The Phase 2 Implementation Plan: Testing Feasibility of Reintroduced Salmon in the Upper Columbia River Basin

Prepared by:
The Upper Columbia United Tribes

Version:

August 4, 2022

EXECUTIVE SUMMARY

Background

In 2015, the Columbia Basin Tribes and First Nations (CBTFN) finalized the Joint Paper "Fish Passage and Reintroduction into the U.S. and Canadian Upper Columbia Basin" (CBTFN 2015). The Joint Paper describes a four phased approach to guide the development of fish passage and reintroduction efforts upstream of Chief Joseph and Grand Coulee dams. An initial draft of the phased approach was refined and adopted by the Northwest Power and Conservation Council (NPCC) in the 2014 Columbia River Basin Fish and Wildlife Program (NPCC 2014) prior to the finalization and publication of the Joint Paper.

In 2019 the Upper Columbia United Tribes[1] (UCUT) completed Phase 1 and published its findings (UCUT 2019). Phase 1 studies consisted of a reintroduction risk and donor stock assessment, multiple assessments of habitat availability and suitability, an evaluation of fish passage technologies at high-head dams, Grand Coulee and Chief Joseph dams' operations and configurations, and life cycle modeling. Results from these studies indicate reintroduction of salmon to the blocked area could result in the production of 76,000 adult Sockeye salmon and 44,000 adult summer/fall Chinook given current habitat conditions, available stocks of fish and with the construction of effective fish passage systems at existing dams.

Following publication of the Phase 1 Report it was reviewed by the NPCC's Independent Scientific Advisory Board (ISAB; ISAB 2019). The ISAB found it reasonable that salmon reintroduction to blocked areas could be successful but noted that there is considerable uncertainty around dam passage and reservoir survival, the resulting number of adult salmon that will return, and the type of management required to sustain them. They suggested that a strategic implementation plan with an adaptive management process is needed to address uncertainties.

Phase 2 Implementation

This Phase 2 implementation plan describes research needed to resolve Phase 1 uncertainties and the tools that will be used to guide management actions and evaluate their success. The objectives of Phase 2 are:

- Test the key biological assumptions made in Phase 1 considered critical for the success of the reintroduction effort.

- Establish the sources (and regulatory approvals) of Chinook (*Oncorhynchus tshawytscha*) and Sockeye (*Oncorhynchus nerka*) salmon donor stocks and broodstock that will be used to produce

[1] The Upper Columbia United Tribes are comprised of the Coeur d'Alene Tribe, Confederated Tribes of the Colville Reservation, Kalispel Tribe of Indians, Kootenai Tribe of Idaho, and the Spokane Tribe of Indians.

the juveniles and adults required to conduct biological studies and test fish passage facilities.

- Develop the interim hatchery and passage facilities required to evaluate reintroduction.
- Provide the data and analyses needed for Phase 3 decision-making. This includes data necessary to determine the need, type, and costs of permanent fish passage systems and hatchery production facilities.
- Conduct the studies and implement Phase 2 reintroduction work such that it does not:
    a. introduce ESA-listed species into the blocked area
    b. require major operational changes to the hydrosystem such as power production, flood control or irrigation
    c. reduce salmon harvest downstream

Scientific Framework

During Phase 1, a life cycle model (LCM) was developed to evaluate the feasibility of reintroduction. This new LCM is like those used in Willamette River fish passage planning. During Phase 2, locally collected empirical data will replace LCM assumptions used in Phase 1. The LCM will be continually updated as results from Phase 2 studies are generated both annually and at the conclusion of individual research projects. Outputs from the LCM will then be used to refine studies; informing sample sizes required to meet desired levels of confidence, and the order in which studies and actions are carried out. Once all assumptions are replaced with locally derived data the LCM will provide measures of fish and population performance and allow for the testing of different management scenarios. A stepwise and adaptive management framework has been developed to collect the data necessary to resolve critical modeling uncertainties.

Stepwise Approach

Phase 2 will be completed in a stepwise fashion. It is separated into two main steps and is forecasted to span approximately 20 years. The first step focuses on the collection of baseline information and the development of support programs and facilities. The second step focuses on the incremental design, build, and testing of fish passage facilities, breaking Step 2 into sub-steps that coincide with individual dams.

Step 1 – Baseline Studies and Interim Facilities (Years 1 – 6)

Step 1 will begin by evaluating blocked area outmigration and dam passage survival of juvenile hatchery summer/fall Chinook and juvenile Sockeye released at locations associated with presumed production areas (Rufus Woods Lake, Sanpoil River, Hangman Creek, Little Spokane River, and the Transboundary Reach). Acoustic telemetry will be used to estimate juvenile migration survival, dam passage survival and passage location (turbines and spill) through various reaches and dams in the study area. Results from this acoustic juvenile survival study will inform release group sizes in subsequent years and subsequent studies.

Large groups of juvenile Chinook and Sockeye (50,000 – 200,000 per species) will be tagged with a passive integrated transponder (PIT tag) and released with acoustic-tagged fish. Fish from the PIT tagged groups will be used to evaluate outmigration timing and survival through the Columbia River downstream of Chief Joseph Dam. An additional purpose of these larger release groups is to produce enough returning adults to allow for the estimation of upstream migratory behavior and survival as well as to seed blocked area spawning habitats[2]. These local-origin adults will also be used to estimate the collection efficiency of the Chief Joseph Hatchery ladder, determine the feasibility of using it as an interim adult collection facility and to determine if additional adult collection facilities are necessary at Chief Joseph Dam.

The initial interim upstream passage strategy will be a trap-and-haul program from below Chief Joseph Dam using transport trucks. Collected adults will be sorted according to their juvenile release location as determined by PIT code (or other mark). After fish are sorted, a genetic sample will be collected from each fish, and a subset will be implanted with an acoustic transmitter and hauled to the forebay of Grand Coulee Dam or the forebay of the first dam they encountered as juveniles. These translocated local-origin adult fish will be tracked through river impoundments and riverine habitats to determine migration survival, homing behavior and spawning areas. Tagged adults will also be tracked to determine tailrace behavior at each dam they encounter to gather data for the development of upstream passage options.

Each translocated adult will be genetically sampled for parentage-based tagging (PBT). In subsequent years, natural-origin adults returning to interim upstream passage facilities at Chief Joseph Hatchery and/or Dam will undergo PBT sampling, assigning their parentage and origin (hatchery or natural). The PBT sampling program will be used to estimate adult recruits per spawner (AR/S). AR/S will be used as a metric to evaluate fish and population performance under current conditions.

Several infrastructure improvements will be necessary to facilitate Step 1 activities. Interim small-scale artificial production programs will be needed to generate juveniles. The proposed production strategy is to use existing hatchery infrastructure, or to develop new interim small-scale facilities for egg incubation and early rearing to the sub-yearling life stage. The subyearlings will then be transferred to net pens and

---

[2] The need to produce returning adults is the major reason yearling Chinook will be used for the initial PIT tag group. Yearlings are expected to have double the survival rate of subyearling Chinook, thus reducing the number of fish and tags required to perform the study.

acclimation facilities associated with each release location (yearling Chinook) or planted directly into a reservoir or tributary (subyearling Sockeye salmon). Additional net pens for in-reservoir rearing and multiple interim acclimation facilities will be needed at certain tributary sites (e.g., Sanpoil River and Hangman Creek).

