.3). In both months, the majority of fish entrained were in the 2 to 4 inch size range. Spottail shiner were collected during all twelve months of study and ranged in size from 0 to 8 inches. The highest entrainment level occurred in August (n = 1,623.2) and the majority of collected fish were in the 2 to 4 inch size range.

Of the Normanskill target species Largemouth Bass (n = 695.5,4.05%), and White Crappie (n = 38.1, 0.22%) were collected during the study.

Largemouth Bass were collected in March and June to December. Collected fish ranged in size from less than 2 inches to 10 inches. Sixty five percent of Largemouth Bass were collected in November (n = 449.7) and ranged in size from 2 to 6 inches.

White Crappie were collected in March, November, and December. Collected fish ranged in size from 2 inches to 6 inches. Seventy percent of White Crappie were collected in November (n = 26.4).

4.1.2.4 Sandstone Rapids Project

The Sandstone Rapids Project is located at river mile 50 on the Peshtigo River in Wisconsin. The EPRI database lists the total hydraulic capacity as 1,300 cfs with a trashrack clear spacing of 1.75 inches. No average velocity at the trashrack is provided.

The study at Sandstone Rapids collected 16,595 fish (adjusted for collection efficiency) during 2,160 hours of sampling from January to December. The dominant species collected during the study was White Sucker (n = 5,407) (32.6%). White Sucker were collected during all months of study and ranged in size from 0 to 15 inches. The highest entrainment of White Sucker occurred in July (n = 4,218) and the majority of these fish were in the 0 to 2 inch size range.

Of the Normanskill target species Largemouth Bass (n = 2,523, 15.20%), Northern Pike, a surrogate species for Chain Pickerel, (n = 190, 1.14%), and White Crappie (n = 1, 0.01%) were collected.

Largemouth Bass were collected from July to October and in December. Collected fish ranged in size from less than 2 inches to 6 inches. Eighty nine percent of Largemouth Bass were collected in July (n = 2,257.0, 89.46%) and were less than 2 inches in size.

Northern Pike were collected in April and June to November. Collected fish ranged in size from 2 to 20 inches. Sixty six percent of Northern Pike were collected in July (n = 125) and most were in the 4 to 6 inch range.

One White Crappie was entrained in July and was less than 2 inches in size.

4.1.2.5 Luray Project

The Luray Project is located on the South Fork Shenandoah River in Virginia. The total hydraulic capacity is 1,477 cfs and the trashrack spacing is listed as 2.75 inches. No average velocity at the trashracks is provided.

The Luray Project conducted a specific entrainment study for American Eel. During 518.5 hours of sampling from September to December, 278.9 American Eels were collected. Collected eels ranged in size from 20 to greater than 30 inches. The majority of eels were collected in October (n = 105.3) and November (n = 126.3).

4.1.3 Entrainment Evaluation for Target Species

The EPRI entrainment data allows for the development of patterns that are useful in predicating the potential for entrainment of the target species at the Project. Results from these data can be applied to the Project and compared with life history and habitat traits from the literature.

4.1.3.1 American Eel

American Eel is a benthic species with an obligate fall outmigration to the ocean for spawning upon maturity. Based on the life history traits, with a benthic orientation and established home range during the yellow phase (juvenile), American Eels have a low probability of encountering the intake structure at the Project for the majority of the year. During the outmigration period, generally September through November, silver eels (adult phase) will out-migrate to the ocean at night. Obligate migrants will search for any route that will allow them to continue downstream and the probability of encountering the intake is high if the Project is generating during this time period. Historically, the Project generates approximately 37% of the nighttime[12] hours from September through November. The Project is offline for the remaining 63% of the nighttime hours from September through November. Figure 4.1.3-1 shows the generation flow duration for the eel outmigration season.

4.1.3.2 Chain Pickerel

Chain Pickerel are a cover-oriented ambush species that will utilize deeper waters on occasion. Northern Pike were used as a surrogate because Chain Pickerel were not found in the EPRI database. The majority were juvenile fish entrained in July which corresponds with dispersal from nursery/rearing areas to other habitat areas. During July, the Project is typically offline for approximately 18 days of the month, which reduces entrainment risk. Based on this life history

[12] Nighttime for this analysis is defined as 6pm to 6am.

information and lack of cover at the Project intake, Chain Pickerel have a low probability of encountering the intake.

4.1.3.3 Largemouth Bass

Largemouth Bass are a cover oriented littoral zone species. They were recorded as entrained at four of the EPRI database projects and with the exception of one project, the majority were entrained in July and were approximately 2 to 6 inches in size. This timeframe corresponds with dispersal from rearing and overwintering areas to other types of cover habitats, such as weed beds. For the majority of the year the probability of Largemouth Bass encountering the intake is low. During summer dispersal months (June-August), Largemouth Bass could encounter the intake at the Project, though the probability of them encountering the intake during generation at this time is low because the Project is typically offline during 52% of June, 71% of July, and 81% of August (see Appendix A). This would reduce entrainment risk for juvenile Largemouth Bass.

4.1.3.4 White Crappie

White Crappie are a littoral zone species that will migrate into open water areas and different portions of the water column, particularly during fall and over winter. Crappie were collected at three of the five EPRI projects in a variety of months and seasons. However, maximum entrainment catches were typically in the summer (i.e. July), or in the fall (September through November), depending on the Project. Due to the surface location of the intake structure, water column movements, and the movement to open water areas, White Crappie have a moderate probability of encountering the Project intake during generation, particularly during the fall when the Project has a greater likelihood of generating when compared to the summer.

4.1.4 Comparison of Swim Speeds to Calculated Intake Velocities

Figure 4.1.4-1 shows the velocity duration curve for Project generation that occurred between 1995 and 2018. These are the velocities that fish would have typically encountered during Project generation; note that the Project did not operate 45% of the time during this period, and fish could also encounter the intake area during idle periods when entrainment would not be possible (see Figure 2.4.1-1 for the full curve that also includes idle periods). Idle periods were not included in this portion of the assessment because the comparison of swim speeds to intake velocities is an assessment of the fish's capability of escaping intake velocities during generation, and is a separate issue from the probability of encountering the intake area. To compare fish swim speeds to intake velocities, the 25%, 50%, and 75% exceedance values during generation were chosen to represent what would occur during typical Project generation. The corresponding velocities are 0.95 ft/s, 1.54 ft/s, and 2.29 ft/s, respectively.

Figure 4.1.4-2 provides the prolonged and burst speeds for the adult target species compared to the representative intake velocities. Figure 4.1.4-3 provides the same information for the juvenile target species. There are two general scenarios to be considered when analyzing swim speeds and the calculated intake velocities with regard to the Project's intake configuration: 1) For fish that attempt to escape upon initially encountering the intake structure; 2) For fish that enter the intake structure, reach the trash racks inside, and attempt to escape.

Under the first scenario, fish could encounter the intake structure and avoid entering the structure. When the Project is generating, all adult target species possess burst speeds that exceed the representative intake velocities, and would be able to escape the entrance area to the intake, should they choose to do so. For the juvenile target species, yellow phase American Eel have burst speeds that would allow them to escape the intake at each of the representative intake velocities. However, juvenile Largemouth Bass and Chain Pickerel would not be able to escape the 25% exceedance velocity of 2.29 ft/s, though they could escape at velocities that occur more often (i.e. 50% and 75% exceedance values of 1.54 and 0.95 ft/s). Juvenile White Crappie do not have burst speeds that would exceed the intake velocity.

The first scenario assumes that fish would attempt to escape when encountering the outside of the intake structure. However, there is no rack structure or other physical barrier that would prevent fish from entering the intake structure, and fish may not attempt to escape until after they enter the structure and reach the trash racks, which are located inside. If a fish encountered the trashrack inside the intake structure and attempted to avoid entrainment by swimming back out of the intake structure, they would need to traverse at least 16.3 ft against the flow, and would need to pass through the highest velocities located at the intake gate. Depending on the water elevation and trajectory past the intake gate that fish choose to take, the total distance from the face of the intake structure to the current trashrack location ranges from 16.3 ft to 17.5 ft. Due to the complexity of escapement, an assessment of this scenario for each species is detailed in the subsections below.

4.1.4.1 American Eel

For adult American Eel (silver phase), the burst speed is 4.4 ft/s (assuming it can be maintained for 10 seconds). At the burst speed of 4.4 ft/s, needing to traverse 17.5 ft back to the reservoir, without fighting the intake velocity, it would take approximately 4 seconds to traverse from the trashrack back to the reservoir. At an intake velocity of 0.95 ft/s, it would take 5 seconds to traverse from the trashrack back to the reservoir, because headway speed[13] would be 3.45 ft/s. When intake velocities equal 1.54 ft/s, the headway speed would be 2.86 ft/s and it would take approximately 6 seconds to reach the reservoir. When intake velocities equal or exceed 2.29 ft/s, the headway speed would be 2.11 ft/s. At a headway speed of 2.11 ft/s, adult American Eels would be able to traverse the 17.5 ft distance in 8.3 seconds, assuming they could maintain their burst speed for 10 seconds. As such, adult American Eels could possess the swimming speeds to avoid entrainment and swim back upstream out of the intake structure during most conditions, should they choose to do so.

For juvenile American Eel (yellow phase), burst speed is 2.8 ft/s. At the burst speed of 2.8 ft/s (assuming the burst speed can be maintained for 10 seconds), headway speed is 1.85 ft/s when intake velocity is 0.95 ft/s. It would take approximately 9.5 seconds to reach the reservoir from the trashrack. When the intake velocity is equal to 1.54 ft/s, the headway speed would be 1.26 ft/s. It would take approximately 14 seconds to reach the reservoir. When intake velocities equal or exceed 1.54 ft/s, juvenile American Eels do not have swim speeds that would allow for escapement of the intake structure.

4.1.4.2 Chain Pickerel

For adult Chain Pickerel, the burst speed is 8.3 ft/s (assuming it can be maintained for 10 seconds). When intake velocities equal 0.95 ft/s, the headway speed is 7.35 ft/s. At this headway speed, it would take approximately 2.4 seconds to reach the reservoir. When intake velocities equal 1.54 ft/s, the headway speed would be 6.76 ft/s and it would take approximately 2.6 seconds to reach the reservoir. When intake velocities equal 2.29 ft/s, the headway speed would be 6.01 ft/s, and it would take approximately 3 seconds to reach the reservoir. Adult Chain Pickerel have swim speeds that would allow for escapement of the intake structure.

[13] Headway speed = burst speed – intake velocity

For juvenile Chain Pickerel (approximately 5 inches), the burst speed is 1.79 ft/s (assuming it can be maintained for 10 seconds). When the intake velocities equal 0.95 ft/s, headway speed is approximately 0.84 ft/s. It would take approximately 20.8 seconds to reach the reservoir from the trashrack. When intake velocities equal or exceed 0.95 ft/s, juvenile Chain Pickerel at approximately 5 inches in length would not have swim speeds that would allow for escapement of the intake structure.

4.1.4.3 Largemouth Bass

For adult Largemouth Bass, the burst speed is 3.5 ft/s (assuming it can be maintained for 10 seconds). When the intake velocity equals 0.95 ft/s, at the burst speed of 3.5 ft/s, the headway speed is approximately 2.55 ft/s. It would take approximately 7 seconds to reach the reservoir from the trashrack. When the intake velocity is equal to 1.54 ft/s, the headway speed would be 1.96 ft/s and it would take approximately 9 seconds to reach the reservoir. When the intake velocity equals 2.29 ft/s, the headway speed would be 1.21 ft/s and it would take approximately 14.5 seconds to reach the reservoir. When intake velocities reach 2.29 ft/s, adult Largemouth Bass do not have swim speeds that would allow for escapement of the intake structure.

