FISH ENTRAINMENT AND TURBINE PASSAGE SURVIVAL ASSESSMENT

WEST CANADA CREEK HYDROELECTRIC PROJECT
FERC NO. 2701-NY

Prepared for:

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DEFINITIONS OF TERMS, ACRONYMS, AND ABBREVIATIONS

Brookfield	Brookfield Renewable
cfs	cubic feet per second
Commission	Federal Energy Regulatory Commission
Erie or Licensee	Erie Boulevard Hydropower, L.P.
FERC	Federal Energy Regulatory Commission
ft	foot/feet
ILP	Integrated Licensing Process
MW	Megawatts
NYSDEC	New York State Department of Environmental Conservation
PAD	Pre-Application Document
Project	FERC Project No. 2701, West Canada Creek Project
Project Area	The area within the FERC project boundary
Project Vicinity	The general geographic area in which the Project is located; the towns of Trenton and Prospect, New York
RSP	Revised Study Plan
SPD	Study Plan Determination
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

1.0 INTRODUCTION

Erie Boulevard Hydropower, L.P. (Erie or Licensee), a Brookfield Renewable company (Brookfield), is the Licensee, owner, and operator of the existing West Canada Creek Hydroelectric Project (FERC Project No. 2701) (Project). The West Canada Creek Project consists of two developments, Prospect and Trenton, and is located on West Canada Creek in Oneida and Herkimer counties, New York. A detailed description of the Project is provided in the Pre-Application Document (PAD) (Erie 2018).

The Federal Energy Regulatory Commission (FERC or Commission) issued the current license for the Project on March 18, 1983, which expires February 28, 2023. Erie is pursuing a new license under FERC's Integrated Licensing Process (ILP) and intends to file an application for a new license with FERC before February 28, 2021. On December 11, 2018, Erie filed a Revised Study Plan (RSP), and on March 7, 2019, FERC issued the Study Plan Determination (SPD) approving the RSP with modifications. On October 31, 2019, Erie requested a revision of the Process Plan and Schedule, and on December 5, 2019, FERC granted this revision to change the Initial Study Report (ISR) filing date to March 7, 2020, to align with one year following the issuance of FERC’s SPD.

As part of the study implementation and in accordance with FERC’s SPD, Erie initiated consultation with agencies regarding aspects of the Project’s relicensing studies. FERC identified specific topics for consultation with the U.S. Fish and Wildlife Service (USFWS) and New York State Department of Environmental Consultation (NYSDEC) regarding the Aquatic Mesohabitat Assessment, Macroinvertebrate and Mussel Surveys, Fish Assemblage Assessment, and Fish Entrainment and Turbine Passage Survival Assessment studies. Accordingly, Erie conducted consultation calls with USFWS and NYSDEC on April 18, 2019, July 16, 2019, and August 9, 2019. Documentation of this consultation was provided in the Study Progress Reports filed with FERC and distributed to the stakeholders on July 29, 2019, and October 31, 2019.

This report describes the methods and results of the Fish Entrainment and Turbine Passage Survival Assessment for the Prospect and Trenton developments. The purpose of the Fish Entrainment and Turbine Passage Survival Assessment is to assess the potential effects of Project operations on fish entrainment and turbine strike mortality.

2.0 METHODOLOGY

2.1 STUDY AREA

As proposed in the RSP, the study area consists of the Prospect and Trenton impoundments and the Prospect power canal.

2.2 DATA COLLECTION

Kleinschmidt conducted a literature review of species of interest, identified site specific data (intake depth, location and velocities, and generating unit characteristics and hydraulic capacities), and conducted an estimate of entrainment and turbine passage survival. In addition, Kleinschmidt reviewed data collected from the Fish Assemblage Assessment (Kleinschmidt 2020d) including species occurrence, distribution, and relative abundance. FERC recommended in the SPD that Erie provide an analysis or discussion of potential impingement effects based on trash rack spacing, intake velocities, size of fish species present in the impoundment, and swimming speeds of these species. In addition, FERC recommended that Erie describe its goals and methods for collecting site-specific data (e.g., intake velocity) and provide this information to USFWS and NYSDEC so that the agencies may provide comments and recommendations prior to conducting the study. Accordingly, Erie consulted with USFWS and NYSDEC on April 18, 2019, as documented in Study Progress Report 1, filed July 29, 2019.