Step 2 – Interim Passage and Supporting Studies (Years 7 – 21)

Step 2 is broken into sub-steps, with each corresponding to the design, installation, and testing of interim fish passage facilities at individual dams. The sequence of developing interim fish passage facilities proposed herein is based on results from life cycle modeling performed in Phase 1. The need for, and identification of, the types of interim facilities to be tested will be based on recommendations of the fish passage development team with policy concurrence (Section 3).

Dam passage survival data from Step 1 will be used to adaptively manage the sequence in which interim passage facilities are developed. Step 1 fish passage routing and fish behavior data will be used to inform the design of upstream and downstream interim passage facilities. Based on results from the Phase 1 LCM, and what is considered to provide the most benefits for salmon reintroduction, the proposed sequence for interim fish passage development is:

- Upstream passage at CJD (design/install initiated in Step 1)
- Downstream passage at GCD
- Upstream passage at GCD
- Upstream passage at Spokane River dams
- Downstream passage at CJD and Spokane River dams

Research, monitoring, and evaluation (RM&E) and supporting activities from Step 1 will need to be continued in Step 2. Interim hatchery production will be used to provide juveniles necessary for testing the effectiveness of downstream passage facilities. Releases of PIT tagged juvenile Chinook and Sockeye will continue to update survival estimates and provide a consistent supply of returning local-origin adults needed for testing upstream passage facilities. The trap-and-haul program will be re-scaled as upstream passage facilities become operational and adult production increases. PBT sampling of returning adults along with continual RM&E will be used to update metrics of fish and population performance.

Adaptive Management and Decision Making

Adaptive management will occur during and between steps and sub-steps. Research projects will also be adaptively managed on an annual basis to improve results and performance metrics. At the conclusion of each study year, levels of statistical confidence and LCM outputs will be reviewed to inform modifications to the study design to improve results for the following study year (e.g., increase sample sizes) or subsequent study. Once the study is complete, performance metrics will guide decision-making by following decision flow charts (see Section 2.7). The decision flow charts for fish passage planning rely on several performance metrics: juvenile passage survival per dam and AR/S per associated production area and combined production. These performance metrics will initially be used to inform the sequence of installing interim fish passage facilities. As fish passage is provided at one project, RM&E will continue, and the updated performance metrics will guide the next action by following the subsequent flow chart.

Fish Passage Facility Development

Several concepts for upstream and downstream fish passage strategies were developed during Phase 1. These include both traditional passage techniques such as ladders and trap-and-haul, as well as emerging technologies such as floating surface collectors and pneumatic tubes. Little is known about fish behavior at each of the five dams, and therefore it is premature to subscribe to a particular passage strategy at an individual project. Instead, fish passage planning will follow the framework described in the U.S. Army Corps of Engineers (USACE) *Surface Bypass Program Comprehensive Review Report* (Compendium; USACE 2007). Research performed in Step 1, and continued throughout Phase 2, will be critical to guide how passage is prepared, interim facilities are developed, and eventually produced and operated.

Cost Estimates

The studies and actions described herein were designed to use existing infrastructure, tools, and technologies to reduce costs while also achieving program objectives. Cost estimates for Phase 2 studies, infrastructure, and operation and maintenance (O&M) were generated by applying costs associated with similar fish passage projects in the region to the blocked area. Cost estimates were scaled to reflect the magnitude of this effort, the unique conditions of each dam, and the existing body of regional knowledge and infrastructure.

The adaptive management approach of Phase 2 provides flexibility with respect to the actions required and the costs associated with them. There is more certainty for near-term actions and costs (i.e., those associated with Step 1). While actions and costs for Step 2 are less certain and more so the further they project into the future.

Phase 2 is estimated to cost ~$208 million, with Step 1 estimated to cost $39 million and $169 million for Step 2. Research, monitoring, and evaluation is estimated to cost $79 million over the 21-year phase, with $129 million associated with infrastructure, operations, and maintenance. These estimates were made in 2022 and will periodically be adjusted for inflation.

Phase 3 Decision-Making

The Phase 2 Implementation Plan lays out a framework to evaluate the technical feasibility of fish passage and salmon reintroduction to the blocked area of the upper Columbia River. Results from Phase 2 research, with updated performance metrics, will be synthesized into a comprehensive report to guide the development of alternatives that could be implemented for Phase 3.

Carrying out the actions described herein will provide the region with a better understanding of the benefits of permanent salmon reintroduction; cultural healing for local tribes, economic opportunities for local communities, increased fish production to support Columbia River and marine fisheries, and support for ecosystems dependent on robust populations of anadromous species. These benefits, in addition to the financial costs and technical feasibility, will all have to be weighed by policy and decision-makers as they determine if and how Phase 3 should be implemented.

Contents

List of Figures

List of Tables

1 INTRODUCTION

1.1 Background

Prior to European settlement of the Pacific Northwest, the abundance of salmon in the Columbia River was estimated to range from 7.5 to 16 million returning adults each year (Chapman, 1986; NPPC, 1987). Many of those salmon were from the area upstream of Chief Joseph Dam (CJD) and Grand Coulee Dam (GCD), which were built without fish passage structures. Even prior to the construction of GCD and CJD, the development of the Spokane River hydro-projects eliminated salmon from that river system. The loss of salmon from these watersheds has affected tribal people in many ways. Salmon were an abundant supply of healthy food, a critical part of tribal culture and spirituality; they brought nutrients back to freshwater ecosystems which bolstered aquatic and terrestrial food webs. The loss of salmon to the Upper Columbia Region has also affected people and animals in other areas, including the endangered Southern Resident Orcas, and sport, tribal, and commercial fishing in the lower Columbia River and Pacific Ocean. For many decades little was done to address the loss of salmon to the blocked area, until some grass roots efforts began in the 1990's and early 2000's. Then in 2004, reintroduction[3] was included in the Northwest Power and Conservation Council's Intermountain Provincial Plan. Shortly thereafter, in preparation for the re-negotiation of the Columbia River Treaty, the tribes on both sides of the border convened to outline a vision for how to bring salmon back to the blocked area of the Upper Columbia River. That effort culminated in the development of a report that outlined a phased approach for fish passage[4] and reintroduction[5] to the blocked area of the Upper Columbia River.

1.2 Phased Approach

In 2015, the Columbia Basin Tribes and First Nations (CBTFN) finalized the Joint Paper, "Fish Passage and Reintroduction into the U.S. and Canadian Upper Columbia Basin," to inform the Governments of the United States and Canada, and other sovereigns and stakeholders on how anadromous salmon may be successfully reintroduced into the upper Columbia River Basin.