For juvenile Largemouth Bass, the burst speed is 1.92 ft/s (assuming it can be maintained for 10 seconds). When the intake velocity equals 0.95 ft/s, the headway speed would be 0.97 ft/s. It would take approximately 18 seconds to travel from the trashrack back to the reservoir. When the intake velocity equals 1.54 ft/s, the headway speed would be 0.38 ft/s and it would take approximately 46 seconds to return to the reservoir. Juvenile Largemouth Bass do not have swim speeds that would allow for escapement of the intake structure when intake velocity equals or exceeds 0.95 ft/s.

4.1.4.4 White Crappie

Adult White Crappie have a burst speed of 2.4 ft/s (assuming it can be maintained for 10 seconds). When the intake velocity is equal to 0.95 ft/s, the headway speed would be 1.45 ft/s and it would take approximately 12 seconds to travel from the trashrack to the reservoir. When the intake velocity equals 1.54 ft/s, the headway speed would be 0.86 ft/s. It would take approximately 21 seconds to travel from the trashrack to the reservoir. When intake velocity equals or exceeds 0.95 ft/s, adult White Crappie do not have swim speeds that would allow for escapement from the intake structure.

Juvenile White Crappie have a burst speed of 0.90 ft/s. When the intake velocity is 0.95 ft/s, no headway speed would be made. They do not have swim speeds that would allow for escapement from the intake structure when the intake velocity equals or exceeds 0.95 ft/s.

4.1.5 Overall Potential for Entrainment

In general, the potential for entrainment is typically low to moderate at the Normanskill Project for most of the target species. Table 4.1.5-1 summarizes entrainment potential by species. There is a combination of factors that contribute to this, including:

- Species habitat preferences: Limited habitat is available in the intake area for most species and life stages, which reduces the chance of fish being attracted or taking up residence. White Crappie tend to have a higher probability of encountering the intake during generation due to their tendencies to use open-water areas more often than the other target species.

- Species life histories: Silver phase American Eel migrate downstream in the fall (September through November), which increases their entrainment risk during this time period. White Crappie, if dispersing during the fall, could also encounter the intake during generation. The other target species and life stages have a lower likelihood of encountering the intake during generation due to their non-migratory characteristics, their life history movements, and based on entrainment rates at other Projects.

- Potential for escapement: Higher intake velocities relative to adult and juvenile fish at the trashracks make it less likely for fish to escape entrainment. Additionally, the configuration of the intake structure reduces the probability of escapement because to escape, a fish would need to traverse a longer area against current when compared to avoiding the entrance to the intake initially.

- Project operations: When generating, the Project operates in a manner that provides an intake velocity of 1.54 ft/s or less approximately 50% of the time, and an intake velocity of 2.00 ft/s or less 37% of the time (Figure 4.1.4-1).

- Limited operation: On average, the Project is offline approximately 122 days per year (33%) (based on period of record, see Table 2.3-1). During these periods there is no risk of entrainment. Of the offline days, approximately 88 offline days occurred from June to October, with the most days offline typically occurring in August (22). Overall, on the basis of the annual velocity duration curve (Figure 2.4.1-1), the Project did not generate 45% of the time between 1995 and 2018.

- Alternative routes of passage: When the Project is operating at maximum capacity, a spill scenario typically occurs, which would provide an alternate route of passage. Other than spill events, there are no alternative routes of passage currently at the Project. This is primarily an issue for American Eel, which need to emigrate to the ocean to spawn.

Table 4.1.2-1: EPRI (1997) Project with Relevance to Normanskill

Site Name	State	River	Reservoir Area (acres)	Capacity (cfs)	Trashrack Spacing (in)	Target Fish Species Present	Relevance
Belding	MI	Flat	110	416	2	Largemouth Bass *Pomoxis spp*.	Similar capacity and trashrack spacing Fish collected included target species
Caldron Falls	WI	Peshtigo	1180	1.300	2	Largemouth Bass *Pomoxis spp*	Similar trashrack spacing Fell within the hydraulic capacity filter (Fish collected included target species
Johnsonville	NY	Hoosic	450	1,288	2	Largemouth Bass, White Crappie	Similar reservoir area and trashrack spacing Fish collected included target species Located in same watershed
Sandstone Rapids	WI	Peshtigo	150	1,300	1.75	Largemouth Bass, Northern Pike (Chain Pickerel Surrogate), White Crappie	Similar trashrack spacing and included target species not accounted for at other Projects
Luray	VA	SF Shenandoah	126	1,477	2.75	American Eel	Dedicated American Eel entrainment study

Table 4.1.5-1: Summary of Entrainment Potential at the Project

Species	Life Stage	Potential to Encounter the Intake During Generation	Entrainment Potential based on Swim Speed	Overall Entrainment Potential	Comments
American Eel	Adult	High	Low*	High	High from September through November due to obligate downstream migration
	Juvenile	Low	Moderate	Low - Moderate	Can only escape from inside of the intake when velocity is less than 1.54 ft/s
Chain Pickerel	Adult	Low	Low	Low	
	Juvenile	Low	Moderate	Low - Moderate	Can only escape from inside of the intake when velocity is less than 0.95 ft/s
Largemouth Bass	Adult	Low	Moderate	Low - Moderate	Can only escape from inside of the intake when velocity is less than 2.29 ft/s
	Juvenile	Low	Moderate	Low-Moderate	Most vulnerable during summer dispersal months (June – August), but generation is limited during this time. Can only escape from inside of the intake when velocity is less than 0.95 ft/s
White Crappie	Adult	Moderate	Moderate	Moderate	Can only escape from inside of the intake when velocity is less than 0.95 ft/s
	Juvenile	Moderate	High	Moderate - High	Most vulnerable in summer and fall during dispersal; generation would be limited during summer, but would be more likely to occur during the fall.

**Though American Eel have swimming speeds to escape intake velocities, they may not attempt to escape due to their behavioral migration downstream.*

Figure 4.1.3-1: Generation Flow Duration Curve for the American Eel Migration Season (6 PM–6 AM September–November, 1995-2018)

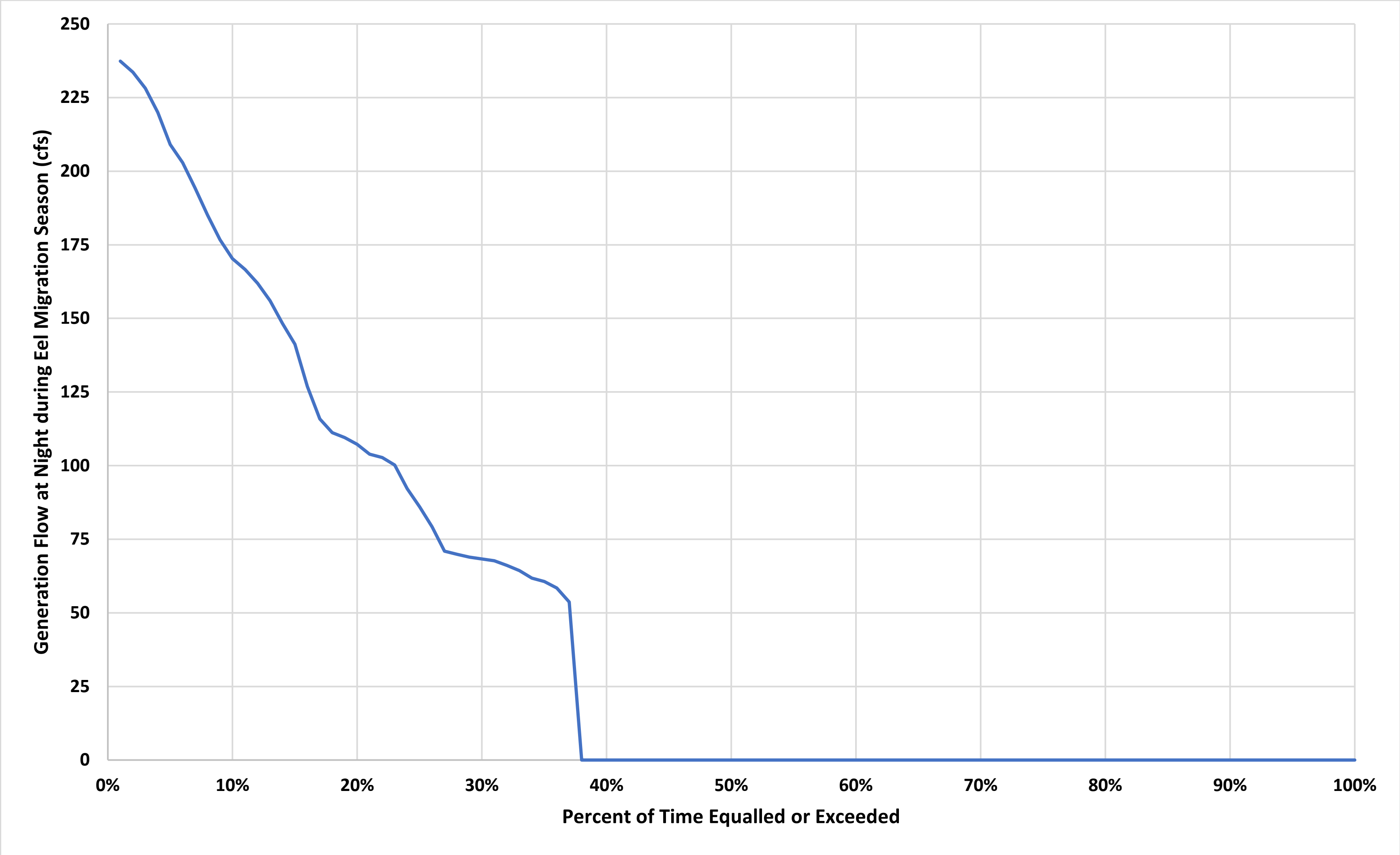


Figure 4.1.4-1: Annual Calculated Intake Velocity When Generating Duration Curve (1995-2018)