2.3 DATA ANALYSIS

Estimates of entrainment and the rate of mortality from turbine stressors are provided with equations that predict the probability of a leading-edge turbine strike (Franke et al. 1997). The blade strike equations use turbine parameters specific to each development. The blade strike model allows for the manipulation of parameters such as fish size or turbine characteristics to determine the relative effect on turbine passage survival. This predictive model is based on the work of Von Raben (Bell 1981). Franke et al. (1997) refined the Von Raben model to consider the effect of tangential projection of the fish length on blade strike probability, as a large percentage of entrainment mortality is caused by fish striking a turbine blade or some other turbine component.

A correlation factor is utilized in the Advanced Hydro Turbine model to adjust the predictive model results to correspond with documented empirical data. This correlation factor was originally introduced by Von Raben (cited by Bell 1981) because the contact of a fish with a turbine component does not always result in injury or mortality (Bell 1981; Cada 1998). Therefore, Von Raben introduced the correlation factor to adjust the predicted turbine strike results to more closely match empirical results. The correlation factor is necessary because not all strikes lead to death, and not all mortality is due to blade strike. This factor also extends the applicability of these predictive equations to all injury mechanisms related to the variable parameters. As stated in Franke et al. (1997) "*such mechanisms could include mechanical mechanisms such as leading-edge strike and gap grinding as well as fluid induced mechanisms related to flow through gaps or other flow phenomena associated with blades.*" Based on a substantial number of test results obtained from studies conducted with salmonids on the west coast, Franke et al. (1997) recommends a correlation factor between 0.1 to 0.2.

The blade strike correlation factor is calibrated with turbine mortality rates for target fish species estimated from literature values. Turbine passage survival studies have been independently performed at numerous hydroelectric projects throughout the country for a wide range of species (Franke et al. 1997). Study data were reviewed to identify a subset of applicable source studies that were used to estimate mortality and strike probability of target fish species based on the design characteristics of the Trenton and Prospect developments.

The results of the entrainment and turbine stressor mortality analysis were used to determine the basis to explore any fish passage or protection alternatives, if needed, at the Project. The desktop analysis followed a six-step iterative process. The steps included the following:

1. Development of estimates of fish entrainment rates based upon applicable entrainment study data from existing literature;
2. Development of total annual entrainment at the Project based upon Project-specific operational data combined with estimated entrainment rates;
3. Development of estimates of species and length class composition of potentially entrained fishes at the Project based upon available site-specific sampling data;
4. Development of physical and biological filters used to screen the total annual entrainment estimate;
5. Development of estimated turbine mortality based on existing literature; and
6. Estimation of turbine mortality fish losses computed by applying site specific turbine mortality rates to annual entrainment estimates.

Each of the steps is described below in greater detail. Their order reflects the actual chronology of the analysis.

2.3.1 DEVELOPMENT OF ENTRAINMENT DATABASE AND ENTRAINMENT RATE

The FERC (1995) database of existing entrainment data was reviewed to establish a database of surrogate studies at sites similar to the Project. To identify appropriate source data, a wide range of site characteristics were reviewed. This included identification of projects with similar physical characteristics, such as:

- Project size: discharge capacity and power production.
- Location: geographic proximity to the Project
- Mode of operation - e.g., peaking, run-of-river, etc.
- Biological factors: similarity of fish species composition.
- Impoundment characteristics: general water quality, impoundment size, flow regime.
- Physical project characteristics: trash rack spacing, intake velocity, etc.

Using these criteria, the list of potential surrogate studies was narrowed to sites with characteristics similar to the Trenton and Prospect developments of the West Canada Creek Hydroelectric Project. These sites were then used to develop an entrainment rate for the Project.

The reported annual entrainment rates for each of the sites were averaged to provide an annual entrainment rate for the Project. Annual entrainment rates were used due to differences in how monthly entrainment rates were calculated in surrogate studies. The annual entrainment rates for all projects in the FERC entrainment study database were reported in fish per hour using 100 percent of the plant capacity. These hourly entrainment rates were converted to fish per million cubic feet (MCF) using the reported maximum plant capacity for each site. Entrainment rates expressed as fish per volume of water allow for the comparison of entrainment at different sites despite varying characteristics, such as plant hydraulic capacity. Once an entrainment rate, in fish per MCF, was established for each site, the rates were averaged together to produce an estimated annual entrainment rate for the Project.