The Joint Paper identified the following four goals for the reintroduction of anadromous salmon to habitat located upstream of Chief Joseph and Grand Coulee dams:

1. Restore naturally spawning and hatchery-based runs of Sockeye and Chinook salmon into the

---

[3] Within this document specific terms are defined to articulate the context in which it is used herein and avoid confusion that may arise from pre-existing definitions or applications. These terms are defined as footnotes.
[4] Passage: The act of, or means by which, fish overcome a migration barrier.
[5] Reintroduction: Returning locally extirpated anadromous species to historically occupied habitats to carryout freshwater stages of their life cycle. This may require management actions such as providing fish passage, assisted migration, and artificial production.

upper Columbia River basin, above Chief Joseph, Grand Coulee and Canadian dams to meet native peoples' cultural and spiritual values and benefits for all, including subsistence and harvest opportunities.

2. Increase Columbia River basin fish abundance, habitat diversity, ecosystem health and long-term sustainability of salmon and other fish species.

3. Establish and increase ceremonial and subsistence, sport and commercial fish harvest opportunities for all communities and citizens along the Columbia River in the U.S. and Canada – for the benefit of all.

4. Restore access and population structure of Bull Trout, Pacific Lamprey, White Sturgeon, and other native fish species to historical habitat.

To determine if the goals were achievable, an initial draft of the Joint Paper outlined a phased approach to reintroduction that was further refined and adopted by the Northwest Power and Conservation Council (NPCC) in the 2014 Columbia River Basin Fish and Wildlife Program (NPCC 2014). The Upper Columbia United Tribes (UCUT) adopted the four phases defined in the Joint Paper (CBTFN 2015):

Phase 1: Pre-assessment planning for reintroduction and fish passage.

Phase 2: Experimental, pilot-scale salmon reintroductions and interim[6] passage facilities.

Phase 3: Construct permanent juvenile and adult passage facilities and supporting propagation facilities. Implement priority habitat improvements.

Phase 4: Monitoring, evaluation, and adaptive management. Continue needed habitat improvements.

This implementation plan builds on the body of work developed by UCUT member tribes and their partners as part of the phased approach. It leverages lessons learned and processes currently applied to other salmon reintroduction efforts underway in the Columbia Basin and along the west coast. Pursuing this plan will continue progress towards meeting goals of the Tribal Coalition (CBTFN 2015) and is consistent with measures in the Northwest Power and Conservation Council's Columbia River Basin Fish and Wildlife Program (NPCC 2014, 2020), and approaches and strategies of the Columbia Basin Partnership Task Force (CBPTF 2020), the Washington State Governor's Office Executive Order (No.

[6] Interim: A temporary solution to evaluate the feasibility of an action, facility, or strategy developed to meet a specified goal and inform the design and development of permanent alternatives.

18-02; WSGO 2018) and 2021 update to the Governor's Salmon Strategy (WSGO 2021), and the Southern Resident Orca Task Force (SROTF 2019). Reintroduction of salmon upstream of Chief Joseph and Grand Coulee dams has received further support from Washington State's Department of Fish and Wildlife and Department of Ecology, as well as the US Geological Survey, the City of Spokane (City Council Resolution No. 2014-0070; CS 2014), and numerous other organizations and individuals throughout the Basin including the Pacific Fisheries Management Council who provided a letter of support for the ongoing studies and projects related to reintroduction. Upper Columbia Tribes and their partners are confident they can carry out the research needed to answer the remaining questions as to whether reintroducing anadromous fish to these historic habitats is indeed feasible[7].

1.3 Phase 1 Findings and Conclusions

The Phase 1 report was completed by the UCUT organization and its member tribes in 2019 (UCUT 2019). The report synthesized the suite of research performed by the UCUT member tribes and their partners, presenting findings on possible donor stocks, risks to resident species and downstream populations[8] from reintroduction, stream and reservoir habitat quality and quantity, feasibility of implementing effective upstream and downstream fish passage, and expected adult summer/fall Chinook and Sockeye production in the U.S. portion of the basin. The abundances and productivity of the populations were based on the results of a life-cycle model developed specifically for the reintroduction effort that used values from the literature on juvenile and adult survival rates through the mainstem Columbia and habitat analyses for the region[9]. Total adult production for both summer/fall Chinook and Sockeye combined was estimated to range from a few thousand to tens of thousands of fish. These findings confirmed that the reintroduction of salmon to the United States portion of the upper Columbia River upstream of Chief Joseph Dam was likely to achieve the first three identified tribal goals presented in the Joint Paper given current dam operations, existing riverine and reservoir habitat

> **Phase 1 Conclusion**
>
> Given habitat conditions, availability of donor stocks, and likely effectiveness of fish passage systems, the reintroduction of salmon to the blocked area is likely to achieve tribal and regional goals.

[7] Feasible: Able to achieve, build, or carryout.
[8] Population: A group of fish that are from a similar geographic area, which may include being released from a hatchery or generated from a spawning event. For the purposes of this report and the reintroduction work, the term "population" does not imply that the group of fish has a unique genetic background or differentiation from other areas.
[9] The Spokane River basin was not modeled in Phase 1 as EDT modeling outputs were not available at that time. Since then, an LCM has been developed for summer/fall Chinook populations in that basin and the results incorporated into this plan.

conditions, donor stock availability, risks to resident fish species, and the likely effectiveness of state-of-the-art juvenile and adult passage technology.

1.3.1 Donor Stocks

Disease, genetic, and policy constraints associated with the Endangered Species Act (ESA) have led managers to focus on summer/fall Chinook and Sockeye salmon for reintroduction activities in Phase 2. Species and stocks listed under ESA may be considered for reintroduction once ESA policy constraints are resolved. Concurrently, the UCUT member tribes will continue to utilize unlisted spring Chinook in meeting some cultural and ceremonial needs.

There are multiple donor sources available for reintroducing summer/fall Chinook and Sockeye to areas upstream of Chief Joseph and Grand Coulee dams. Most stocks from within the Evolutionary Significant Unit (ESU) had similar scores and would be acceptable donors, if/when they are available. Natural-origin fish are preferable with respect to genetics and productivity, but generally are not abundant enough in most years for translocation.

The Chief Joseph Hatchery stock of summer/fall Chinook was the highest ranked donor source because the program broodstock consists of a high proportion of natural-origin (NOR) broodstock from the Okanogan River and generally return in high enough numbers that surplus fish will be available for brood and adult transplants. Hanford Reach and Wenatchee River hatchery programs were the next highest ranked donor stocks for summer/fall Chinook followed by natural-origin Okanogan River fish, which were ranked lower due to limited availability. Other stocks such as Wells Fish Hatchery and Entiat National Fish Hatchery may also be considered given their availability and similar genetic lineage.

For Sockeye salmon, Lake Roosevelt native kokanee were the highest ranked donor stock because of their local adaptation, low genetic risk, and low disease risk (but only by a very narrow margin over Okanogan River Sockeye). However, Lake Roosevelt kokanee are not readily available as a brood source, making them impractical as a donor source for testing feasibility. The second-highest ranked donor was the Okanogan River natural-origin Sockeye Salmon, followed by the Lake Wenatchee Sockeye Salmon and the Penticton Hatchery (Okanogan River) Sockeye Salmon.

