Thompson Falls Hydroelectric Project
FERC Project No. 1869

NorthWestern Energy
Final Study Report
Updated Literature Review of Downstream Fish Passage

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List of Abbreviations and Acronyms

2007 Literature Review	*Literature Review of Downstream Fish Passage Issues at Thompson Falls Hydroelectric Project* (GEI 2007)
cfs	cubic feet per second
FERC	Federal Energy Regulatory Commission
fish passage facility	Thompson Falls Upstream Fish Passage facility
flow	Project discharge
FWS	U.S. Fish and Wildlife Service
ILP	FERC's Integrated Licensing Process
Licensee	NorthWestern Energy
mm	millimeters
NorthWestern	NorthWestern Energy
PIT	passive integrated transponder
Project	Thompson Falls Hydroelectric Project
Thompson Falls Project	Thompson Falls Hydroelectric Project
Updated Literature Review	Updated Literature Review of Downstream Fish Passage
U.S.	United States

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1. Introduction

The Thompson Falls Hydroelectric Project (Thompson Falls Project or Project) is located on the Clark Fork River in Sanders County, Montana. Non-federal hydropower projects in the United States (U.S.) are regulated by the Federal Energy Regulatory Commission (FERC) under the authority of the Federal Power Act. The current FERC License expires December 31, 2025. As required by the Federal Power Act and FERC's regulations, on July 1, 2020, NorthWestern Energy (NorthWestern, Licensee), the current licensee, filed a Notice of Intent to relicense the Thompson Falls Project using FERC's Integrated Licensing Process (ILP). Concurrently, NorthWestern filed a Pre-Application Document.

The ILP is FERC's default licensing process which evaluates effects of a project based on a nexus to continuing Project operations. In general, the purpose of the pre-filing stage of the ILP is to inform Relicensing Participants[1] about relicensing, to identify issues and study needs (based on a project nexus and established FERC criteria), to conduct those studies per specific FERC requirements which are included in the FERC Study Plan Determination, issued May 10, 2021, and to prepare the Final License Application.

This Updated Literature Review of Downstream Fish Passage (Updated Literature Review) has been prepared to comply with the requirements of NorthWestern's Revised Study Plan (NorthWestern 2021), filed with FERC on April 12, 2021, as approved in FERC's Study Plan Determination.

1.1 Updated Literature Review of Downstream Fish Passage – Background

When water is spilling over or through the dams at the Thompson Falls Project, fish can migrate downstream *via* the spillways, outlet works, or through the turbines. During non-spill periods, the primary means of downstream passage is through the turbines. In 2007, the previous Licensee (PPL Montana) prepared a *Literature Review of Downstream Fish Passage Issues at Thompson Falls Hydroelectric Project* (GEI 2007) (2007 Literature Review)[2] which included specific consideration of federally-listed Bull Trout and Westslope Cutthroat Trout, a sensitive species and Montana Species of Special Concern (GEI 2007).

Studies done on anadromous fishes have generally indicated that passage *via* spill poses less risk than *via* turbine (Muir et al. 2001). Fish mortality is typically 0 to 2 percent for standard spill bays and 5 to 15 percent for turbine passage, with Kaplan turbines generally at the lower

1 Relicensing Participants includes local, state, and federal governmental agencies, Native American Tribes, local landowners, non-governmental organizations, and other interested parties.

2 The Literature Review is available for download at: https://northwesternenergy.com/docs/default-source/default-document-library/clean-energy/environmental-projects/thompson-falls/thompson_falls_literature_review_of_downstream_fish_passage_issues_2007.pdf?sfvrsn=5e2b0dfa_7

end of this mortality range and Francis turbines generally greater (Whitney et al. 1997). However, mortality at a specific facility can vary depending on the specific configuration of the turbines and spillways and type and timing of fish being passed.

The 2007 Literature Review (GEI 2007) calculated overall survival for downstream trout passage through the Project based on the following assumptions:

- Spillway effectiveness is 1:1 so fish will pass the Project in numbers proportional to flow. That is, if 50% of the flow is through the spillway, then 50% of the fish will pass over the spillway
- Fish will also pass the two powerhouses in proportion to flow through the powerhouses

The 2007 Literature Review estimated that survival estimates at the Project are 94 percent through the new powerhouse (Kaplan turbine), 85 percent through the original powerhouse (Francis turbines), and 98 percent through the spillway. Combined survival estimates for trout measuring greater than 100 millimeters (mm) was estimated to likely be 91 to 94 percent.