2.3.2 ESTIMATION OF TOTAL ANNUAL ENTRAINMENT

Annual estimates of total entrainment (entrainment abundance) were developed for the Project by multiplying the annual entrainment rate by the estimated monthly generation flows. Due to differences in methods used to calculate monthly entrainment rates for sites within the FERC database, annual entrainment was applied across all months. Monthly generation flow estimates were derived using mean monthly values from the USGS gage at Kast Bridge (USGS 01346000), located on West Canada Creek, for the full calendar years of 1997 through 2017. Mean daily flows were pro-rated to account for the difference in drainage area at the USGS gage vs the Project. Mean daily flows were also adjusted to account for the limitations of the powerhouse hydraulic capacity. Flows were limited to the maximum powerhouse flow of f 1,855 cfs for the Prospect Development and 1,425 cfs for the Trenton Development. Flows in excess of this would pass over the dam and were not included in the calculation of generation flows. After calculating the average daily flows that will pass through the powerhouse, monthly flow estimates were calculated by multiplying the average daily powerhouse flows by the number of days in the month. The monthly flow in cfs was then converted to the volume of water expected to pass through the powerhouse in MCF. The monthly MCF values were summed to calculate the annual volume of water that is expected to be passed through the Project powerhouse. This approach is very conservative and assumes that the Project operates at maximum capacity with no turbine outages during the year.

2.3.3 SPECIES AND LENGTH CLASS COMPOSITION

Site-specific data from the 2019 electrofishing efforts at the Prospect impoundment were deemed the most appropriate data for characterizing typical species and length class composition at the Project. Species composition was applied from the September 2019 electrofishing study conducted in the Prospect impoundment and power canal (Kleinschmidt 2020d). For the purposed of the Trenton entrainment analysis, the use of fish data collected in the Prospect impoundment is likely to result in an over estimation as there are more fishes and available habitat in the Prospect impoundment when compared to the Trenton impoundment. Some fish collected during sampling were weighed but not measured. Lengths for these fish were estimated using species specific length weight relationships (Schneider et al. 2000). Relative abundance from this data was applied to the annual entrainment estimates to develop annual estimates of fish species entrainment at the Project.

The same data was also used to define length class composition of fish subject to entrainment. Length data reported from the electrofishing sampling was used to report relative abundance of fish within the following length classes: 0-2 in, 2-4 in, 4-6 in, 6-8 in, 6-10 in, 10-15 in, 15-20 in, and 20-25 in.

2.3.4 ENTRAINMENT SCREENING

Physical and biological filters refer to the physical layout of the Project intakes or biological factors that could influence entrainment. Examples of this are: trash rack spacing that is so small that fish cannot enter the intakes; intake velocities that are so low that fish would not be entrained into the intakes; and/or lake stratification that would create a low dissolved oxygen environment excluding fish from the intake areas.

The first potential filter analyzed was the expected approach velocity of water into the Project intakes. This was calculated theoretically using Project specific characteristics. These characteristics include trash rack spacing (inches), intake area (ft^2), and the maximum flow capacity (cfs) (Table 2-1 and Table 2-2).

TABLE 2-1 PROSPECT DEVELOPMENT INTAKE AND TRASHRACK DIMENSIONS

INTAKE AND TRASHRACK DIMENSIONS	
Intake Height (ft)	29.0
Intake Width (ft)	30.0
Intake Area (ft^2)	870.0
Trash Rack Bar Spacing (in)	3.6
Trash Rack Bar Thickness (in)	0.4
Bar Percentage	0.1
Bar Area (ft^2)	91.2
Free Area (ft^2)	778.8

TABLE 2-2 TRENTON DEVELOPMENT INTAKE AND TRASHRACK DIMENSIONS

INTAKE AND TRASHRACK DIMENSIONS	
Intake Height (ft)	25.0
Intake Width (ft)	20.0
Intake Area (ft^2)	500.0
Trash Rack Bar Spacing (in)	2.0
Trash Rack Bar Thickness (in)	0.4
Bar Percentage	0.2
Bar Area (ft^2)	95.0
Free Area (ft^2)	405.0

After using Project specific parameters to calculate the approach velocity of water (feet per second or fps) at the intakes, velocity was compared to the swimming speeds of fish that could potentially encounter the intakes. Fish swimming speeds were estimated using methods described in a USFWS bulletin (USFWS 1989). The bulletin offers methods for calculating maximum intake velocities at power plant intakes. The bulletin defines a conservative estimate of a fishes sustained swimming speed as 3 times its body length. We calculated the expected swimming speed of fish at the Project using the following equation:

$$\text{Swimming Speed (ft/s)} = \text{Fish Length (ft)} \times 3 \text{ body lengths per second (ft/s)}$$

This information was used to exclude fish that can escape intake flows from the entrainment estimate.

2.3.5 FISH IMPINGEMENT

Impingement could occur if a fish is too wide to travel through the trash racks but cannot escape the intake flow. Widths of fish potentially entrained at the Project were estimated using interorbital width. Interorbital width is the distance between eyes as measured across the head and is roughly equivalent to skull width. The skull is the least compressible part of the fish body and provides a conservative index of what size fish the trashrack may exclude. Interorbital widths were calculated using the relationships of a fish’s total length, standard length, and interorbital width as defined in Smith (1985).