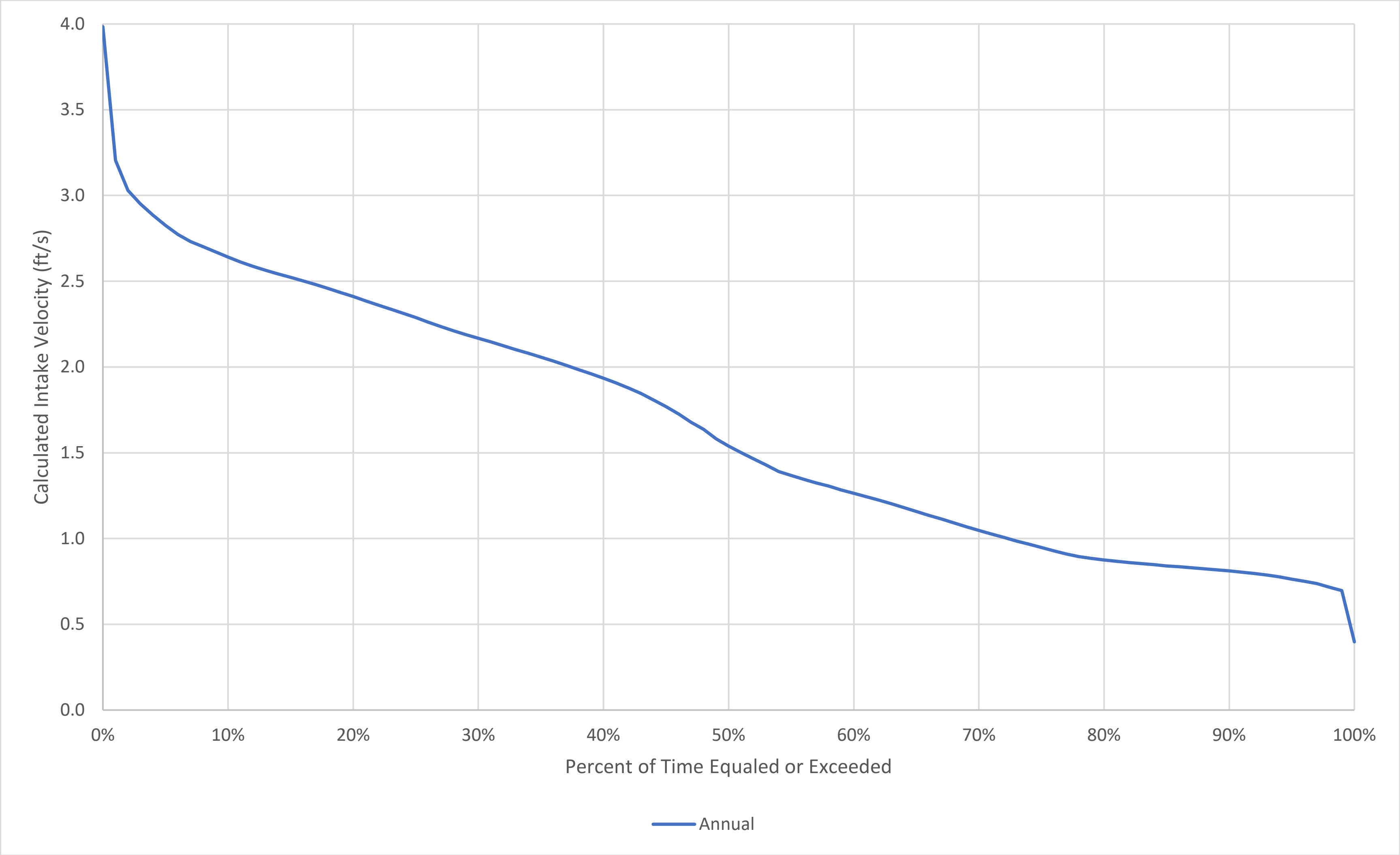
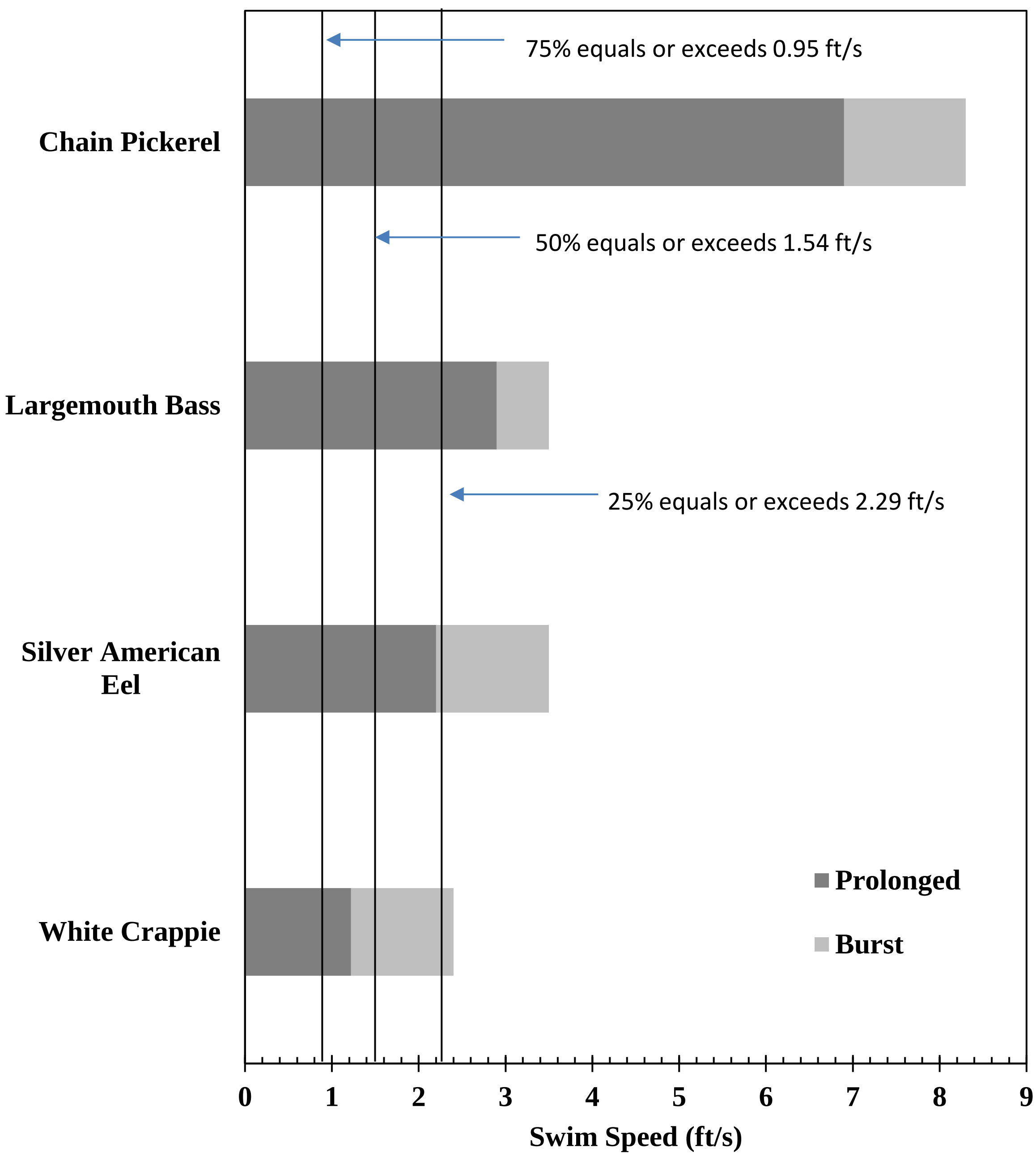
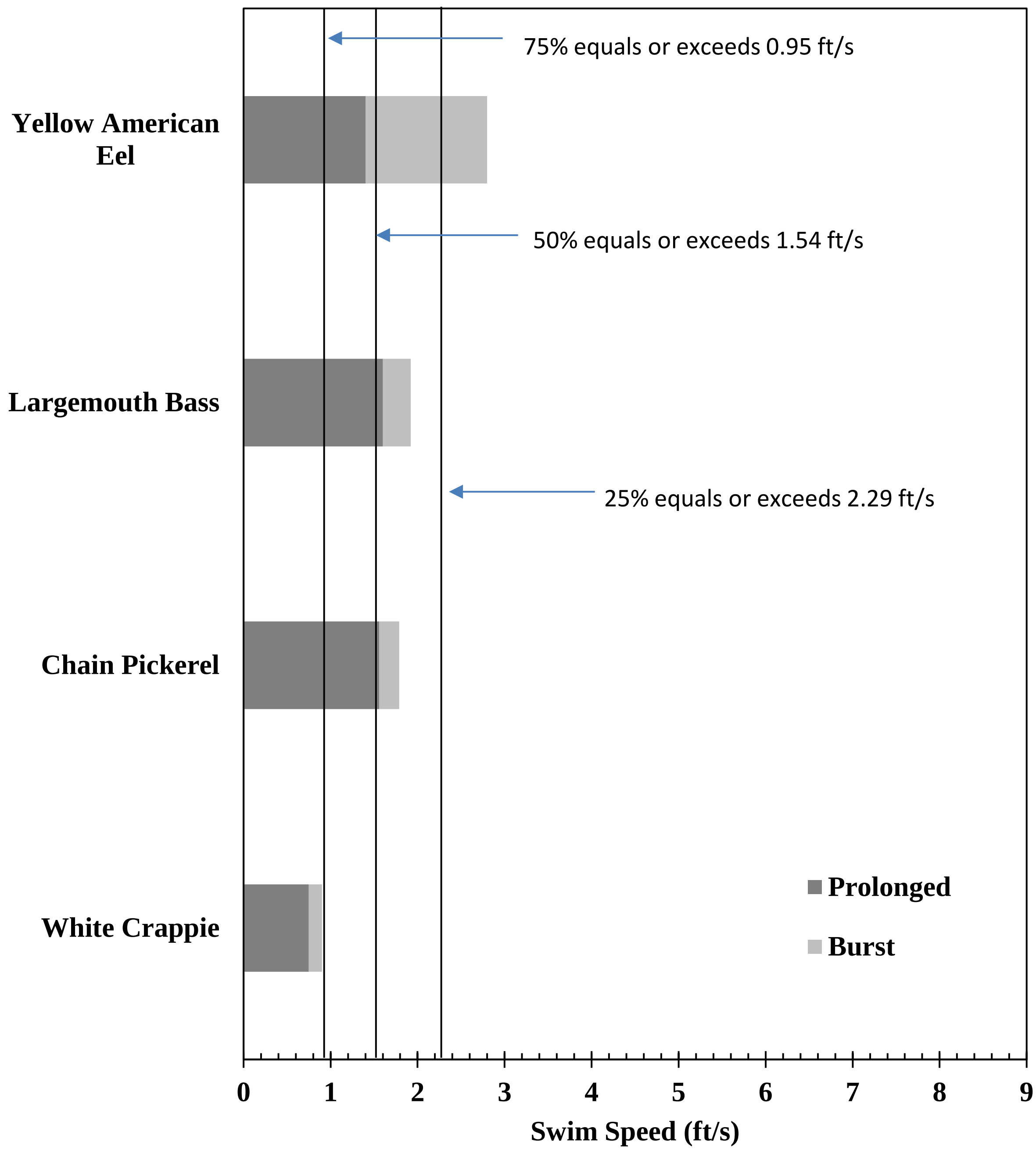


Figure 4.1.4-2: Comparison of Swimming Speeds of Target Species (adult) relative to Calculated Intake Velocities When Generating.[14]



[14] Exceedance intake velocity values shown pertain only to when the Project is generating and does not include idle periods.

Figure 4.1.4-3: Comparison of Swimming Speeds of Target Species (juvenile) relative to Calculated Intake Velocities When Generating.[15]



[15] Exceedance intake velocity values shown pertain only to when the Project is generating, and does not include idle periods.

4.2 Survival

4.2.1 Impingement

Impingement refers to the involuntary contact and entrapment of fish on the surface of an intake protection device due to approach velocities exceeding swimming capability. The likelihood of a fish to become impinged rather than entrained is a function of the spacing between the bars on an intake structure, as well as the size and body shape of the fish.

To determine the potential for the fish species in the Project impoundment to become impinged, the correlation between fish size and bar rack spacing was investigated. The estimated length of each species that would be physically excluded by the trashrack spacing was determined by using proportional measurements for each species that was reported by Smith (1985). These proportional measurements were used to calculate a scaling factor of body width to total length (i.e. scaling factor = width/total length) for each species, which in turn was used to estimate the total length of each species that would be physically excluded by the 2-inch trashrack spacing interval.

Estimated sizes of fish that would be physically excluded by the present rack configuration (2-inch clear spacing) are provided in Table 4.2.1-1. For example, any Largemouth Bass less than 15 inches long would be able to physically pass through the 2-inch spacing, while those greater than 15 inches long would be excluded.

Another important factor in the impingement potential of a fish is the approach velocity at the intake structure and the burst speed of the fish. Fish whose total lengths are greater than those listed in Table 4.2.1-1 are susceptible to impingement only if they are unable to escape the velocities associated with each intake structure. The burst swim speeds presented in Figure 4.1.4-2 for the adult American Eel, Chain Pickerel, and Largemouth Bass are greater than the calculated approach velocities at the Project. While White Crappie do not have a burst speed that would exceed the calculated approach velocities at the Project, the New York State Freshwater Fishing Records lists the record White Crappie as 18.5 inches in length which would still pass through the current 2 inch trashracks at the Project. Impingement at the Project is currently expected to be low due to the size of fish that can pass through the trashracks and the adult burst swim speeds. Impingement risks would increase if the trashrack size is decreased.

Table 4.2.1-1: Estimated Total Length (Inches) of Target Species that would be Physically Excluded by the Project Trashracks.

Common Name	Scaling Factor[16]	Size Excluded By 2" Racks (Current Rack Spacing)	Size Excluded By 1" Racks	Size Excluded By 3/4" Racks
American Eel	0.04	53	27	20
Chain Pickerel	0.09	23	11	9
Largemouth Bass	0.13	15	7	6
White Crappie	0.09	23	12	9

[16] The scaling factor is developed from Body Width/Total Length. Body width is developed from Standard Length *(Body Width Proportion/100). Total Length is developed from Standard Length*(Total Length Proportion/100). Standard Lengths are from Smith, 1985.