1.3.2 Habitat

Five different types of habitat analyses were conducted in Phase 1 to determine habitat potential upstream of the two dams. The analyses were as follows:

1. Intrinsic potential model of tributary habitats to identify and quantify streams and reaches that may support spawning and rearing activity for Chinook and steelhead (*O. mykiss*) (Giorgi 2018).

2. An Ecosystem Diagnosis and Treatment (EDT) model to summarize the potential performance of

spring Chinook, summer/fall Chinook and steelhead in select tributaries, given current habitat conditions (ICF 2017 and 2018).

3. An assessment of the quantity of potential spawning habitat for summer/fall Chinook in free-flowing large mainstem sections of the Columbia River, in Rufus Woods Lake and the Transboundary reach (Hanrahan et al. 2004, Baldwin and Bellgraph 2017, Bellgraph et al. 2020, Golder Associates 2016 and 2017).

4. Estimations of potential Sockeye spawner abundance in the Sanpoil River (Baldwin 2018).

5. An assessment of the rearing capacity of Lake Roosevelt for juvenile Sockeye Salmon based on recent trends in reservoir productivity (Giorgi and Kain 2018).

For summer/fall Chinook, there is approximately 17 miles of large river habitat in the free-flowing section of Rufus Woods Lake, 60 miles in the Sanpoil River, 230 miles in the Spokane River watershed, and 36 miles of large river habitat in the U.S. portion of the Transboundary Reach.

There is approximately 40 miles of Sockeye habitat in the Sanpoil River. Grand Coulee Reservoir has sufficient juvenile rearing habitat to support between 12 million and 48 million fish. Adult spawning capacity in Christina Lake and the Transboundary Reach is sufficient to support several thousand spawners.

Additional habitats are available for spring Chinook and steelhead, although as the most appropriate donor stocks for these species are constrained by ESA and disease concerns, Phase 2 activities will primarily occur in habitats most suitable[10] to summer/fall Chinook and Sockeye.

[10] Suitable: Provides the conditions necessary for an organism or species to perform one or more aspects of its life cycle. Often in reference to habitats a species is expected to use during a specific life-stage and the behaviors associated with that life-stage.

1.3.3 Fish Passage and Project Operations for Chief Joseph, Grand Coulee, and Spokane River Dams

In Phase 1, the environmental, operational, and structural conditions at Chief Joseph Dam and Grand Coulee Dam were evaluated to determine the potential to build effective upstream and downstream fish passage for Chinook and Sockeye at each project. The evaluations showed that the construction of such passage systems was feasible and would likely provide safe, timely and effective passage at both Chief Joseph Dam and Grand Coulee Dam under current dam operations and configurations.

The theorized effectiveness of juvenile fish passage systems was due in part to the configuration of the dams that result in small effective forebay[11] areas. The effective forebay areas for Chief Joseph Dam and Grand Coulee Dam are 51 acres and 11 acres, respectively, based on preliminary locations for siting a floating surface collector (FSC)[12]. Research has shown that FSCs located in forebays with effective areas of <50 acres have shown fish collection efficiency (FCE) of greater than 95% for some salmon species (Kock et al. 2019).

For adult upstream passage, the existing fish ladder at the Chief Joseph Hatchery could be used as a temporary facility to collect adult returns in the near term for upstream passage. Dependent on the fish collection efficiency and capacity of this ladder, a second facility may be needed at the base of Chief Joseph Dam.

Grand Coulee Dam is not equipped with an upstream fish passage system. The Phase 1 report identified a possible location (left bank) to trap and collect fish for transport and release upstream of the dam.

Rocky Reach Corner Collector

The third powerhouse of Grand Coulee is configured like that of Rocky Reach Dam. At that facility, a corner collector, located similarly as the FSC in Figure 2, has been successful at collecting and bypassing juvenile salmonids.

---

11 Effective Forebay: The area of the forebay that downstream migrants can access between the dam and the 500m mark located upstream of a collector entrance (Kock et al. 2019).

12 Note that the forebay area presented for Grand Coulee is for the third powerhouse. Forebay area for the other two powerhouses would be larger. Data collected at Grand Coulee dam indicated that over 85% of all hydroacoustic detections of fish were at the third powerhouse (see Phase 1 Report).

Figure 1. Image showing the potential location of a floating surface collector (blue box) at Chief Joseph Dam. White line denotes powerhouse effective forebay area. Total effective forebay area is 51 acres.

For Spokane River dams, high levels of spill during the assumed juvenile outmigration period may result in relatively low juvenile passage mortality. Therefore, juvenile passage facilities may not be necessary at Little Falls and Nine Mile dams to achieve LCM survival assumptions. Recently installed de-gassing structures at Long Lake Dam may increase passage mortality at this project, however. An effective forebay area of 5.6 acres indicates that a surface collector would be a viable option at Long Lake Dam for juvenile passage. Survival studies outlined in Phase 2 will help to determine the potential need for and location of juvenile bypass facilities at all three Spokane River projects.

Figure 2. Image showing potential location for a floating surface collector (blue box) at Grand Coulee Dam. White line denotes powerhouse effective forebay area. Total effective forebay area is 11 acres.

The relatively small size and low head of Spokane River dams increases the feasibility of upstream passage solutions. Little Falls Dam historically had a fish ladder that was later decommissioned after the construction of dams upstream that created migration barriers and eliminated the need for passage at Little Falls at that time.

1.3.4 Life-Cycle Modeling Results

Estimates of adult summer/fall Chinook and Sockeye natural production were generated by the LCM given best estimates of habitat conditions, adult and juveniles survival rates through dams and reservoirs and hypothesized effectiveness of juvenile and adult passage facilities at each hydroelectric project

Again, it needs to be emphasized there is considerable uncertainty associated with model assumptions. Adult and juvenile production could be much higher or lower than assumed, depending on how accurate the assumptions are to realized results from reintroduction efforts.

1.3.4.1 Summer/Fall Chinook

LCM estimates of summer/fall Chinook production with hatchery supplementation of adults and juveniles for each production area are shown in Table 1. The model estimates that approximately 6.1 million NOR Chinook juveniles will arrive below Chief Joseph Dam. Most of these fish (91%) are expected to migrate as subyearlings during the spring and summer (April through August) with smaller numbers migrating in the fall (September through October) and the following spring (April through May) as yearlings.

Summer/fall Chinook equilibrium adult abundance (NEQ) estimates for the natural populations modeled using the LCM ranged from 850 to 33,000 and adult productivity from 1.01 to 2.92 (Table 2). Due to the low adult productivity values, the harvest rates these populations can withstand and remain viable[13] are less than 42%, given modeling assumptions (see MSY Harvest Rate in Table 2). Currently, combined harvest rates on summer/fall Chinook in marine and freshwater fisheries downstream of Chief Joseph Dam are greater than 55% in most years. Thus, summer/fall Chinook natural production may require supplementation with hatchery fish to sustain production.