2.3.6 TURBINE MORTALITY RATES AND ESTIMATION OF TOTAL FISH MORTALITY

Mortality estimates were calculated using methods defined in Franke et al. (1997). Franke et al. developed equations for calculating the probability that a turbine blade would strike an entrained fish based on Project specific turbine parameters. Table 2-3 and Table 2-4 contain the parameters at the Project assuming the plant is operating at maximum hydraulic capacity. The equation used to calculate the blade strike probability for a Francis unit is as follows:

$$P = \lambda \frac{N \cdot L}{D} \cdot \left[\frac{\sin\alpha_t \cdot \frac{B}{D_1}}{2Q_{\omega d}} + \frac{\cos\alpha_t}{\pi} \right]$$

S = 1 – P where,

λ = Blade strike correlation factor

N = Number of buckets

L = Fish length

D = Diameter of runner

B = Runner height at inlet

D1 = Diameter of runner at inlet

$Q_{\omega d}$ = Discharge coefficient = $(Q/\omega D^3)$

TABLE 2-3 PROSPECT DEVELOPMENT SPECIFICATIONS OF FRANCIS TURBINE

TURBINE CHARACTERISTICS	GENERATION
Turbine Type	Francis
No. of Blades	14
Runner Diameter (ft.)	8
RPM	180
Head (ft.)	135
Hydraulic Capacity (cfs)	1855

TABLE 2-4 TRENTON DEVELOPMENT SPECIFICATIONS OF THREE FRANCIS TURBINES

TURBINE CHARACTERISTICS	GENERATION
Turbine Type	Francis
No. of Blades	13
Runner Diameter (ft.)	5
RPM	327
Head (ft.)	255
Hydraulic Capacity (cfs)	475

Mortality rates for each length class at the Project were calculated using the longest fish in a length class. For example, all fish within the six to eight-inch length class were assigned the mortality rate calculated for an eight-inch fish. After calculating the mortality rate for each length class, mortality rates were applied to the estimated number of fish entrained annually for each length class. This provided an estimate of annual Project induced mortality.

2.4 VARIANCES FROM APPROVED STUDY PLAN

The Fish Entrainment and Turbine Passage Survival Assessment was implemented according to Erie's RSP and the FERC SPD.

3.0 STUDY RESULTS

3.1 ENTRAINMENT DATABASE AND ENTRAINMENT RATES

Using the methods described in Section 2.1, the FERC database of entrainment studies was narrowed to nine sites that are comparable to the Trenton and seven sites that are comparable to Prospect. To increase the number of projects within the database, sites with similar characteristics outside of the geographic area of the Project were included.

Once the sites used for the Project database were selected, the entrainment rate for the Project was calculated using the results of studies at the database sites. If a database site had multiple completed entrainment studies, the most appropriate and/or complete study was selected. For example, the Kleber site had both a netting and hydroacoustic study completed. However, only the hydroacoustic study reported annual entrainment, so that particular study was deemed more complete. Another example includes the Millville site, which had three years of entrainment study results. Only one of the years represented a contiguous, year-long, sample, so the results of that particular study were used. Tables 3-1 and 3-2 contain information on the sites that make up the Project database and the calculated entrainment rates for the Project.

TABLE 3-1 PROSPECT DEVELOPMENT ENTRAINMENT DATABASE

PROJECT (FERC NO.)	PROJECT SIZE (MW)	TOTAL HYDRAULIC CAPACITY (CFS)	OPERATING MODE	LOCATION	ENT. RATE (FISH/MCF)
Dam #4 (2516)	2.1	1,849	run-of-river	West Virginia	0.1
Millville (2343)	2.8	2,220	run-of-river	West Virginia	0.4
Tower (10615)	0.6	360	run-of-river	Michigan	2.6
Saluda (516)	2.4	800	peaking	South Carolina	2.9
Lower (2421)	1.2	930	run-of-river	Wisconsin	3.5
99 Islands (2331)	18.0	4,498	peaking	South Carolina	1.1
Hawks Nest (2512)	102.0	10,000	run-of-river	West Virginia	0.2
West Canada Creek- Prospect[1]	17.3	1,855	peaking	New York	1.5

[1] Estimated entrainment rate for the Prospect Development.