4.2.2 Field Studies and EPRI Data

Winchell et al. (2000) summarized turbine passage survival data reported in the EPRI (1997) database by turbine type and characteristics and fish size. To estimate survival of fish that may be entrained and passed through the turbines at the Project, mortality studies conducted at hydropower facilities with similar turbine types were examined. The survival rates reported were based on field tests at sites with axial-flow (i.e. propeller and Kaplan[17]) turbines per size class of test fish that met specific acceptability criteria for control fish mortality (could not exceed 10%).

Data are reproduced herein for high speed (>300 rpm) propeller and Kaplan type turbines to examine general trends (Table 4.2.2-1). The speed of the Watervliet turbine is 600 rpm. The survival rates are reported for all species combined, irrespective of local site conditions. The survival trend among the reviewed studies of turbines was higher survival for a variety of size classes of fish. Based on survival tests of fish less than 8 inches in length through high speed axial-flow turbines in the EPRI database, mean immediate survival estimates ranged between 78.0 % and 81.3%. No 48-hour survival data was presented.

Table 4.2.2-1: Immediate Fish Survival Rates for Kaplan Turbines (>300 rpm)

Turbine Type	Runner Speed (rpm)	Hydraulic Capacity (cfs)	Fish Size (inches)	N[18]	Minimum	Maximum	Mean
Axial flow	> 300	530	< 3.94	1	81.3 %	81.3%	81.3%
Axial flow	>300	530	3.94 – 7.83	1	78.0%	78.0%	78.0%

Source: Winchell et al., 2000.

4.2.3 Franke Formula

An additional analysis of turbine survival was made using the formula developed by Franke et al. (1997). The formula grew out of efforts by the Department of Energy (DOE) to design more "fish-friendly" turbines. The formula developed by Franke et al. (1997) to estimate survival through a Kaplan turbine and used to predict survival at the Kaplan turbine at the Project is:

$$P = \lambda\left[\frac{N * L}{D}\right]\left[\frac{\cos\alpha_a}{8Q_{\omega d}} + \frac{\sin\alpha_a}{\pi\frac{r}{R}}\right]$$

$$S = 1 - P$$

where,

P = probability of strike,

λ = strike mortality correlation factor,

[17] See Section 2.2.1.1 for explanation of the similarities between tube-type and Kaplan turbines.

[18] Number of turbines for which survival estimates are available.

N = number of turbine runner blades,
L = fish length,
D = maximum turbine runner diameter,
α_a = angle to axial of absolute flow upstream of turbine runner,
$Q_{\omega d}$ = discharge coefficient ($Q/\omega D^3$),
ω = rotational speed (rpm x $2\pi/60$),
R = turbine runner radius,
r = turbine runner radius at point fish enters turbine, and
S = survival probability.

The formula calculates the probability (P) of blade strike by relating such turbine parameters as the number of buckets or blades, runner diameter, and runner height to fish length and operating condition (see Table 2.2.1-1 for turbine parameters). The formula does not consider whether the turbine blades were blunt or sharp. Fish length and available passage space are the principal drivers of the output. For the tube turbines at the Project, three points of entry to the turbine, from hub to tip of blade, were selected. Since the turbine efficiency was unknown, two operating conditions were considered to establish a mortality range: a turbine efficiency rate of 80% and a turbine efficiency rate of 90%. The correlation factor (λ) accounts for variability in strike potential and also to relate the output to empirical data available from the Franke study. The value of λ at 0.2 was determined by Franke et al. (1997) from Kaplan survival tests. Although the formula calculates a probability, in the present context it is more conventionally used in the formula Survival (S) = 1 – P, with results expressed as a survival percentage. In developing the formula, Franke et al. (1997) considered previous works that calculated turbine strike probability and new information developed by the authors. Existing empirical data were used to validate the model for conventional hydro projects. A thorough discussion of the derivation and application of the formulas is provided in Franke et al. (1997).

Using a turbine efficiency rating of 80% (Table 4.2.3-1), the survival of a fish less than eight inches in length ranged from 77.2% to 97.1%. For a fish eight to twelve inches in length, survival rates ranged from 65.8% to 77.2%. For fish twelve to twenty-four inches in length, survival rates ranged from 31.5% to 65.8%.

Using a turbine efficiency rating of 90% (Table 4.2.3-2), the survival of a fish less than eight inches in length ranged from 78.0% to 97.2%. For a fish eight to twelve inches in length, survival rates ranged from 66.9% to 78.0%. For fish twelve to twenty-four inches in length, survival rates ranged from 33.9% to 66.9%.

Table 4.2.3-1: Predicted Turbine Survival at 80% Efficiency

Fish Length (ft)	Survival Estimate (%)			
	Point of Entry from Hub Center (ft)			Average
	0.56	1.22	1.88	
1	96.6%	97.3%	97.6%	97.1%
2	93.1%	94.7%	95.1%	94.3%
3	89.7%	92.0%	92.7%	91.4%
4	86.2%	89.3%	90.2%	88.6%
5	82.8%	86.6%	87.8%	85.7%
6	79.4%	84.0%	85.3%	82.9%
7	75.9%	81.3%	82.9%	80.0%
8	72.5%	78.6%	80.4%	77.2%
9	69.0%	75.9%	78.0%	74.3%
10	65.6%	73.3%	75.6%	71.5%
11	62.1%	70.6%	73.1%	68.6%
12	58.7%	67.9%	70.7%	65.8%
13	55.3%	65.2%	68.2%	62.9%
14	51.8%	62.6%	65.8%	60.1%
15	48.4%	59.9%	63.3%	57.2%
16	44.9%	57.2%	60.9%	54.3%
17	41.5%	54.5%	58.4%	51.5%
18	38.1%	51.9%	56.0%	48.6%
19	34.6%	49.2%	53.6%	45.8%
20	31.2%	46.5%	51.1%	42.9%
21	27.7%	43.8%	48.7%	40.1%
22	24.3%	41.2%	46.2%	37.2%
23	20.9%	38.5%	43.8%	34.4%
24	17.4%	35.8%	41.3%	31.5%
25	14.0%	33.1%	38.9%	28.7%
26	10.5%	30.5%	36.4%	25.8%
27	7.1%	27.8%	34.0%	23.0%
28	3.6%	25.1%	31.6%	20.1%
29	0.2%	22.4%	29.1%	17.3%
30	0.0%	19.8%	26.7%	15.5%
31	0.0%	17.1%	24.2%	13.8%
32	0.0%	14.4%	21.8%	12.1%
33	0.0%	11.7%	19.3%	10.4%
34	0.0%	9.1%	16.9%	8.7%
35	0.0%	6.4%	14.5%	6.9%
36	0.0%	3.7%	12.0%	5.2%

Source: Based on Blade Strike Formula Developed by Franke et al. (1997).

Table 4.2.3-2: Predicted Turbine Survival at 90% Efficiency

Fish Length (ft)	Survival Estimate (%)			
	Point of Entry from Hub Center (ft)			Average
	0.56	1.22	1.88	
1	96.6%	97.4%	97.7%	97.2%
2	93.3%	94.9%	95.3%	94.5%
3	89.9%	92.3%	93.0%	91.7%
4	86.5%	89.7%	90.7%	89.0%
5	83.1%	87.2%	88.4%	86.2%
6	79.8%	84.6%	86.0%	83.5%
7	76.4%	82.0%	83.7%	80.7%
8	73.0%	79.5%	81.4%	78.0%
9	69.7%	76.9%	79.1%	75.2%
10	66.3%	74.3%	76.7%	72.4%
11	62.9%	71.8%	74.4%	69.7%
12	59.5%	69.2%	72.1%	66.9%
13	56.2%	66.6%	69.8%	64.2%
14	52.8%	64.1%	67.4%	61.4%
15	49.4%	61.5%	65.1%	58.7%
16	46.1%	58.9%	62.8%	55.9%
17	42.7%	56.4%	60.5%	53.2%
18	39.3%	53.8%	58.1%	50.4%
19	35.9%	51.2%	55.8%	47.7%
20	32.6%	48.6%	53.5%	44.9%
21	29.2%	46.1%	51.1%	42.1%
22	25.8%	43.5%	48.8%	39.4%
23	22.5%	40.9%	46.5%	36.6%
24	19.1%	38.4%	44.2%	33.9%
25	15.7%	35.8%	41.8%	31.1%
26	12.4%	33.2%	39.5%	28.4%
27	9.0%	30.7%	37.2%	25.6%
28	5.6%	28.1%	34.9%	22.9%
29	2.2%	25.5%	32.5%	20.1%
30	-1.1%	23.0%	30.2%	17.3%
31	-4.5%	20.4%	27.9%	14.6%
32	-7.9%	17.8%	25.6%	11.8%
33	-11.2%	15.3%	23.2%	9.1%
34	-14.6%	12.7%	20.9%	6.3%
35	-18.0%	10.1%	18.6%	3.6%
36	-21.4%	7.6%	16.2%	0.8%

Source: Based on Blade Strike Formula Developed by Franke et al. (1997).

4.3 Entrainment and Survival Conclusions

Based on the target species investigated for this study, some entrainment is anticipated for some species and life stages. However, given that adult Largemouth Bass and Chain Pickerel possess swimming capabilities that should allow them to escape the intake most of the time, the overall impact to populations of these species is likely to be low. Additionally, survival of small adult and juvenile fish that are entrained is likely to be high. Entrained fish that survive could move downstream and take up residence elsewhere, such as in the Hudson River. Under the current project configuration, impingement of adult fish on the trashracks is low when intake velocities are less than 1.54 ft/s, due to the current 2.0 inch spacing and the swimming capabilities of adult fish that are large enough to become impinged.

Due to the Project intake configuration, the risks of entrainment and impingement are greatest when intake velocities exceed 1.54 ft/s which occur 27% of the time. Additionally, intake velocities exceed the USFWS guidelines of 2.00 ft/s only 20% of the time. These estimates and exceedance probabilities of intake velocities are also conservative because they assume that these fish would encounter the intake during Project generation. Because the Project does not generate for extended periods, especially during the warmer months when many warmwater fish may be active and moving, the probability of fish encountering velocities that would result in entrainment are considerably lower than if the Project generated most or all of the time.

The primary concern for entrainment at the Project is for American Eel. Silver phase American Eels have a high overall entrainment potential at the Project because they need to emigrate downstream to reach their spawning areas in the ocean and successfully complete their life cycle. If no spill is occurring when an emigrating eel encountered the Project during generation, they would likely seek passage through the intake and turbines. Adult eels are relatively long and have a higher likelihood of injury or mortality than the other target species due to turbine blade strike. Additionally, emigrating American Eels could become delayed at the Project if no generation or spill is occurring when they encounter the Project dam.

5 DOWNSTREAM FISH PASSAGE AND PROTECTION

Formal downstream fish passage facilities do not currently exist at the Project. Downstream fish passage can occur via the dam spillway when spill flows are occurring or through the Project turbines when the facility is generating.

Design of downstream fish passage facilities requires careful consideration of the life history and life stage of fish of interest at the Project as well as physical variables of the project. This section provides an overview of downstream fish passage and protection measures and discusses the measures evaluated with potential applicability to the Normanskill Project.

5.1 Current Condition

The current condition at the Normanskill Project includes the existing 2.0-inch clear spaced trashracks. The existing intake configuration would allow some resident fish to become entrained, should they enter the intake area. Additionally, adult silver-phase American Eel encountering the dam during their downstream emigration to the ocean would likely be entrained if the Project was generating and little to no spill was occurring; also, these fish could become delayed should they encounter no routes of flow passing downstream (as occurs at this Project due to its use as a water supply dam).