The results also show that the modeled combination of hatchery and natural production could result in an increase in Columbia River summer/fall Chinook production of 44,124 fish pre-harvest (Table 1). These adults would contribute to marine and lower river freshwater fisheries, provide fish for harvest upstream of Grand Coulee Dam, and meet regional goals of having summer/fall Chinook spawning naturally in historic areas while increasing salmon production from the Columbia Basin. These estimates do not quantify the number of fish that benefit river, estuary, and ocean ecosystems by providing prey to avian, pinniped and Orca predators.

1.3.4.2 Sockeye Salmon

LCM results from Phase 1 indicate that Sockeye salmon reintroduction to habitats upstream of Grand Coulee Dam could result in the production of 2.1 million NOR juvenile yearlings and 75,000 adults (NOR + HOR) (Table 3). These fish would contribute to fisheries and re-establish natural spawning in historic areas. Most of the Sockeye salmon production is expected to come from the Sanpoil River, followed by the Transboundary Reach and then Christina Lake.

Unlike summer/fall Chinook, the current harvest exploitation rate on Sockeye salmon (~19%) is less than the estimated MSY harvest rate (20%)[14] for the two largest production areas, the Sanpoil River and Transboundary Reach (Table 2). Thus, if all modeling assumptions regarding habitat, fish passage survival, etc. are accurate, Sockeye production upstream of Grand Coulee may be self-sustaining without long term supplementation with hatchery fish.

---

[13] Viable: Capable of surviving or successfully carrying out a life stage or behavior under environmental conditions. Not in the context of Endangered Species Act, recovery criteria, or other regulatory frameworks.

[14] Phase 1 modeling included an additional 10% harvest rate upstream of Grand Coulee Dam.

Table 1. LCM results for summer/fall Chinook production areas associated with Rufus Woods Lake, Sanpoil River, Spokane River, and Transboundary Reach. Results reflect supplementation of natural production with hatchery-origin juvenile and/or adult summer/fall Chinook.

Model Results (after 100 Generations)					
Summer/Fall Chinook Juvenile Production	**Rufus**	**Sanpoil**	**Spokane**	**Transboundary**	**Total**
NOR Fry Production (before passage)	3,751,969	223,747	595,497	4,833,094	9,404,307
Hatchery Releases - Subyearlings	0	500,000	1,000,000	1,000,000	2,500,000
Hatchery Releases - Yearlings	0	0	0	0	0
NOR Subyearling - Spring/Summer Migrants Below CJD	2,673,861	60,289	123,048	2,716,514	5,573,712
NOR Subyearling - Fall Migrants Below CJD	200,090	9,451	22,019	249,104	480,664
NOR Yearling - Spring Migrants Below CJD	17,026	3,301	7,867	21,162	49,356
Hatchery Subyearlings Below CJD	0	486,750	243,607	925,539	1,655,896
Hatchery Yearlings Below CJD	0	0	13,211	1,429	14,640
Total Juveniles Below CJD	2,890,980	559,791	409,752	3,913,753	**7,774,276**
Total Juveniles below BON	802,340	152,637	120,040	1,088,450	**2,163,467**
Summer/Fall Chinook Adult Production	**Rufus**	**Sanpoil**	**Spokane**	**Transboundary**	**Total**
Adult Runsize (before Harvest and Passage)	16,329	3,049	2,547	22,199	44,124
Adult Runsize (before Harvest and Passage) - NORs	16,329	447	951	17,054	34,781
Adult Runsize (before Harvest and Passage) - HORs	0	2,602	1,597	5,145	9,344
Adult Runsize to below CJD	6,451	1,195	1,000	8,751	17,397
Total Adult Loss to Passage	1,705	367	433	3,076	5,581
Broodstock Removal - NORs	0	73	170	59	302
Broodstock Removal - HORs	0	221	512	529	1,262
Adult Outplants - NORs	0	0	0	0	0
Adult Outplants - HORs	1,000	0	1,000	2,000	4,000
Spawning Escapement - NORs	5,220	42	75	4,654	**9,991**
Spawning Escapement - HORs	1,000	359	1,000	2,803	**5,162**

Table 2. LCM derived Beverton-Holt production function parameters for summer/fall Chinook and Sockeye production areas associated with Rufus Woods Lake, Lake Roosevelt, and the Spokane River.

Summer/Fall Chinook				
Parameter	Chief Joseph - Rufus Woods Lake	Sanpoil River and Lake Roosevelt Tributaries	Spokane River and Tributaries	Mainstem Columbia River Upstream Lake Roosevelt (Transboundary)
Productivity	2.92	1.01	1.47	2.13
Capacity	46,447	129,364	2,681	61,690
NEQ	30,527	1,502	854	32,732
RMSY	19,254	753	468	19,424
Escapement	5,220	749	386	13,308
MSY Harvest Rate	0.41	0.01	0.17	0.31
Modeled Harvest Rate	0.58	0.62	0.58	0.58

Sockeye			
Parameter	Christina Lake	Sanpoil River and Lake Roosevelt Tributaries	Mainstem Columbia River Upstream Lake Roosevelt (Transboundary)
Productivity	1.13	1.58	1.58
Capacity	4,228	84,165	12,172
NEQ	487	30,832	4,458
RMSY	251	17,167	2,482
Escapement	236	13,665	1,976
MSY Harvest Rate	0.06	0.20	0.20
Modeled Harvest Rate	0.27	0.27	0.27

NEQ – Equilibrium Adult Abundance; RMSY – Adult Recruits at Maximum Sustainable Yield; MSY – Maximum Sustainable Yield.

Table 3. Phase 1 LCM results for Sockeye salmon. Results reflect supplementation of natural production with hatchery-origin juvenile and adult Sockeye.

Model Results (after 100 Generations)				
Sockeye Juvenile Production	**Chistina Lake**	**Sanpoil**	**Mainstem**	**Total**
NOR Fry Production (before passage)	379,048	6,187,439	1,560,792	8,127,279
Hatchery Releases - Subyearlings	1,500,000	2,000,000	2,999,709	6,499,709
Hatchery Releases - Yearlings	0	0	0	0
NOR Subyearling - Spring Migrants Below CJD	0	0	0	0
NOR Subyearling - Fall Migrants Below CJD	0	0	0	0
NOR Yearling - Spring Migrants Below CJD	74,793	1,648,056	415,841	2,138,690
NOR Age 2 - Spring Migrants Below CJD	0	0	0	0
Hatchery Subyearlings below CJD	0	0	0	0
Hatchery Yearlings below CJD	295,975	510,262	754,941	1,561,178
Total Juveniles below CJD	370,768	2,158,318	1,170,782	**3,699,868**
Total Juveniles below BON	152,015	884,910	480,021	**1,516,946**
Sockeye Adult Production	**Chistina Lake**	**Sanpoil**	**Mainstem**	**Total**
Adult Runsize (before Harvest and Passage)	7,601	44,246	24,001	75,848
Adult Runsize (before Harvest and Passage) - NORs	1,533	33,785	8,525	43,843
Adult Runsize (before Harvest and Passage) - HORs	6,067	10,461	15,476	32,004
Adult Runsize to below CJD	4,934	28,724	15,581	49,239
Total Adult Loss to Passage	2,352	13,691	7,427	23,470
Broodstock Removal - NORs	365	487	730	1,582
Broodstock Removal - HORs	1,096	1,461	2,191	4,748
Adult Outplants - NORs	.	1,000	1,000	2,000
Adult Outplants - HORs	.	0	0	0
Spawning Escapement - NORs	278	13,692	2,848	**16,818**
Spawning Escapement - HORs	1,450	2,929	4,304	**8,683**

1.4 Independent Science Advisory Board Review of Phase 1 Report

The ISAB reviewed the Phase 1 report in November of 2019 (ISAB 2019). The ISAB found it reasonable to expect that reintroduction to blocked areas could be successful, although there is great uncertainty about the number of adult salmon that will return, and the management actions required to sustain them. They suggested that a strategic plan for future steps and an adaptive management process are needed to address these uncertainties.