The Biological Opinion (FWS 2008) issued by the U.S. Fish and Wildlife Service (FWS) October 28, 2008, concurred with the survival estimate in the 2007 Literature Review.

This Updated Literature Review focuses on information in the scientific literature published since 2007, including information on survival of different fish sizes, any turbine or generator upgrades after 2007, spillway changes due to the new radial gates, and relevant operational changes.

1.2 Goals and Objectives of Study

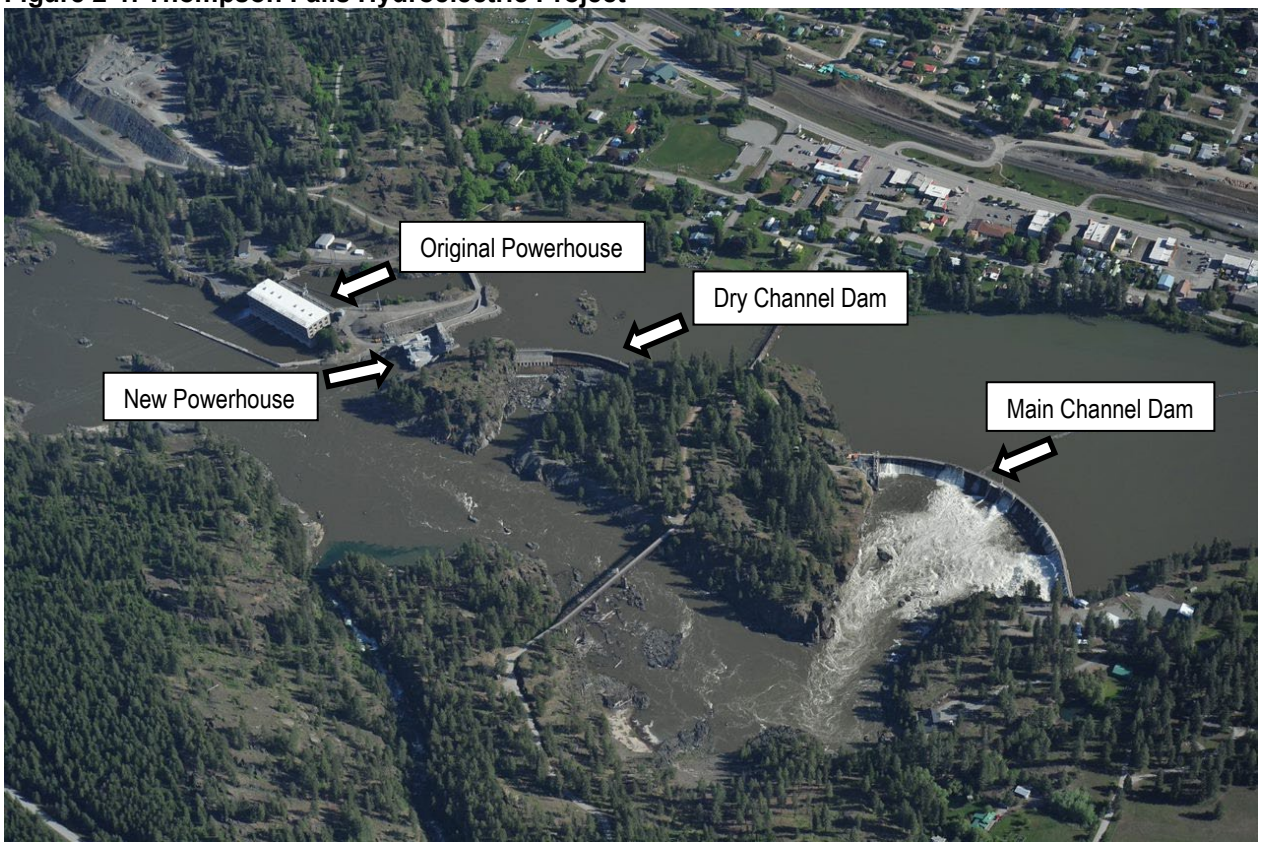
This Updated Literature Review provides updates, as available, to estimates of downstream passage survival of various size classes of fish, with respect to current Project configuration and operations.

2. Methods

2.1 Study Area

Downstream fish migration can occur at four locations at the Project, which define the study area. The study area includes two spillways (Main Channel Dam; Dry Channel Dam) and two powerhouses (original and new [completed in 1995]) (**Figure 2-1**). When water is spilling over or through the dams, fish can migrate downstream *via* the spillways, outlet works, or through the turbines. During non-spill periods, the primary means of downstream passage is through the turbines.