5.2 Fish Protection Technologies

The main types of downstream fish protection technologies, categorized by mode of protection, include: fish diversion systems, physical barriers, and behavioral guidance devices. Each category contains a subset of systems and technologies with varying degrees of applicability to the Normanskill Project. Both diversion systems and physical barriers create a boundary that guide fish into a bypass. Behavioral deterrents operate by altering or taking advantage of the natural behavior patterns of fish to direct them towards the bypass and/or away from the intake. As an overview, current technologies are listed below.

- Diversion Systems
  - Angled Screens
  - Angled Bar Racks
  - Louvers
  - Guide Walls
  - Eicher Screen
  - Modular Inclined Screen
- Physical Barriers
  - Narrow Trashracks
  - Barrier Net
- Behavior Guidance
  - Sound
  - Lights
  - Air Bubble Curtains
  - Electric Fields
- Operational - Seasonal or Diel Shutdowns combined with Alternate Route of Egress

5.2.1 Target Species-Specific Measures

The target species evaluated at the Project include American Eel, Chain Pickerel, Largemouth Bass, and White Crappie; juvenile White Crappie and juvenile Largemouth Bass, along with adult White Crappie, had the greatest potential out of all resident species and life stages to become entrained. With the exception of American Eel, the other species with potential for entrainment are considered resident, non-migratory fish and are grouped together with regard to fish protection technologies. Summaries of fish protection measures for eels and resident fish are described below.

American Eel

General downstream migratory behaviors of American Eel as outlined by Towler (2014) include:

- Movements primarily at night
- Occupy all depths during migration
- Tend to follow dominant flows
- Reactive to some physical, visual, chemical, and sound stimuli
- Environmental conditions can initiate, suspend or terminate downstream migration
- Late summer, Fall, and possibly Spring movements of silver phase; primarily during rain events/high flows

Angled bar racks may be used as a guidance device to a safe passage route (i.e., bypass) for downstream migrating eels. The bar rack should be installed at no greater than 45 degrees to the flow field and spacing should be a maximum of ¾ inches for adult American Eel. Angled bar racks must be frequently checked and cleaned of debris. While research involving physical barriers such as bar racks or louvers has demonstrated guidance potential, high costs may limit their utility to small river systems and small projects (EPRI 2001).

Behavioral barriers such as light, sound, and bubble screens are considered experimental and have not shown consistent performance in guiding American Eel (Towler 2014).

Operational alternatives such as nightly project shutdowns can be effective at passing eels provided an alternative egress (e.g., spillway, bypass) is available. The lost revenues during project shutdown, however, typically make this an unattractive mitigation approach. Furthermore, determining the project shutdown period can be difficult because existing migration models do not accurately predict when pulses of migrants may pass any individual hydroelectric facility (EPRI 2001). One cue for downstream migration is precipitation events that typically result in higher flows.

Resident Species/Generic Requirements

According to the USFWS, most hydroelectric projects relicensed in New York since the early 1990s now have 1”-clear-spaced trashracks or similarly-effective fish protection measures in place and most have some form of downstream passage route for fish.

5.2.2 Applicability of Measures and Technologies to the Project

The fish protection and downstream passage measures listed above were evaluated for applicability to the Normanskill Project, considering its configuration and the target fish species. Certain protection measures may be ruled out of consideration for application at the Project and the reasons are listed below. In general, guidance measures that attempt to divert downstream-migrating fish at the Project would only apply to American Eel.

- Angled screen– target species for these devices are typically out-migrating salmonids (e.g. American Eel), would require specialized cleaning systems and may be hindered by debris.

- Eicher screen - Eicher screens are used at hydroelectric facilities with penstocks. These screens pivot between two positions around a pivot point in the middle of the screen. When the screen is tilted upstream it prevents fish from being sent through the turbine and towards a bypass system instead. To clean the screen it can be tilted in the downstream direction but will not necessarily prevent fish from entrainment or going through the turbine. The configuration of the Project would call for significant modification in order for this technology to be installed.

- Modular Inclined Screen are typically located downstream from a trashrack structure and lead to a bypass for directing diverted fish to a transport pipe. The configuration of the Project would call for significant modification in order for this technology to be installed.

- Barrier nets are most effective under low velocity conditions and without heavy debris floating in the water, so they are not suitable for implementation at the Normanskill Project given issues with water chestnut (*Trapa natans*).

- Guide walls are typically surface-oriented and would likely need to be coupled with an alternate route of egress outside of the intake area. Given the intake configuration in a reservoir and toward the center of the dam, locations to anchor guide walls are not likely to be present.

- Behavior measures – While installation would be feasible at the Project, these technologies have had limited success for reducing entrainment of the target species. Behavioral barriers such as light, sound, and bubble screens are considered experimental and have not shown consistent performance in guiding American Eels (Towler 2014). Some behavioral measures such as lights may also attract some resident fish.

- Electrical fields do not appear to be a viable option for preventing downstream entrainment at hydroelectric facilities. Fish are not able to detect and avoid the electric fields before entering them. Sensitivities of fish to electrical fields are highly variable and more sensitive species may be immobilized. Immobilized fish may then be drawn further into the area of concern where they may be killed or passively entrained.

Certain technologies may be feasible at the Project should additional protection and downstream passage measures be needed. These are discussed below.

5.2.2.1 Narrowly-Spaced Trashracks

To prevent fish, including eels, from being trapped between the high velocities at the existing intake gate and the existing intake trashracks narrowly-spaced trash racks could be fitted upstream of the existing stoplog slot as shown in Figure 5.2.2.1-1 and Figure 5.2.2.1-2. This configuration would be advantageous over placing narrow-spaced trashracks or trashrack overlays on the existing rack within the intake structure because it would prevent fish entry into the intake structure. Narrowly-spaced trash racks placed inside of the intake structure at the current trash rack location would result in increased impingement.

The net cross-sectional area of trashracks at the upstream end of the intake structure would be approximately 71.8[19] square feet. Velocities through the proposed trashracks would be approximately 3.34 fps at maximum generation and 0.84 fps at minimum generation. Headlosses through the proposed trashracks would be approximately 0.18 ft at maximum generation.

The existing trashracks are cleaned approximately six times per year. The debris primarily consists of aquatic vegetation and is cleared by laborers with hand tools from the top of the intake tower above and around the existing trash sluice. The same cleaning procedure would be proposed for the conceptual, smaller-spaced trashracks; although, the narrowly-spaced racks would likely require additional cleanings each year compared to current practices at the site.

The existing trash racks have a trash sluice upstream of them which is used to clear debris from the intake. The trash is then swept out the side of the intake tower through a hole in the concrete wall. To avoid raking the debris twice and using the existing trash sluice a second trash sluice could be added just upstream of the stop log slot and above the high pond elevation (el. 262 feet). The proposed trash sluice would be similar in size to the existing sluice and function similarly.

Resident fish would be protected by encountering the proposed racks at the intake entrance and avoid the area, rather than entering the intake structure as they may do given the current intake configuration. However, given the limited anticipated effects of entrainment on resident fish at the Project, it may be most beneficial to focus narrow-spaced trashrack efforts on eels. This could include seasonal installation of narrow trash racks, targeting the downstream passage season for eels. Adult eels would be excluded from entrainment, but would still need to be provided with a route of passage downstream so that they can continue their emigration and complete their life cycle.

An alternative to installing narrowly spaced trashracks at the upstream end of the intake would be to install overlays over the existing trashracks. This alternative would likely increase impingement and would not prohibit fish from being trapped near the overlay as the flow velocity barrier through the slide gate area would remain. To provide fish passage from this area a hole through the concrete intake tower wall similar to the existing sluice would need to be constructed in conjunction with a flume and plunge pool system similar to the concept discussed in Section 5.3. Using the existing sluice as an exit would be difficult as the sluice is higher than the normal pond elevation.

[19] Area and velocity calculations include an assumption that 15% of the trashracks could be blocked by debris/vegetation.

Figure 5.2.2.1-1: Conceptual Forward-Positioned Trash Racks – Plan View

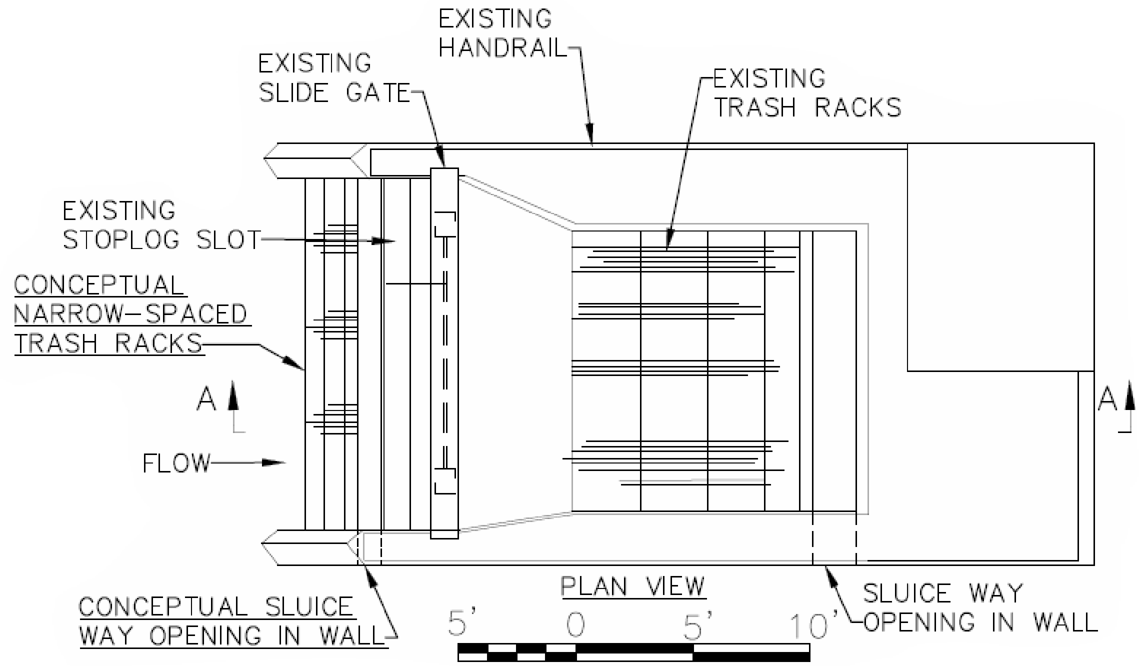
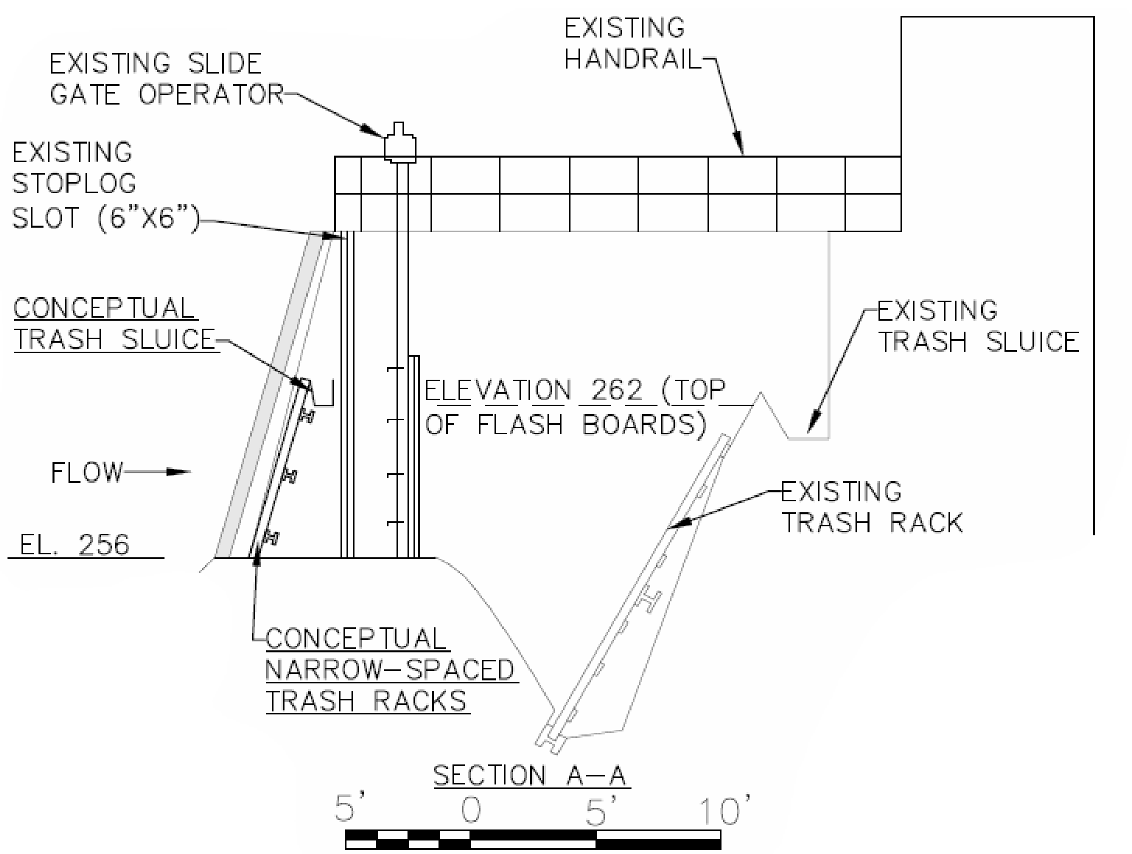