Due to the large uncertainty surrounding estimates of salmon capacity and habitat availability, the ISAB encouraged UCUT member tribes and the Council to make decisions conservatively and with caution as they move forward with the reintroduction effort.

The ISAB suggested that in Phase 2, additional information is needed on the following:

- estimated costs of fish passage facilities,
- predation, disease, and climate effects[15],
- total dissolved gas levels in project tailraces and effect on salmonids,
- donor stock availability and management,
- interactions of hatchery and natural-origin fish, and
- possible use of ESA listed stocks in reintroduction efforts.

The ISAB also suggested that UCUT member tribes may wish to consider a "steppingstone" approach of progressively establishing reintroduction programs from lower to upper regions in the anadromous blocked zone to allow for research on potential impacts of juvenile releases.

The ISAB review of the Phase 1 report was extremely valuable to UCUT member tribes in developing plans for Phase 2. This present document represents the strategic plan and the associated adaptive management process suggested by the reviewers. Described within this plan are estimated costs of fish passage facilities, a modified steppingstone approach, a genetics-based monitoring program, and an adaptive management process that will help identify limiting factors. This plan does not propose to study the effects of total dissolved gas (TDG) in the blocked area. A cursory evaluation of available information on TDG was conducted and it appears that TDG levels in the blocked area are generally similar to or less than downriver sites (Appendix F). It also appears that TDG is not likely to be an issue during normal to low flow years. Consistent with the ISAB recommendation, available data on TDG will continue to be summarized and evaluated with respect to potential effects on reintroduced salmon throughout the implementation of Phase 2.

Based on Phase 1 results, ISAB review of these results, and subsequent analyses, the UCUT member tribes and their partners are proceeding to Phase 2. Phase 2 feasibility studies will include the entire historic range of anadromous fish upstream of Chief Joseph Dam within the United States, including habitats in the Spokane River watershed. LCM results for expected Chinook production from this basin have been incorporated into this report. Field studies addressing critical uncertainties associated with

---

[15] Additional analysis of climate effects on the reintroduction effort, or how habitat upstream of the dams can alleviate climate impacts to salmonids, has not been included in this report. The plan envisions that it will require 21-years to decide whether to reintroduce fish to the blocked area. Rather than forecasting climate effects this far into the future, we will use updated climate data at that time to address the issue and include it in the Phase 3 decision process.

juvenile rearing, migratory, and passage survival will be performed in a stepwise manner. Simultaneous efforts will focus on conducting field studies to collect new data along with advancing the development of fish production and passage facilities. Phase 2 is expected to take approximately 21 years to complete, if adequately funded. The stepwise approach and adaptive management process are described in the following section of this document.

2 PHASE 2

2.1 Goals and Objectives

The primary goal of Phase 2 is to further test and pursue the feasibility of salmon passage and reintroduction through the implementation of experimental releases of adult and juvenile salmon upstream of Chief Joseph, Grand Coulee, and Spokane River dams, and testing of interim fish passage facilities. Combined, these actions will address critical uncertainties and modeling assumptions and determine if the reintroduction effort should move to Phase 3. It is in Phase 3 where permanent fish passage and hatchery facilities are to be constructed and operated.

> **Salmon Population Goals**
>
> Population abundance, harvest and adult escapement goals for Rufus Woods Lake, Sanpoil River, Spokane River, and the Transboundary Reach will be developed as part of Phase 2 activities.

Phase 2 objectives are as follows:

- Test the key biological assumptions made in Phase 1 considered critical for the success of the reintroduction effort.
- Establish the sources (and regulatory approvals) of Chinook and Sockeye donor sources and broodstock that will be used to produce the juveniles and adults required to conduct biological studies and test fish passage facilities.
- Develop the interim passage and hatchery facilities required to evaluate reintroduction.
- Provide the data and analyses needed for Phase 3 decision-making. This includes data necessary to determine the need, type, and costs of permanent fish passage systems and hatchery production facilities.

2.2 Implementation Strategy Principles

The Phase 2 implementation strategy is guided by the following principles:

- Studies will be prioritized based on their ability to support decision-making related to adult or juvenile passage facilities.
- Studies will be prioritized on their ability to gather the most data at the lowest cost.
- Performance metrics will be used to link study results to passage and hatchery supplementation decision-making.
- Lower cost fish passage alternatives are preferred when fish benefits are similar.
- Fish passage systems must have negligible effect on Chief Joseph Dam and Grand Coulee Dam power, water supply, and flood control operations.
- Actions that lead to the earliest attainment of program goals are preferred.

Principles

The principles represent initial policy direction for the reintroduction program. These principles will be continuously reviewed during Phase 2 as more is learned about the likely success of reintroduction efforts.

- Actions that provide continuing benefits to fish (anadromous and resident) regardless of reintroduction success are preferred.
- Studies and actions to meet program goals will be implemented in a manner that minimizes impacts to ESA listed species and critical habitat.
- ESA-listed donor stocks will not be used for Phase 2 research unless their protective restrictions are removed when in the blocked area.
- Harvest rates for fisheries occurring downstream of Chief Joseph Dam will not be altered by the reintroduction effort.

2.3 Scientific Framework

The estimated adult production of summer/fall Chinook and Sockeye salmon from the reintroduction of these species to habitat upstream of Chief Joseph, Grand Coulee, and Spokane River dams are based on the results of life cycle modeling. These results incorporated estimates of Chinook and Sockeye salmon population(s) productivity and capacity by life stage (egg-to-adult), upstream and downstream fish passage survival rates to and from the reintroduction area, interactions between hatchery-origin and natural-origin fish, marine survival, and harvest in freshwater and marine fisheries. The LCM thus forms the scientific framework upon which the reintroduction effort is based. As more is learned about fish performance and the effectiveness of fish passage facilities, this information will replace assumptions within the LCM and the model rerun, sequentially eliminating critical uncertainties, and informing next steps. Only after all critical assumptions are replaced by locally collected data, including evaluations of interim passage facilities, and the model is rerun, can conclusions be drawn about feasibility[16]. To further inform reintroduction feasibility, various scenarios of artificial production strategies will be modeled to determine the scope of hatchery programs needed to support salmon colonization and harvest.