Figure 2-1. Thompson Falls Hydroelectric Project



2.2 Study Methods

This Updated Literature Review focused on downstream fish passage literature published since 2007. The scientific literature on downstream fish passage was screened for relevance for species and size classes of fish and turbine configurations found in the Project area. Survival studies conducted at similar hydroelectric facilities with similar turbine types and hydraulic capacities were examined and used as the basis to estimate fish survival through the turbines

at the Project. The search strategy utilized ProQuest and EBSCO databases which are standard databases within the research, academic, corporate, and government sectors for researching scholarly science-based topics across multiple publications. Search criteria included relevant terms such as "downstream passage," "Kaplan or Francis turbine," and "entrainment" and were limited to years after 2006. Results included journal articles, white papers, and biological assessments. These were then reviewed specifically looking for applicability to the Thompson Falls Project turbine configurations, dam characteristics, species similarities, and fish lengths or juvenile and adult age classes.

This Updated Literature Review also includes an update on current Project operations and configuration and a summary of documented successful downstream fish passage at the Project.

2.3 Variances from the FERC-approved Study Plan

There were no variances from the FERC-approved Revised Study Plan.

3. Results

3.1 Documentation of Downstream Passage at the Project

The Licensee has documented downstream fish movement through the Project since the construction and operation of the Thompson Falls Upstream Fish Passage facility (fish passage facility) commenced in 2011. Salmonids, and some non-salmonids, which are passed upstream are tagged with a passive integrated transponder (PIT) tag. Subsequent recaptures of tagged fish have demonstrated that adult salmonids can survive downstream passage at the Project. From 2011 to 2018, PIT-tag data collected at the fish passage facility indicate a minimum of 10 percent of the PIT-tagged fish released upstream of the dam (264 out of 2,644 tagged-fish) returned and ascended the fish passage facility a second, third, fourth, or sixth time. These 264 fish include one Bull Trout, 164 Rainbow Trout, 73 Brown Trout, 12 Westslope Cutthroat Trout, six Rainbow x Westslope Cutthroat hybrids, four Mountain Whitefish, three Northern Pikeminnow, and one Largescale Sucker (NorthWestern 2019). Additionally, about 6.5 percent of the 1,107 Floy-tagged Smallmouth Bass ascended the fish passage facility two or more times; two fish ascended three times; one fish ascended four times; and one fish ascended five times (NorthWestern 2018).

On an annual basis, an average of 8 percent (between 3 and 13.5%) of the salmonids PIT-tagged each year, return to the fish passage facility the following year. For example, in 2019, there were 543 PIT-tagged fish (341 salmonids; 202 non-salmonids) released upstream of the fish passage facility and 8 percent of the salmonids (18 Rainbow Trout; 9 Brown Trout; 1 Mountain Whitefish) and 6 percent of the non-salmonids (10 Northern Pikeminnow; 2 Largescale Sucker) returned to the fish passage facility in 2020 (NorthWestern unpublished data).

PIT tagged adult and juvenile Bull Trout have been detected in tributaries both upstream and downstream of the Project (NorthWestern 2019; 2019a), indicating that the fish survived downstream passage through the Project.

Determining whether a fish moved downstream over the spillway or through the turbines depends on streamflow conditions. The combined capacity of the seven generating units at the Project is approximately 23,000 cubic feet per second (cfs). When river inflows exceed this capacity, spill is initiated at the Main Channel Dam spillway. Therefore, when streamflows are less than 23,000 cfs, it is assumed that all downstream fish passage is through turbines. When streamflows are above 23,000 cfs, fish can pass downstream through the turbines or over the spillway. Data indicate Rainbow and Brown trout, as well Largescale Sucker have survived migrating downstream through the turbines. Additional detection data collected from 10 years of fish passage facility operations indicate Bull Trout, Rainbow Trout, Westslope Cutthroat Trout, Rainbow hybrids, Brown Trout, Northern Pikeminnow, Largescale Sucker, and

Smallmouth Bass have all successfully migrated downstream of Thompson Falls Dam, either through the turbines or over the spillway.