Figure 5.2.2.1-2 Conceptual Forward-Positioned Trash Racks – Section View



5.2.2.2 Operational Shutdown

Operational shutdowns could be effective in reducing entrainment of American Eels. It would be most effective for this species and life stage because emigration typically peaks with defined seasonality and is often correlated with rain events and increases in river flow. Their migration also occurs primarily at night. If no spill is occurring at the Project during eel emigration, and shutdowns are performed, a route of passage would be necessary for them to pass downstream through the Project.

5.3 Downstream Fish Passage

The design of downstream fish passage facilities varies with site-specific characteristics and the timing and movement of the fish of interest. Typically, these systems consist of four primary components (USFWS 2017):

- Physical exclusion/behavioral guidance (discussed in Section 5.2 above)
- Bypass openings (e.g., weir, chute, sluice, or orifice)
- Conveyance structure
- Receiving pool (e.g., plunge pool)

Downstream fish passage measures relevant to the Project configuration and target species are evaluated below.

5.3.1 **Downstream Eel Passage**

An alternative to provide downstream passage for eels would be to install a system similar to the one established at the Eel Weir project (FERC No. 2984) in Maine. The facility consists of four main components: a z-shaped intake structure, a conveyance conduit, a transition tank, and a discharge hose/conduit (see Figure 5.3.1-1 and Figure 5.3.1-2).

The z-shaped intake structure consisting of an approximately 6-inch conduit with 2.5-inch diameter holes would be attached to the upstream dam face below the minimum pond elevation during eel passage season. These small holes in the conduit would prevent other resident fish species from entering the conduit. Similar systems were designed to pass 250 – 400 GPM (0.56 to 0.89 cfs) to maintain velocities less than 5 fps. In the Downstream Flow Study, a hydrologic analysis demonstrated that a baseflow of 1 cfs could be provided downstream (or through the conceptual eel passage conduit) without significantly impacting the water supply (GSE 2019).

The conduit would be attached to the outside of the intake structure. The conduit would wrap its way around the intake structure to its downstream face until it discharged into a transition tank. The transition tank would maintain a constant water elevation to operate the siphon conduit. The tank would also provide a location to view or inspect eels passing through. From the transition tank a small diameter, non-pressurized hose or conduit would provide eels with passage into the water at the toe of the dam. Flows and velocities through the siphon could be controlled by a valve at the transition tank. The transition tank could include a camera system inside which would allow others to remotely check and see if eels were being passed and to see if the system is operating properly or if it is dry.

Maintenance of this system would require monitoring the area around the intake to check for debris build-up around the inlet conduit. The conduit would have many small openings although there is the potential that some are clogged with debris. The inlet should be located at a depth where floating debris would not impact flows into the inlet. Other maintenance issues include the potential replacement of parts of the conduit system (including but not limited to the pipe, flow control valve, or the transition tank) and restarting or priming the siphon for operation if the water level in the reservoir gets too low.

Engineering considerations for such a design include 1) where the final location of the transition tank could be to ensure access to the tank can be achieved, 2) what elevation the intake will placed at, 3) headlosses within the siphon conduit, 4) how to minimize debris and the potential for clogging, 5) if or should the flow control valve at the tank be controlled automatically, and 6) determine which route will minimize the number of bends in the system.

Figure 5.3.1-1 – Conceptual Downstream Eel Passage Siphon Conduit – Plan View

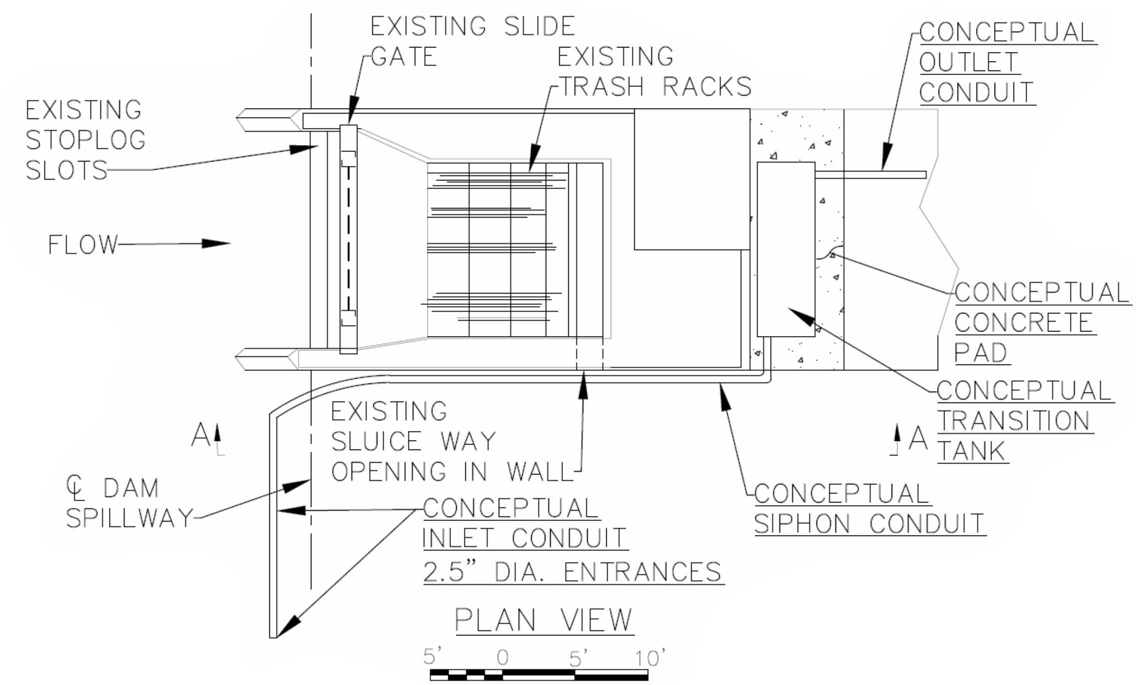
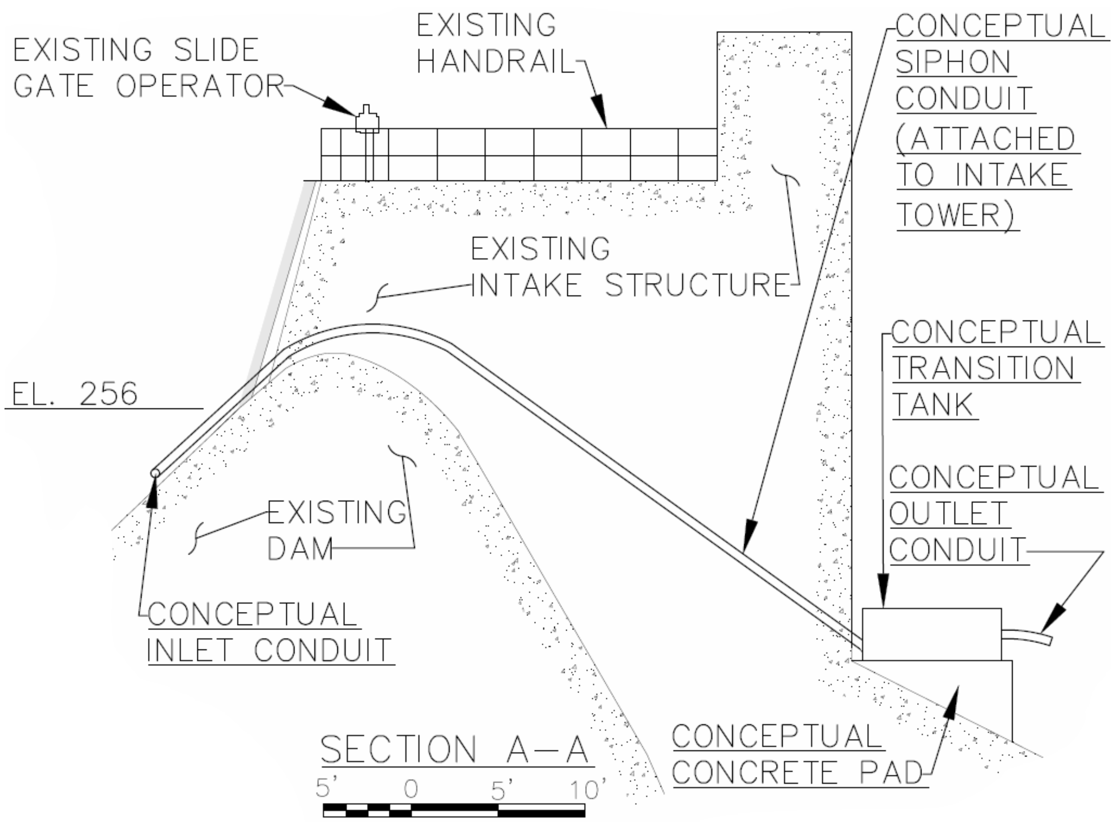


Figure 5.3.1-2 – Conceptual Downstream Eel Passage Siphon Conduit – Section View



5.3.2 Open Channel Sluice/Flume and Plunge Pool

An open channel flume or sluice could be installed near the intake tower to provide a generic means for downstream passage. This alternative would require removing a portion of the flashboards along the crest of the dam to create a notch. This would provide flow for downstream passage. This opening in the flashboards would potentially allow eels as well as larger, resident fish species to pass downstream of the dam (see Figure 5.3.2-1 and Figure 5.3.2-2).

The USFWS has engineering guidelines (2017) associated with downstream fish bypasses and plunge pools; relevant criteria include:

- The downstream bypass should pass a minimum of 5% of station hydraulic capacity or 25 cfs, whichever is larger. At the Project, 5% of the total existing station capacity of 240 cfs equals 12 cfs. Therefore, a downstream bypass flow of 25 cfs (16.2 MGD) would be needed to meet the USFWS criteria. However, a memo prepared by Gomez and Sullivan in March 2018 summarizes that withdrawing 10 cfs (0.65 MGD) could drastically lower the reservoir level and limit the amount of water available for the municipalities that depend on the reservoir for water supply. Therefore, there is not enough water for this fish passage solution. A smaller opening that provides considerably less water may be feasible.

- Bypasses must discharge into safe receiving waters that minimize exposure to predation.

- Plunge pool depth should be equal to 25% of the fall height or 4 feet, whichever is greater. The vertical drop from the flashboard crest (262 feet) to the water surface elevation of the pool at the toe of the dam (225 feet) at the Project is 37 feet; therefore, the plunge pool depth required would be 9.25 feet. Because of the presence of bedrock, a plunge pool would need to be built up from the bottom of the streambed. It is anticipated that 9.25 foot concrete walls would be required to establish the required plunge pool depth. Conceptual sketches are presented in Figure 5.3.2-1 and Figure 5.3.2-2 below.