2.3.1 Life Cycle Model Assumptions and Performance Metrics

The key assumptions used in the LCM form the working hypotheses that capture our understanding of how the system currently influences the reintroduction of Chinook and Sockeye salmon. Phase 2 studies will be focused on testing those assumptions and their associated metrics that 1) influence management decisions 2) are uncertain and 3) are feasible to observe and estimate in a reasonable timeframe.

Of all the key assumptions, adult and juvenile fish passage survival rates past dams were found to be the most critical for achieving reintroduction goals. Habitat quality and quantity is a critical component of reintroduction as well, but unless fish can successfully migrate to the ocean and back at high rates of survival, then stream habitat condition has less relevance to program success.

The critical fish passage uncertainties and their performance metrics for summer/fall Chinook production areas throughout the blocked area, and Sockeye salmon production areas inhabiting stream habitat upstream of Grand Coulee Dam are presented in Table 4 and Table 5. A summary of all major assumptions used in developing the LCM can be found in the Phase 1 Report (UCUT 2019).

[16] Feasible/Feasibility: Able to achieve, build or carryout.

Table 4. Fish passage key assumptions and performance metrics associated with summer/fall Chinook production areas (populations).

Key Assumption	Summer/Fall Chinook Population		
	Spokane River	Transboundary/Sanpoil	Rufus Wood
Riverine and Reservoir Migration Survival	76% (to GCD)	60% Transboundary (to GCD) > 90% Sanpoil (to GCD)	> 90% (to CJD)
Juvenile Collection Efficiency - GCD	85% to 87%	85% to 87%	.
Juvenile survival through GCD	44% to 50%	44% to 50%	.
Juvenile Survival through CJD	44% to 88%	44% to 88%	44% to 88%
Juvenile Collection Efficiency - CJD	70% to 87%	70% to 87%	70% to 87%
Juvenile Survival CJD - BON	27% to 45%	27% to 45%	27% to 45%
Adults Survival Bon - CJD	83%	83%	83%
Smolt to Adult Survival Rate as Measured at CJD	0.44% - 0.96%	0.44% - 0.96%	0.44% - 0.96%
Adult Upstream Collection Efficiency	CJD = 95% GCD = 95% SRDs = 95% (each)	CJD = 95% GCD = 95%	95%

Table 5. Fish passage key assumptions and performance metrics associated with Lake Roosevelt Sockeye production areas (Sanpoil River, Christina Lake, Transboundary Reach).

Key Assumption	Performance Metric
Collection Efficiency - GCD	75%
Juvenile survival through GCD	44%
Juvenile Survival GCD Tailrace to CJD	92%
Juvenile Survival through CJD	88%
Juvenile Collection Efficiency - CJD	70%
Juvenile Survival CJD - BON	41%
Adults Survival Bon - CJD	76%
Smolt to Adult survival rate as measured at CJD	1.56%
Adult Upstream Collection Efficiency	95%

2.3.2 Stepwise Approach

The Phase 2 Implementation Plan is separated into two main steps. Step 1 focuses on conducting preliminary behavioral and survival studies for juvenile and adult fish and the development of fish rearing programs. These studies are essential for the planning of interim passage facilities at each hydroelectric project, and to test and refine many of the survival assumptions entered in the LCM. Step 2 focuses on design, installation, and testing of interim passage facilities, in addition to a RM&E program tailored to monitor the efficacy of fish passage and inform adaptive management of the reintroduction program. Step 2 is broken down into sub-steps that correspond with the installation of individual interim passage systems. Having sub-steps also provides some flexibility in the order of installation, allowing for adaptive management of the installation and testing of interim passage facilities depending on where survival bottlenecks occur, and where the most benefit may be gained. Within step 2, there is also opportunity to expedite the installation and testing of passage systems at multiple projects simultaneously if the resources and authorities to do so are available. Throughout the Phase 2 reintroduction program, regulatory processes will be addressed to secure authorization at the tribal, state, and federal levels (discussed in more detail in Section 5). A more detailed description of each step is outlined in Section 2.5.

2.3.3 Adaptive Management Approach

Flow charts linking performance metrics to decision-making will be used to adaptively manage the stepwise process both within and between steps. At the conclusion of each study year the results will be evaluated by researchers and stakeholders. If the metrics do not meet the level of statistical confidence identified by policy makers, sample sizes for the following year will be adjusted. The result of this feedback loop will be empirically supported by LCM parameters that meet the level of statistical confidence identified by policy makers for decision-making.

The LCM will be used as the tool to evaluate resulting fish production under various combinations of fish passage systems, hatchery production levels, and release locations. Sensitivity and variability analyses associated with new iterations of the LCM will inform studies for subsequent activities.

At the end of each step, a technical team will formally review findings, draw conclusions, and make recommendations for activities to be conducted in the next step. This information will be assembled in a report for formal review by stakeholders at the end of each step.

2.4 Geographic Scope and Associated Salmon Production Areas

Phase 2 studies will focus on all historic habitats within the U.S. for anadromous fish and the associated hydroelectric facilities currently blocking access to them (Figure 3). Key areas likely to support most of the summer/fall Chinook salmon production include Rufus Woods Lake, the Transboundary Reach of the Columbia River, the Sanpoil River, and the Spokane River. Sockeye salmon production within the blocked area include the Transboundary Reach of the Columbia River, Christina Lake, and the Sanpoil River.

2.4.1 Rufus Woods Lake Summer/Fall Chinook

LCM results for summer/fall Chinook indicated that the Rufus Woods Lake production area could be self-sustaining with the construction of effective upstream and downstream fish passage facilities at Chief Joseph Dam. However, population productivity and capacity are based on habitat modeling and not empirical measurements of fish performance. Thus, there is considerable uncertainty around the accuracy of habitat potential and ability to support natural production without continued supplementation with hatchery fish.

LCM results also showed that even if juvenile passage facilities were not built, population productivity and capacity could still be such that a small natural population of summer/fall Chinook could be maintained with continued hatchery supplementation. With annual supplementation of 1,000 hatchery or natural-origin adult transplants in addition to the returning progeny, and no new juvenile bypass facility, total adult production (pre-harvest) could range from ~2,500 to 35,000 returning adults, dependent on marine survival (Figure 4).

Rufus Woods Lake Chinook Production

LCM results indicate that the 17 miles of river habitat in Rufus Woods Lake may produce 1,000’s of fish even without the construction of juvenile fish passage at Chief Joseph Dam.