TABLE 3-2 TRENTON DEVELOPMENT ENTRAINMENT DATABASE

PROJECT (FERC NO.)	PROJECT SIZE (MW)	TOTAL HYDRAULIC CAPACITY (CFS)	OPERATING MODE	LOCATION	ENT. RATE (FISH/MCF)
Dam #4 (2516)	2.1	1,849	run-of-river	West Virginia	0.1
Millville (2343)	2.8	2,220	run-of-river	West Virginia	0.4
Kleber (10615)	1.2	400	run-of-river	Michigan	5.0
99 Islands (2331)	18.0	4,498	peaking	South Carolina	1.1
Saluda (516)	2.4	800	peaking	South Carolina	2.9
Upper (2640)	0.9	720	run-of-river	Wisconsin	2.5
Lower (2421)	1.2	930	run-of-river	Wisconsin	3.5
Pixley (2395)	0.9	675	run-of-river	Wisconsin	2.3
Hawks Nest (2512)	102.0	10,000	run-of-river	West Virginia	0.2
West Canada Creek- Trenton[1]	22.5	1,425	peaking	New York	2.0

[1] Estimated entrainment rate for the Trenton Development.

3.2 ENTRAINMENT ESTIMATE

Table 3-3 and Table 3-4 provides the calculated annual flow through the Project powerhouses for an average water year (i.e. average flows observed during 1997-2017) and the estimated monthly total entrainment. The monthly flows were multiplied by the annual entrainment rate calculated for the (Prospect Development (estimated entrainment rate of 1.55) and Trenton Development (estimated entrainment rate of 2.0) to estimate annual entrainment for each of the Project Developments. This calculation estimated annual entrainment at 52,211 fish per year at the Prospect Development, and 65,125 fish per year at the Trenton Development, prior to the application of biological and physical filters that influence entrainment.

TABLE 3-3 PROSPECT DEVELOPMENT POWERHOUSE FLOWS AND ENTRAINMENT

MONTH	POWERHOUSE MONTHLY FLOW (MCF)	ESTIMATED FISH ENTRAINED
January	3,166	4,911
February	2,761	4,284
March	3,653	5,667
April	4,968	7,707
May	3,327	5,160
June	2,448	3,798
July	1,939	3,008
August	1,551	2,406
September	1,537	2,385
October	2,341	3,631
November	2,906	4,508
December	3,059	4,745
Annual	33,657	52,211

TABLE 3-4 TRENTON DEVELOPMENT POWERHOUSE FLOWS AND ENTRAINMENT

MONTH	POWERHOUSE MONTHLY FLOW (MCF)	ESTIMATED FISH ENTRAINED
January	3174	6,348
February	2767	5,533
March	3661	7,322
April	3817	7,633
May	3335	6,669
June	2453	4,907
July	1942	3,884
August	1553	3,107
September	1540	3,080
October	2346	4,692
November	2911	5,823
December	3064	6,128
Annual	32564	65,125

3.3 SPECIES AND LENGTH CLASS COMPOSITION

Species and length class composition were calculated using the results of 2019 electrofishing surveys within the Prospect impoundment. Species composition and length-class compositions are presented in Table 3-5 and Table 3-6. Yellow perch comprised most of the fish assemblage at 61%, and pumpkinseed were the next most abundant species at 23 percent. Most of these fish were in the 2.1-4 in. length class.

TABLE 3-5 SPECIES COMPOSITION PERCENTAGES WITHIN THE PROSPECT IMPOUNDMENT

COMMON NAME	ABUNDANCE (N)	RELATIVE ABUNDANCE (%)
Yellow Perch	894	60.8
Pumpkinseed	331	22.5
Golden Shiner	63	4.3
Rock Bass	57	3.9
Smallmouth Bass	51	3.5
Chain Pickerel	33	2.2
White Sucker	15	1.0
Spottail Shiner	13	0.9
Brown Bullhead	9	0.6
Tesselated Darter	3	0.2
Banded Killifish	2	0.1
Total	1,471	100.0

TABLE 3-6 LENGTH CLASS COMPOSITION PERCENTAGES BY SPECIES WITHIN THE PROSPECT IMPOUNDMENT

LENGTH CLASS (IN)	PERCENTAGES (%)										
	BROWN BULLHEAD	BANDED KILLIFISH*	CHAIN PICKEREL	PUMPKINSEED	ROCK BASS	SMALLMOUTH BASS	SPOTTAIL SHINER*	TESSELATED DARTER*	WHITE SUCKER	YELLOW PERCH	GOLDEN SHINER
0-2	0	0	0	0	0	0	0	0	0	0	0
2.1-4	0	100	0	99.7	0	0	100	100	0	86.5	0
4.1-6	0	0	42.4	0	80.7	64.7	0	0	0	12.3	98.4
6.1-8	11.1	0	33.3	0.3	17.5	11.8	0	0	0	0.4	0
8.1-10	33.3	0	0	0	1.8	17.6	0	0	0	0.8	1.6
10.1-15	55.6	0	9.2	0	0	5.9	0	0	0	0	0
15.1-20	0	0	12.1	0	0	0	0	0	26.7	0	0
20.1-25	0	0	3.0	0	0	0	0	0	73.3	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