- According to the USFWS design criteria (2017) when conveying fish downstream, any fish bypass flume should maintain a flow depth of 1 foot or two body depths of the largest fish, whichever is greater. For Largemouth Bass – the largest recorded fish in New York State of 25.5 inches would not meet these criteria since its body depth would be approximately 6.5 inches requiring 13" of flow depth. A Largemouth Bass up to 24 inches total length (6 inch body depth) would meet the 2 times body depth requirement. Individuals of the target species found in at the Project are likely much smaller in length compared to the state record fish. The largest White Crappie caught was 18.5 inches which would have a body depth of 4.8 inches requiring 9.6 inches of flow depth. The length for the state record Chain Pickerel was not recorded. Therefore, a minimum depth of 12" of water through any conceptual downstream fishway would be considered sufficient for the purposes of the alternatives analysis discussed below.

One concern with this fish passage alternative is that, during periods when the pond elevation is higher than 261 feet, more flow will be passed through the opening in the flashboards. A sliding gate or an equivalent technology may be required to properly manage the amount of flow being passed through the opening.

An option for egress from the flashboard opening would be to construct a plunge pool for fish to drop into. A steel supported structure would be constructed to extend a flume/sluice from the opening in the flashboards over the plunge pool. It is anticipated that the plunge pool would need to be built up with concrete walls approximately 9.25 feet high based on the USFWS criteria discussed above. A notch in the downstream concrete wall would provide passage for fish from the plunge pool into the river or a transition pool if required.

Note that providing flows in excess of 1 cfs (0.65 MGD) for fish passage would be incompatible with the current operations of the municipal water supply system and the hydropower facility as it would significantly lower the reservoir level as described in a March 2018 memo prepared by Gomez and Sullivan which analyzed a flow of 10 cfs. Water availability for hydropower generation is currently limited by the water supply demand for the City of Watervliet and the Town of Guilderland . A small flume could be installed to limit the release of flows through it to 1 cfs but it would have to be configured to only pass flows when the pond elevation was at its maximum. Consequentially the flume would likely be very narrow, it would be inoperable throughout portions of the year and maintaining adequate depth through the flume would be an issue. Therefore, this downstream fish passage alternative is not recommended.

Figure 5.3.2-1 – Conceptual Open Channel Sluice/Flume and Plunge Pool – Plan View

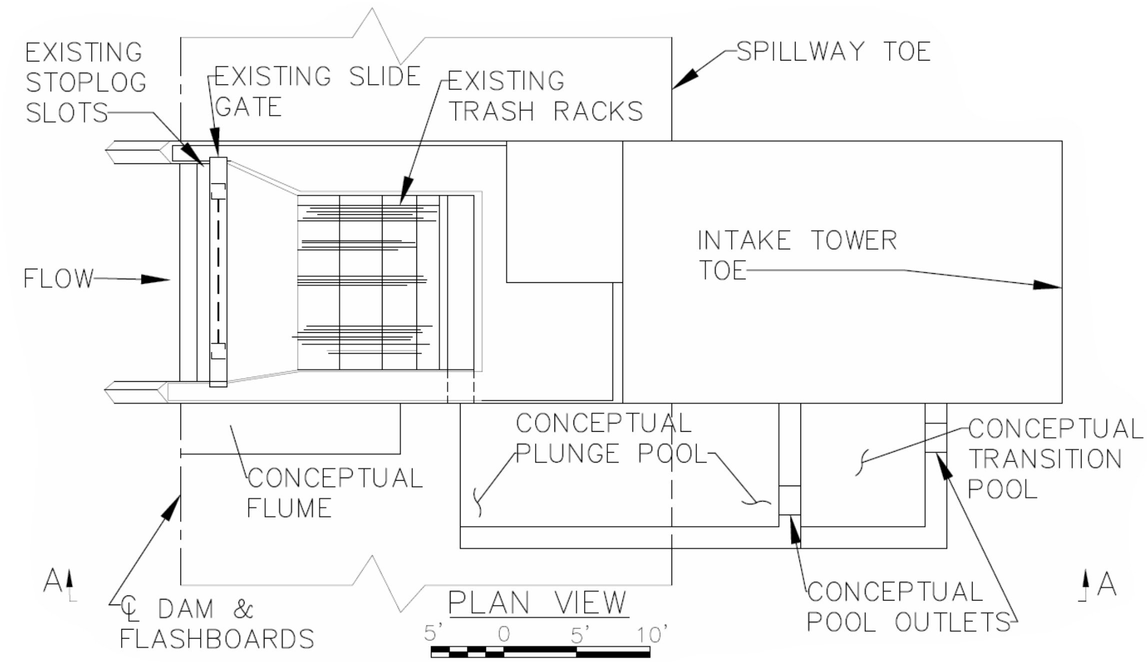
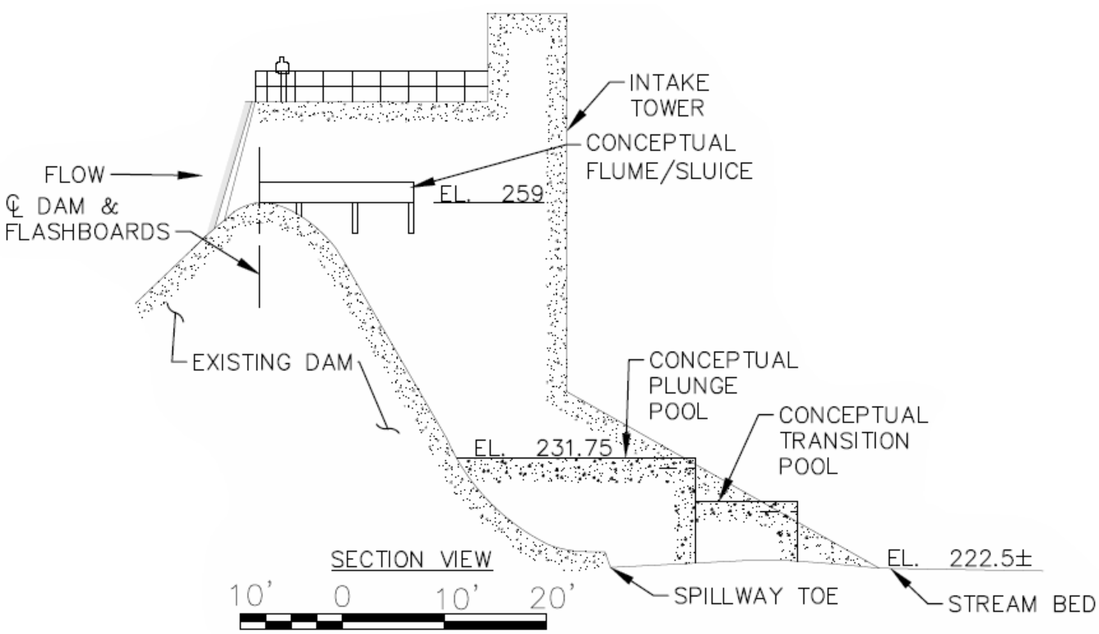


Figure 5.3.2-2 – Conceptual Open Channel Sluice/Flume and Plunge Pool – Section View



5.4 Potential Feasible Fish Passage and Protection Combination Options

Based on the information presented above, there are four potentially-feasible combinations to consider at the Project with regard to downstream fish protection and passage (Table 5.4-1). These options vary in the target species they would be meant to protect and/or pass downstream, and vary in levels of engineering needs, anticipated costs, and potential benefits and issues.

Table 5.4-1: Summary of Fish Protection and Passage Combinations with Potential Feasibility at the Project

Fish Protection and Passage Measures - Combinations	Species Benefitted by Protection Measures	Species with Downstream Passage	Anticipated Costs	Potential Benefits	Potential Issues
Forward-Positioned Narrow-Spaced Trashracks and Downstream Eel Passage System	Resident Fish and American Eel	American Eel	• Design, engineering, and installation of trashracks • Increased maintenance of trashracks • Some loss of revenue due to headloss and flow requirements for fish passage • Design, engineering, and installation of eel passage system • Maintenance of eel passage system	• Allows resident fish to escape the intake area and stay in the reservoir • Provides targeted passage for American Eel	• Continued moderate levels of entrainment of some resident fish such as adult White Crappie and juvenile Largemouth Bass
Forward-Positioned Narrow-Spaced Trashracks and Open Channel Sluice/Flume and Plunge Pool	Resident Fish and American Eel	Resident Fish and American Eel	• Design, engineering, and installation of trashracks • Increased maintenance of trashracks • Some loss of revenue due to headloss and flow requirements for fish passage • Design, engineering, and installation of sluice/flume and plunge pool • Considerable flow requirements that would affect water supply	• Allows resident fish to escape the intake area and stay in the reservoir • Could provide downstream passage for all species	• Due to water supply limitations, the flow passed via a sluice/flume would be limited to considerably less flow and depth and USFWS guidelines, which could hinder the effectiveness of this alternative
Project Shutdowns and Downstream Eel Passage System	American Eel	American Eel	• Loss of revenue due to Project shutdown during fall flow events and flow requirements for fish passage • Design, engineering, and installation of eel passage system • Maintenance of eel passage system	• Prevents entrainment of the bulk of the migrating population of eels • Provides targeted passage for American Eel	• Continued moderate levels of entrainment of some resident fish such as adult White Crappie and juvenile Largemouth Bass
Project Shutdowns and Open Channel Sluice/Flume and Plunge Pool	American Eel	Resident Fish and American Eel	• Loss of revenue due to Project shutdown during fall flow events and flow requirements for fish passage • Design, engineering, and installation of sluice/flume and plunge pool • Considerable flow requirements that would affect water supply	• Prevents entrainment of the bulk of the migrating population of eels • Could provide downstream passage for all species	• Due to water supply limitations, the flow passed via a sluice/flume would be limited to considerably less flow and depth and USFWS guidelines, which could hinder the effectiveness of this alternative

6 DOWNSTREAM FISH PASSAGE AND PROTECTION STUDY SUMMARY

Given the results of the entrainment and survival portion of the study, the current Project intake configuration could result in entrainment for some species and life stages of target resident fish, though the overall impacts on resident fish populations is predicted to be relatively low because the Project does not operate for extended periods, and often does not operate at full hydraulic capacity. The greatest entrainment potential is for emigrating silver-phase American Eel, which would be more likely to follow the flow than attempt to escape. Additionally, the dam's primary use as a water supply often results in little to no downstream flow during some time periods, which could delay emigrating American Eels when no water is flowing from the project and could result in their entrainment if spill at the Project is limited while the Project is generating during their emigration period.

Providing a physical barrier to entrainment at the Project would benefit both American Eel and resident fish species. Therefore, if prevention of entrainment of resident species that are susceptible to entrainment (i.e. White Crappie and juvenile Largemouth Bass) is deemed necessary, installation of a physical barrier such as narrowly-spaced trash racks at the forward end of the intake structure would provide benefits for these species, along with American Eel. However, if the limited effects on resident fish species populations is not a considerable concern to resource agencies, then it may be beneficial to focus on measures to prevent entrainment of American Eel. Potential alternatives for preventing entrainment of American Eel include seasonal physical barriers (i.e. narrowly-spaced trash racks installed for the eel emigration period) or targeted Project shutdowns that could occur when adult American Eel are known to emigrate (i.e. at night in the fall, primarily during and after rain events).

Providing routes of passage, specifically for American Eel, will also be important at the Project. Though development of an open-channel sluice/flume and plunge pool was identified as a potentially-feasible solution at the Project that could be used to pass a variety of species, its effectiveness would be highly limited by water availability and reservoir levels at the Project. As such, downstream passage efforts that focus on emigrating American Eel would likely provide the most benefit. Passage structures for American Eel that have been developed at other projects typically would require less water to operate than a traditional downstream bypass, which is very important at this water supply reservoir. Additionally, the design and construction would typically consist of metal and piping rather than involving extensive concrete-work and excavation that a sluice/flume and plunge pool would require.