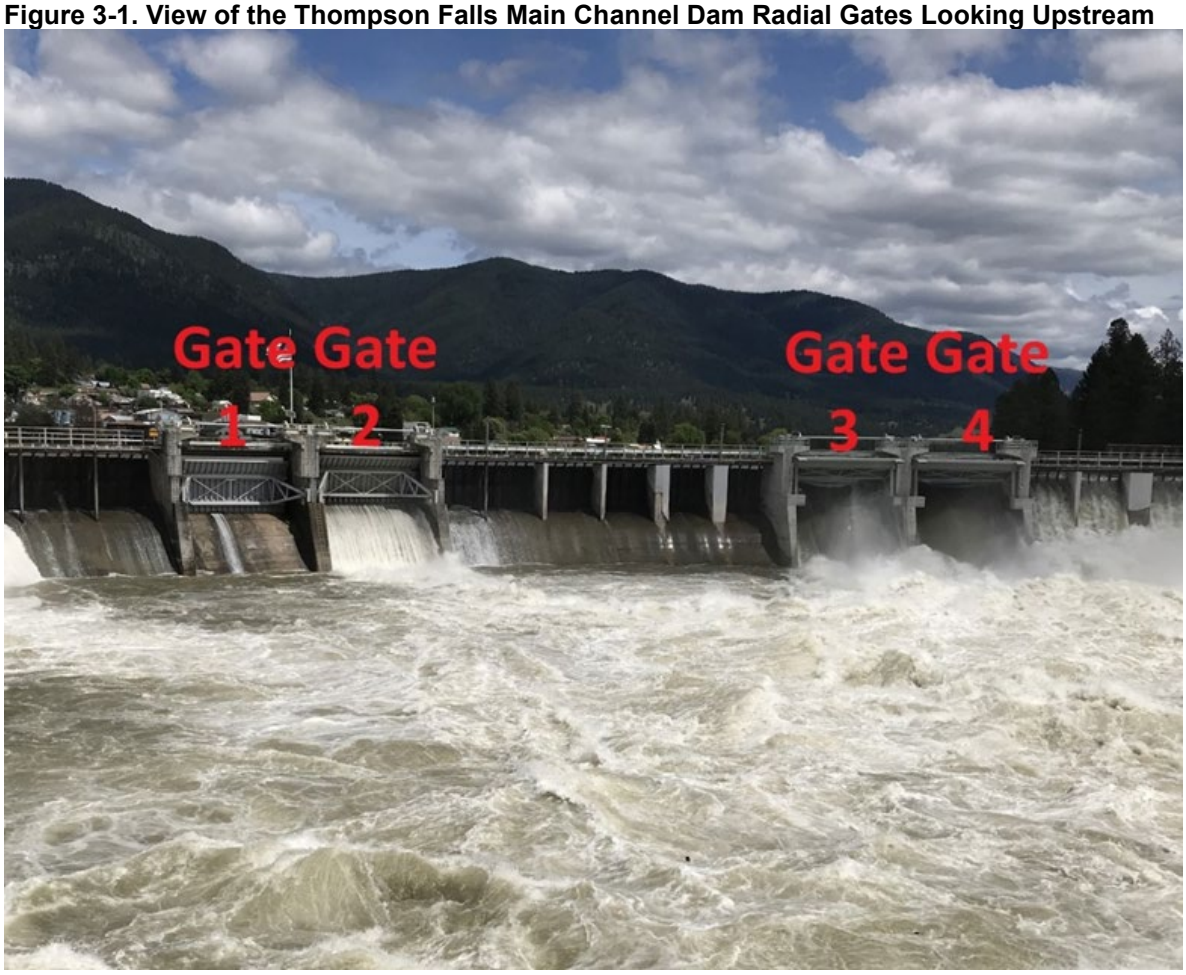
The available data demonstrate that fish are successfully passing both upstream and downstream of the Project, and that some fish make the loop multiple times over the years.

3.2 Current Project Operations and Configuration

Since the 2007 Literature Review (GEI 2007) there have been two relevant operational changes to the Thompson Falls Project. The first change was the installation of the upstream fish passage facility in 2010. To facilitate downstream passage survival all water intakes on the fish passage facility are screened. Maximum flow through the fish ladder is 54 cfs, and adjacent to the ladder entrance is a High Velocity Jet of 20 cfs. Given the low proportion of water moving through the fish ladder in relation to the Clark Fork River and screens as mitigative measures it is not anticipated that a measurable amount of downstream passage occurs through the fish ladder. The installation of the ladder has also led to additional water being released at the main dam using half of a panel on the main dam spillway even when total river discharge is less than 23,000 cfs. The half panel releases approximately 100 cfs and is used as additional attraction flow along the right side of the main dam. It is reasonable to conclude this operational change would not modify downstream passage survival estimates as described in the 2007 Literature Review.