*Length data not provided in electrofishing data. Average adult standard length for both species ranged from 55-90 mm (Jenkins and Burkhead 1993)

3.4 PROSPECT ENTRAINMENT FILTERS

The calculated approach velocity at the maximum station hydraulic capacity is 2.13 ft/s. The calculated approach velocity was then compared to the calculated swimming speed of fish for each length class. Fish swimming speeds were calculated using an assumed minimum sustained swim speed of 3 body lengths/sec (USFWS 1989). Results of the swimming speed calculations are presented in Table 3-7. The swimming speed calculations show that fish greater than 8 inches in length should be able escape flow entering the Project intake; therefore, fish larger than 8 inches were not included in the entrainment estimate.

Species composition and length composition percentages were applied to the total annual entrainment numbers to estimate entrainment rates by species and length class. Entrainment totals after screening all fish larger than 8 inches are presented in Table 3-7.

3.5 TRENTON ENTRAINMENT FILTERS

The calculated approach velocity at the maximum plant hydraulic capacity is 2.85 ft/s. The calculated approach velocity was then compared to the calculated swimming speed of fish for each length class. Fish swimming speeds were calculated using an assumed minimum sustained swim speed of 3 body lengths/sec (USFWS 1989). Results of the swimming speed calculations are presented in Table 3-7. The swimming speed calculations show that fish greater than 11 inches in length should be able to escape flow entering the Project intake, therefore fish larger than 11 inches were not included in the entrainment estimate.

Species composition and length composition percentages were applied to the total annual entrainment numbers to estimate entrainment rates by species and length class. Entrainment totals after screening all fish larger than 11 inches are presented in Table 3-8 for the Prospect Development and Table 3-9 for the Trenton Development.

TABLE 3-7 FISH SWIMMING SPEED BY LENGTH

FISH LENGTH (IN)	SWIM SPEED (FT/S)
1.0	0.2
2.0	0.5
3.0	0.7
4.0	1.0
5.0	1.3
6.0	1.5
7.0	1.7
8.0	2.0
9.0	2.2
10.0	2.5
12.5	3.1
15.0	3.7
17.5	4.4
20.0	5.0
22.5	5.6
25.0	6.2
27.5	6.9
30.0	7.5

TABLE 3-8 PROSPECT DEVELOPMENT FILTERED ANNUAL ENTRAINMENT RESULTS

LENGTH CLASS (IN)	0-2	2.1-4	4.1-6	6.1-8	TOTAL
Brown Bullhead	0	0	0	35	35
Banded Killifish	0	71	0	0	71
Chain Pickerel	0	0	497	390	887
Pumpkinseed	0	11,713	0	35	11,748
Rock Bass	0	0	1,633	355	1,988
Smallmouth Bass	0	0	171	213	1,384
Spottail Shiner	0	461	0	0	461
Tesselated Darter	0	106	0	0	106
White Sucker	0	0	0	0	0
Yellow Perch	0	27,437	3,904	142	31,483
Golden Shiner	0	0	2,201	0	2,201

TABLE 3-9 TRENTON DEVELOPMENT FILTERED ANNUAL ENTRAINMENT RESULTS

LENGTH CLASS (IN)	0-2	2.1-4	4.1-6	6.1-8	8.1-10	10.1-11	TOTAL
Brown Bullhead	0	0	0	44	133	89	266
Banded Killifish	0	89	0	0	0	0	89
Chain Pickerel	0	0	620	487	0	44	1,151
Pumpkinseed	0	14,610	0	44	0	0	14,654
Rock Bass	0	0	2,037	443	44	0	2,524
Smallmouth Bass	0	0	1,461	266	398	0	2,125
Spottail Shiner	0	576	0	0	0	0	576
Tesselated Darter	0	133	0	0	0	0	133
White Sucker	0	0	0	0	0	0	0
Yellow Perch	0	34,223	4,870	177	310	0	39,580
Golden Shiner	0	0	2,745	0	44	0	2,789

3.6 PROSPECT DEVELOPMENT FISH IMPINGEMENT

No fish within the electrofishing dataset collected at the Prospect development were found to be too wide to fit through the 3 5/8 in. width trash racks. If any fish are too wide to fit through that area, it is likely that they would be greater than 8 inches and capable of swimming out of the intake velocities.