In general, the information provided in this report is a starting point for the City and relicensing stakeholders to begin discussions regarding potential PM&E measures at the Project with regard to downstream fish passage and protection.

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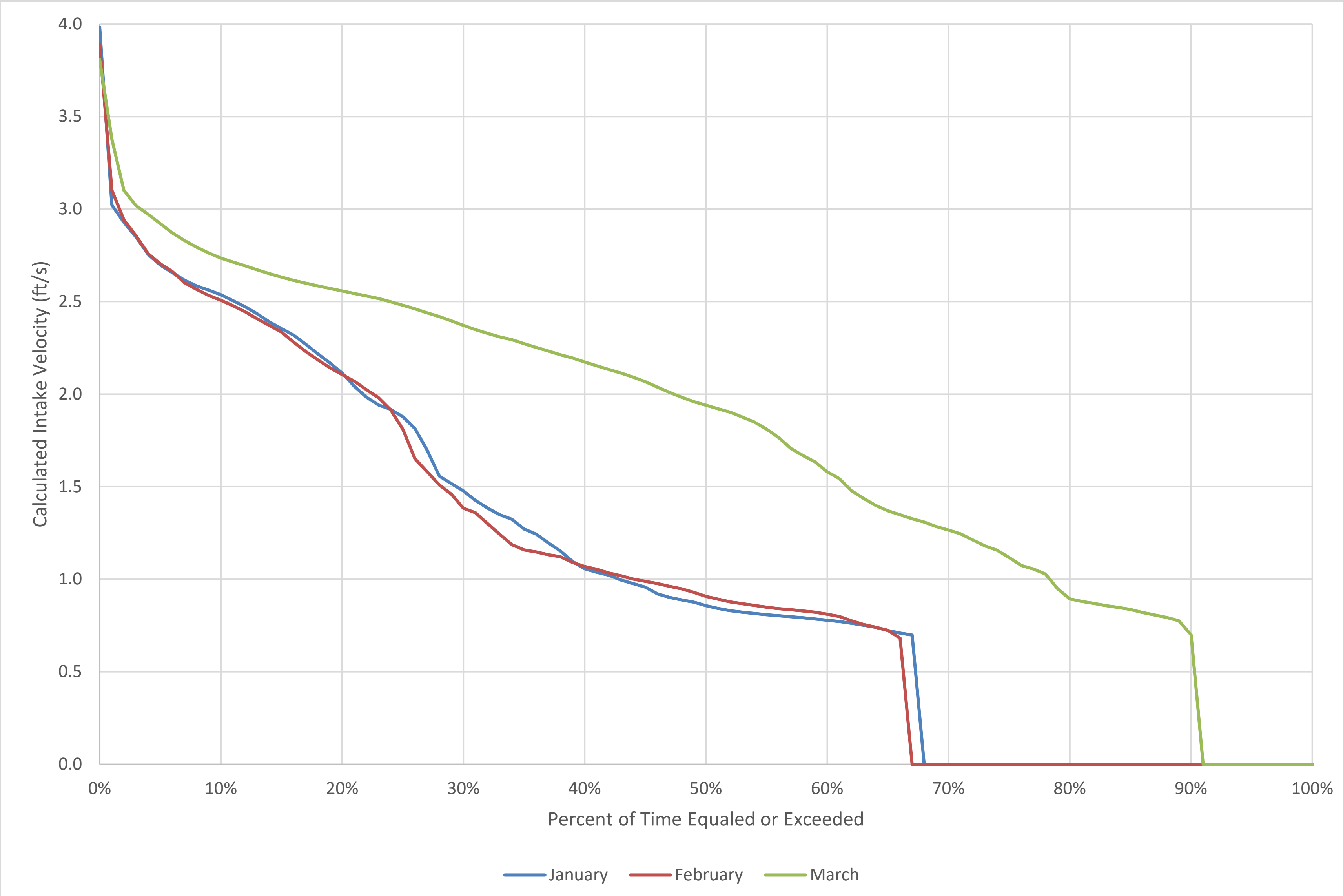
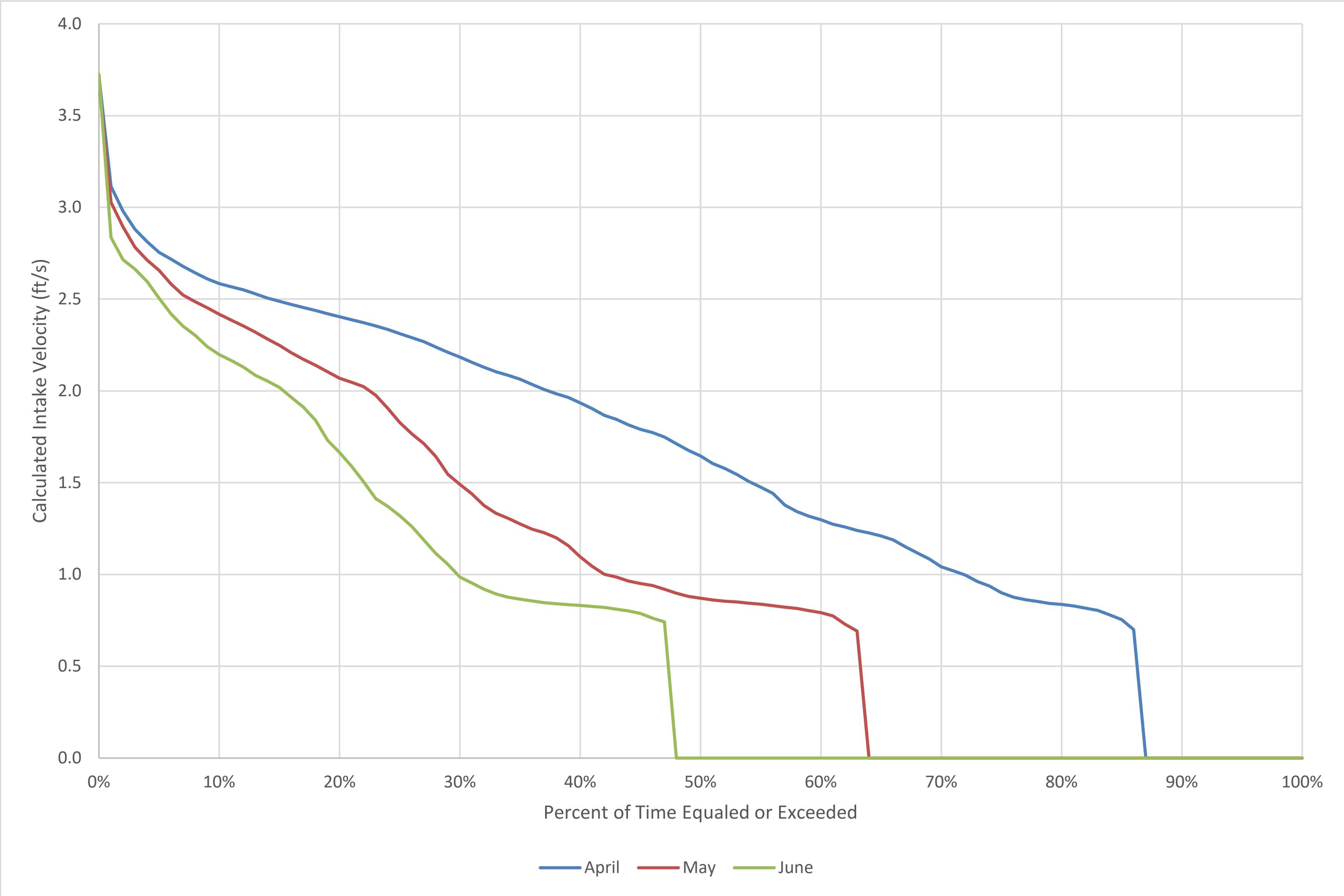
APPENDIX A: MONTHLY CALCULATED INTAKE VELOCITIES

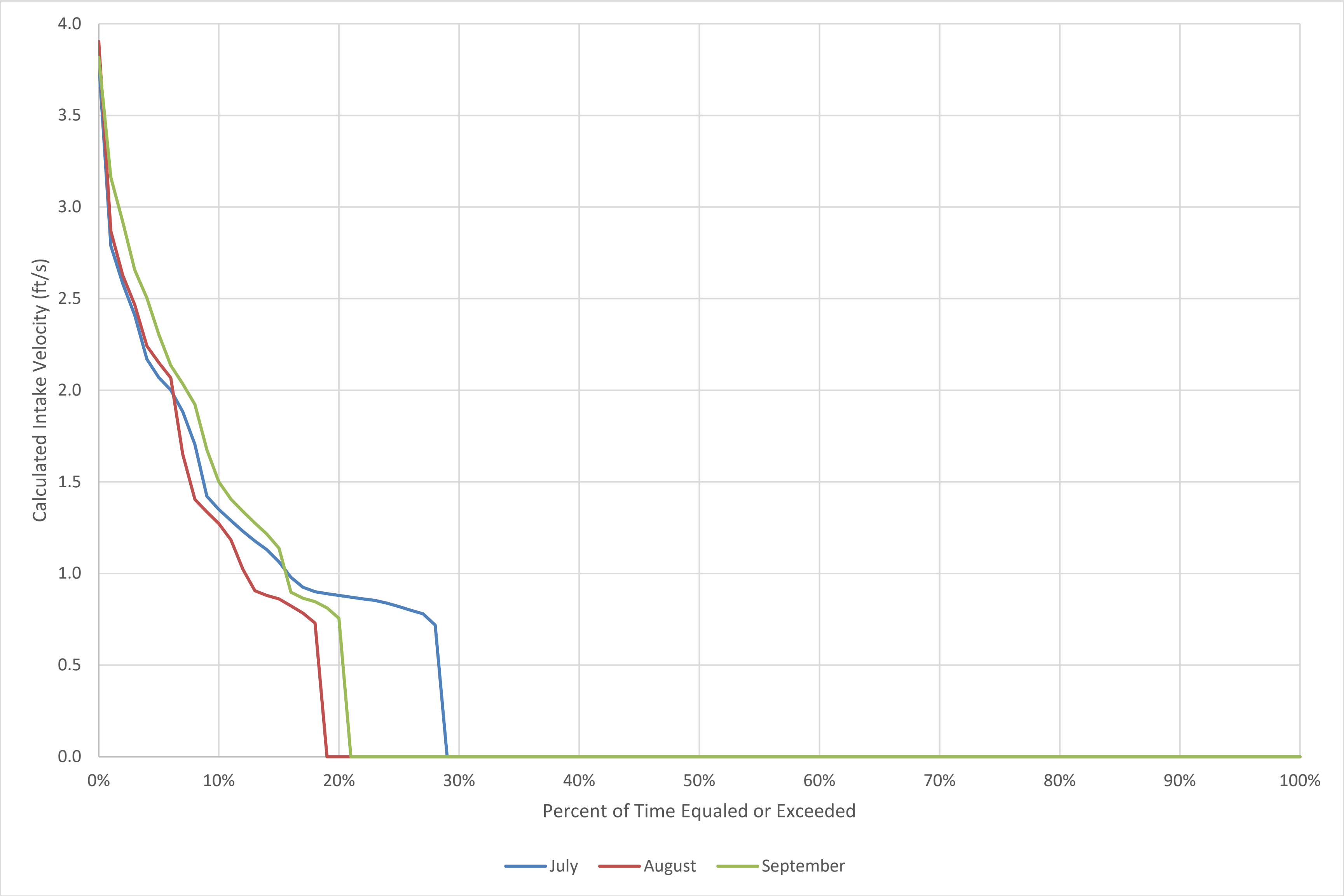
Appendix A-1: January, February, March Intake Velocity Duration Curve (1995-2018)



Appendix A-2: April, May June Intake Velocity Duration Curve (1995-2018)



Appendix A-3: July, August, September Intake Velocity Duration Curve (1995-2018)



Appendix A-4: October, November, December Intake Velocity Duration Curve (1995-2018)