The other relevant operations modification since the 2007 Literature Review is the installation of two additional radial gates located on the Main Channel Dam. These new radial gates (Gates 3 and 4) were installed in 2020 in Bays 25-28 (**Figure 3-1**). Each radial gate passes approximately 10,000 cfs; the capacity for spill is just over 40,000 cfs for all four gates combined. At flows up to 23,000 cfs, all flow passes through the powerhouses, except for the fish attraction flows which are released at the Main Channel Dam to attract fish to the fish passage facility. Throughout the year, the radial gates are opened periodically to pass trash that has accumulated on the trash boom. The gates open automatically to maintain reservoir pool elevation below the set point. As flow increases above powerhouse capacity (23,000 cfs), the new gates are used along with the existing panels to pass additional spill.

Figure 3-1. View of the Thompson Falls Main Channel Dam Radial Gates Looking Upstream



Note: Gates 3 and 4 were installed in 2020.

There have not been any modifications to the powerhouse turbines in either the old powerhouse (Francis turbines) or new powerhouse (Kaplan turbine) that would have an effect on fish survival or hydraulic capacity. The turbine/generator configurations described in Section 4.2 of the 2007 Literature Review are still accurate.

3.3 Literature Review Findings

This Updated Literature Review includes review of a total of five relevant documents. Of these documents, four are peer reviewed primary literature, and one is a white paper (**Table 3-1**). Additional literature was considered but determined to be inapplicable because it lacked relevance to Thompson Falls turbine configurations, dam characteristics, species similarities, and fish lengths or juvenile and adult age classes. As such, it is not discussed in this report.

Table 3-1. Documents Reviewed in this Updated Literature Review

Title	Date	Author	Type	Relevant Findings
Validation of Francis–Kaplan Turbine Blade Strike Models for Adult and Juvenile Atlantic Salmon (Salmo salar, L.) and Anadromous Brown Trout (Salmo trutta, L.) Passing High Head Turbines	2020	Vikstrom et al.	Peer reviewed	Juvenile salmonid survival through Kaplan and Francis turbines is high (100-88%), but lower for salmon over 500 mm (44-19%). Study was on large discharge, high head (75 m) Francis turbines.
What are the Relative Risks of Mortality and Injury for Fish during Downstream Passage at Hydroelectric Dams in Temperate Regions? A Systematic Review	2020	Algera et al.	Peer reviewed	Comprehensive review of 264 studies from 87 articles evaluating consequences of entrainment. Challenges in examining delayed mortality and differences between lab and field-based studies. Recommend addressing knowledge gaps on non-salmonid or non-sportfish species and on population-level consequences of fish entrainment. Overall findings consistent with 2007 Literature Review of Downstream Fish Passage Issues at Thompson Falls.
Intake Approach and Dam Passage by Downstream Migrating Atlantic Salmon Kelts.	2017	Nyqvist et al.	Peer	Intake Approach and Dam Passage by Downstream Migrating Atlantic Salmon kelts[3].
Estimating Total Passage Survival for Fish Migrating Downstream at Hydropower Projects	2013	Amaral et al. Alden Research Laboratory	White paper	Adult Atlantic Salmon survival was typically greater than 75% at 15 sites on the Penobscot River. Higher survival of adults and conditions more similar to Thompson Falls turbines than the other four studies reviewed.
Overwintering and Downstream Migration of Sea Trout Kelts Under Regulated Flows-Northern Sweden	2008	Ostergren et al.	Peer reviewed	Higher mortality for adult sea trout through Francis turbines that was near 69%. Large volume turbines (9,000 cfs).