3.7 TRENTON DEVELOPMENT FISH IMPINGEMENT

Only four white suckers within the electrofishing dataset collected at the Prospect development were found to be too wide to fit through the trash racks. All four fish were greater than 11 inches in length, and should be capable of out swimming intake velocities. No other fishes within the dataset should be susceptible to impingement on the trashracks.

3.8 MORTALITY ESTIMATE

Mortality rates are presented in Table 3-10 and Table 3-11. Tables 3-12 through 3-17 provide estimates for correlation factors of 0.10, 0.15, and 0.20. Estimated annual mortality rates across correlation factors range from 1,059 to 2,117 at the Prospect Development and 3,333 to 6,665 fish per year at the Trenton Development. Mortality estimates for each species and length class are provided in Table 3-10.

TABLE 3-10 PROSPECT DEVELOPMENT MORTALITY RATES

LENGTH CLASS (IN)	CORRELATION FACTOR (%)		
	0.10	0.15	0.20
0-2	0.9	1.4	1.9
2.1-4	1.9	2.8	3.8
4.1-6	2.8	4.2	5.6
6.1-8	3.8	5.6	7.5

TABLE 3-11 TRENTON DEVELOPMENT MORTALITY RATES

LENGTH CLASS (IN)	CORRELATION FACTOR (%)		
	0.10	0.15	0.20
0-2	2.3	3.4	4.6
2.1-4	4.6	6.9	9.1
4.1-6	6.9	10.3	13.7
6.1-8	9.1	13.7	18.3
8.1-10	11.4	17.2	22.9
10.1-15	17.2	25.7	34.3

TABLE 3-12 PROSPECT DEVELOPMENT MORTALITY ESTIMATES WITH CORRELATION FACTOR OF 0.10

LENGTH CLASS (IN)	0-2	2.1-4	4.1-6	6.1-8	TOTAL
Brown Bullhead	0	0	0	1	1
Banded Killifish	0	1	0	0	1
Chain Pickerel	0	0	14	15	29
Pumpkinseed	0	220	0	1	222
Rock Bass	0	0	46	13	59
Smallmouth Bass	0	0	33	8	41
Spottail Shiner	0	9	0	0	9
Tesselated Darter	0	2	0	0	2
White Sucker	0	0	0	0	0
Yellow Perch	0	516	110	5	632
Golden Shiner	0	0	62	0	62
Total	0	800	283	47	**1,059**

TABLE 3-13 TRENTON DEVELOPMENT MORTALITY ESTIMATES WITH CORRELATION FACTOR OF 0.10

LENGTH CLASS (IN)	0-2	2.1-4	4.1-6	6.1-8	8.1-10	10.1-11	TOTAL
Brown Bullhead	0	0	0	4	15	11	30
Banded Killifish	0	4	0	0	0	0	4
Chain Pickerel	0	0	43	45	0	6	93
Pumpkinseed	0	668	0	4	0	0	673
Rock Bass	0	0	140	41	5	0	185
Smallmouth Bass	0	0	100	24	46	0	170
Spottail Shiner	0	26	0	0	0	0	26
Tesselated Darter	0	6	0	0	0	0	6
White Sucker	0	0	0	0	0	0	0
Yellow Perch	0	1,566	334	16	35	0	1,952
Golden Shiner	0	0	188	0	5	0	193
Total	0	2,271	805	134	106	17	**3,333**

TABLE 3-14 PROSPECT DEVELOPMENT MORTALITY ESTIMATES WITH CORRELATION FACTOR OF 0.15

LENGTH CLASS (IN)	0-2	2.1-4	4.1-6	6.1-8	TOTAL
Brown Bullhead	0	0	0	2	2
Banded Killifish	0	2	0	0	2
Chain Pickerel	0	0	21	22	43
Pumpkinseed	0	331	0	2	333
Rock Bass	0	0	69	20	89
Smallmouth Bass	0	0	50	12	62
Spottail Shiner	0	13	0	0	13
Tesselated Darter	0	3	0	0	3
White Sucker	0	0	0	0	0
Yellow Perch	0	775	165	8	948
Golden Shiner	0	0	100	0	100
Total	0	1,200	426	71	**1,697**

TABLE 3-15 PROSPECT DEVELOPMENT MORTALITY ESTIMATES WITH CORRELATION FACTOR OF 0.20

LENGTH CLASS (IN)	0-2	2.1-4	4.1-6	6.1-8	TOTAL
Brown Bullhead	0	0	0	3	3
Banded Killifish	0	3	0	0	3
Chain Pickerel	0	0	28	29	57
Pumpkinseed	0	441	0	3	444
Rock Bass	0	0	92	27	119
Smallmouth Bass	0	0	66	16	82
Spottail Shiner	0	17	0	0	17
Tesselated Darter	0	4	0	0	4
White Sucker	0	0	0	0	0
Yellow Perch	0	1,033	220	11	1,264
Golden Shiner	0	0	124	0	133
Total	0	1,601	569	94	**2,117**

TABLE 3-16 TRENTON DEVELOPMENT MORTALITY ESTIMATES WITH CORRELATION FACTOR OF 0.15

LENGTH CLASS (IN)	0-2	2.1-4	4.1-6	6.1-8	8.1-10	10.1-11	TOTAL
Brown Bullhead	0	0	0	6	23	27	46
Banded Killifish	0	8	0	0	0	0	8
Chain Pickerel	0	0	64	67	0	8	139
Pumpkinseed	0	1,003	0	6	0	0	1,009
Rock Bass	0	0	210	61	8	0	278
Smallmouth Bass	0	0	150	36	68	0	255
Spottail Shiner	0	40	0	0	0	0	40
Tesselated Darter	0	9	0	0	0	0	9
White Sucker	0	0	0	0	0	0	0
Yellow Perch	0	2,349	501	24	53	0	2,928
Golden Shiner	0	0	283	0	8	0	290
Total	0	3,406	1,208	201	160	25	**4,999**

TABLE 3-17 TRENTON MORTALITY ESTIMATES WITH CORRELATION FACTOR OF 0.20

LENGTH CLASS (IN)	0-2	2.1-4	4.1-6	6.1-8	8.1-10	10.1-11	TOTAL
Brown Bullhead	0	0	0	8	30	22	61
Banded Killifish	0	8	0	0	0	0	8
Chain Pickerel	0	0	85	89	0	11	185
Pumpkinseed	0	1,337	0	8	0	0	1,345
Rock Bass	0	0	280	81	10	0	371
Smallmouth Bass	0	0	201	49	91	0	340
Spottail Shiner	0	53	0	0	0	0	53
Tesselated Darter	0	12	0	0	0	0	12
White Sucker	0	0	0	0	0	0	0
Yellow Perch	0	3,132	668	32	71	0	3,903
Golden Shiner	0	0	377	0	10	0	387
Total	0	4,541	1,610	267	213	33	**6,665**

4.0 DISCUSSION AND CONCLUSIONS

The estimates of annual entrainment and turbine mortality presented in this report were developed based on the best-available data and are intended to provide an order-of-magnitude assessment of potential fish entrainment and turbine mortality at the Project. Based on that assumption, the magnitude of the average annual fish entrainment estimate presented in this report, and most desktop entrainment studies, is most likely an overestimate of the actual entrainment that typically occurs at the Project. The method used to determine Project operations was based on “ideal” conditions and assumes the Project is always available to operate at maximum capacity. The ability to account for times when the Project is not operating, or operating at a reduced flow, would further reduce entrainment and mortality estimates. Furthermore, over 75 percent of the estimated number of fish potentially entrained and lost to turbine mortality are yellow perch and pumpkinseed, both of which have high fecundity and can produce thousands of offspring per individual female each season (Jenkins and Burkhead 1993). Additionally, length-frequency data suggests that most fish that may be entrained are juveniles and young-of-year, which have high natural mortality rates due to numerous environmental factors.

4.1 PROSPECT DEVELOPMENT

Mortality estimates vary across correlation factors, but even the highest correlation factor used provides a mortality estimates of less than 2,200 fish killed in a year, and the lowest correlation factor used provides a mortality estimate of less than 1,100 fish killed in a year. Additionally, fish were sampled via electrofishing throughout the Prospect impoundment and power canal, and most fish collected were from reservoir sampling, with much fewer fish coming from the power canal. This canal reach, adjacent to the intake, provides less suitable habitat as compared to the reservoir, and would be less likely to hold fish at high concentrations. Given the results of this analysis, it is reasonable to conclude the operation of the Project will have little effect on the health of the reservoir fishery.

4.2 TRENTON DEVELOPMENT

Mortality estimates vary across correlation factors, but even the highest correlation factor used provides a mortality estimate of less than 6,700 fish killed in a year, and the lowest correlation factor used provides a mortality estimate of less than 3,400 fish killed in a year. Additionally, fish assemblage estimates used for this assessment were collected from the Prospect impoundment. Prospect provides more suitable habitat, including cover and depth ranges, as compared to Trenton. It is likely that there are fewer fish available for entrainment at Trenton, as compared to Prospect. Given the results of this analysis, it is reasonable to conclude the operation of the Project will have little effect on the health of the reservoir fishery.

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