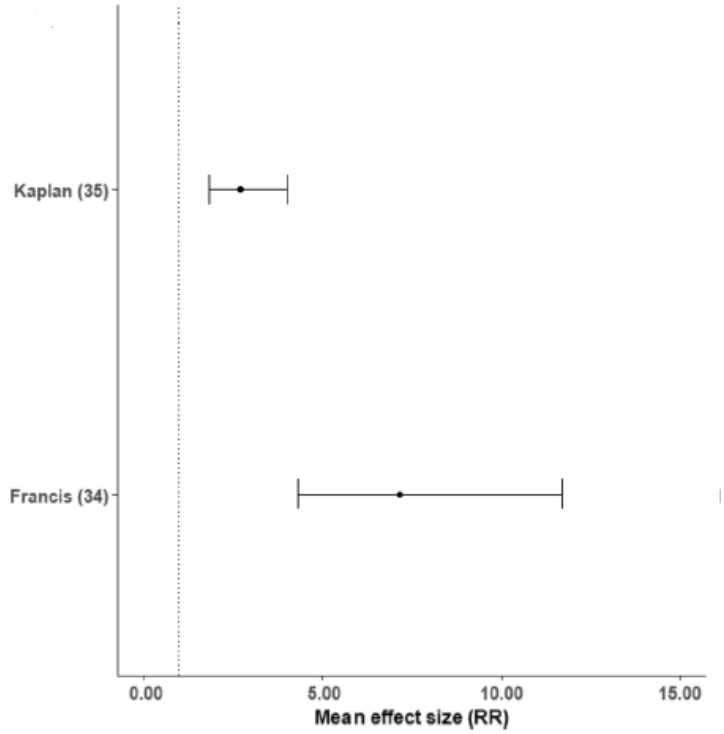
[3] a kelt is a salmon or trout after spawning.

4. Discussion

4.1 Kaplan vs. Francis Turbine Types

As found in the 2007 Literature Review, more recent work confirms the differences in survival between Kaplan and Francis-type turbines. Kaplan units are significantly safer for fish than Francis type units (Vikstrom et al. 2020; Algera et al. 2020). The range of survival through Kaplan turbines for juvenile Atlantic Salmon and Brown Trout is within the estimate previously reported with survival between 100 to 99 percent and Francis juvenile survival 88 to 91 percent (Vikstrom et al. 2020). Algera et al. 2020 summarized 264 studies on downstream passage survival and applied a weighted pool risk ratio methodology to look at immediate fish mortality (**Figure 4-1**). These differences in survival through turbine types continue to be consistent in the literature.

Figure 4-1. Kaplan *versus* Francis turbine types



Notes:

- Values in parentheses are the number of effect size estimates.
- Error bars indicate 95% confidence intervals.
- A mean RR value > 1 (right of the dashed line) indicates an overall increase in risk of fish injury with passage through turbine type relative to controls.
- Figure source: Algera et al. 2020

4.2 Adult and Juvenile Survival

Findings reported for juvenile fishes are consistent with the 2007 Literature Review results with between 88 to 100 percent survival for both Kaplan and Francis turbine types (Vikstrom et al. 2020). Literature published after 2007 generally indicate that juvenile survival results remain consistent with those in the 2007 Literature Review with typically higher rates of survival obtained with smaller fish going through larger openings over lower heads, and slower moving units with laminar flow.

The majority of current literature continues to focus on anadromous salmonids, not fish species and conditions encountered at the Project's fish passage facility.

Regarding adult fish the Vikstrom et al. 2020 paper is especially helpful in that it describes survival differences between juvenile and adult salmonids. Observed adult survival for a Francis type turbine was 19 to 44 percent for large adults near 610 mm, total length. These low adult survival estimates through Francis turbines are similar to other recent studies that report survival ranges of 21 to 28 percent for adult salmonids (Ostergren and Rivinoja 2008; Nyqvist et al. 2017). Of importance to note is that these studies contained larger turbines with greater discharge than what is present at the Thompson Falls Project. Direct comparisons to the Thompson Falls Project are challenging as each facility and turbine configuration is slightly different. Conversely, survival rates for Atlantic Salmon kelts on the Penobscot River were estimated at 15 project sites and indicated adult survival was typically greater than 75 percent for both turbine types, at most sites (Alden Research Lab 2013). Information available from an updated literature search is generally consistent with previous efforts and estimates of downstream fish survival at the Project. There continues to be a research focus on survival of anadromous salmonids, especially within the Columbia River basin (Algera et al. 2020).

Further resolution of downstream passage survival based on the size and species specific to the Clark Fork River at the Thompson Falls Project is limited in the available literature. However, migratory species that are found in the Clark Fork River system spawn more than one time during their life. As PIT tagging of salmonids at the upstream fish passage facility has continued multiple species and individuals have been passed upstream, and then in subsequent years been recaptured in the ladder, indicating downstream adult survival is common (NorthWestern 2019).

5. Conclusions

The 2007 Literature Review concludes that combined survival estimates for passage through the Francis turbines, the Kaplan turbine and the spillway for trout measuring greater than 100 mm is likely 91 to 94 percent. Efforts from the current literature review are consistent with the 2007 work and little research specific to the species at Thompson Falls has been completed since 2006. Thus, no additional literature was identified that would measurably change these existing estimates of downstream survival at the Project.

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