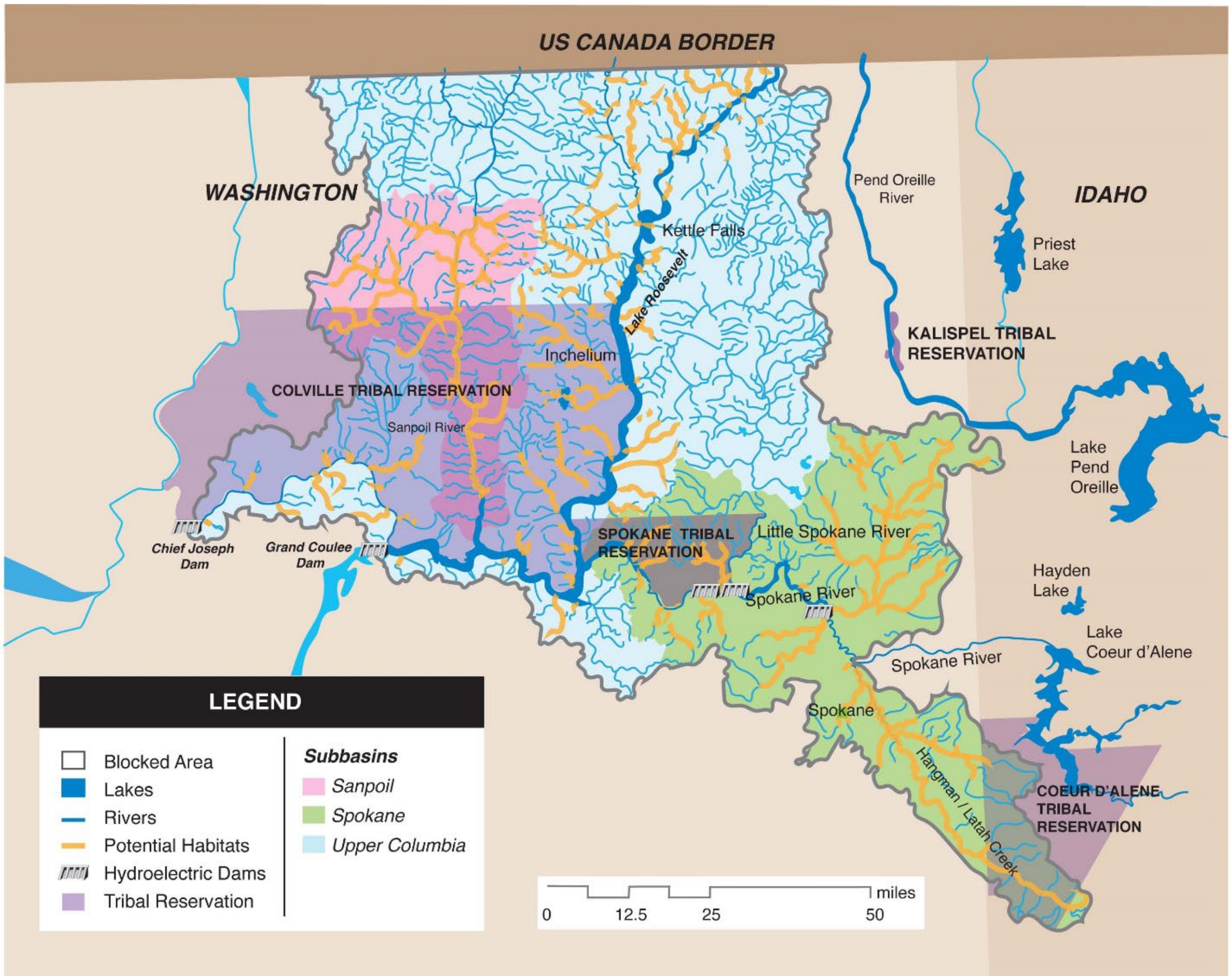


Figure 3. Habitats and passage barriers proposed for Phase 2 reintroduction studies in the Upper Columbia River Basin.

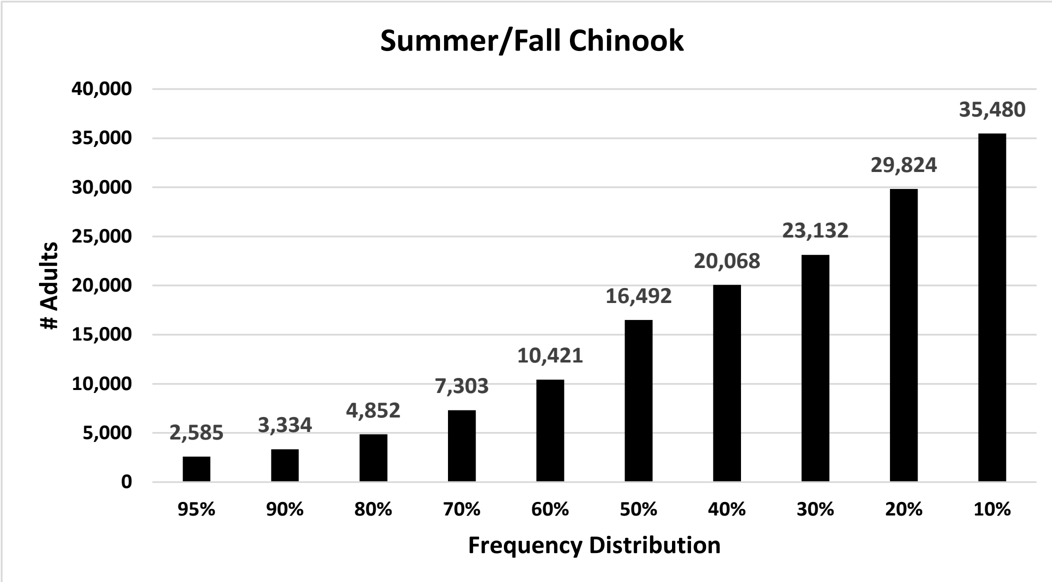


Figure 4. LCM generated 10% to 95% total adult natural-origin summer/fall Chinook frequency distribution for Rufus Woods Lake absent juvenile fish passage facilities at Chief Joseph Dam. The adult numbers are based on Pacific Decadal Oscillation conditions for 1999 – 2013 and an annual release of 1,000 hatchery-origin adults. Each bar represents the frequency of model runs that were greater than the associated adult abundance value (e.g., 95% of the model runs resulted in total adult production of at least 2,585 adults). The adult numbers represent abundance at the Columbia River mouth absent ocean fisheries.

The theoretical relationship between Chief Joseph Dam juvenile survival rate, total adult production and natural spawning escapement is shown in Table 6. The model output indicated that if juvenile survival at Chief Joseph Dam is only 60%, resultant adult production may be sufficient to produce more returning natural-origin adults (1,491) than the hatchery adults (1,000) used to supplement the population, i.e., a net increase in fish production.

Table 6. LCM estimated total adult summer/fall Chinook production and natural escapement for Chief Joseph Dam juvenile passage survival rates. The analysis assumes that 1,000 adult HOR fish are released upstream of the dam each year to supplement NOR adult returns.

Dam Survival Rate	Total Adult Production	NOR Spawning Escapement
*88%	12,873	4,115
70%	6,841	2,187
60%	4,666	1,491
50%	3,145	1,005

*Assumed juvenile dam passage survival rate through turbines and spill. Studies conducted in Phase 2 will confirm the survival estimate for yearling and subyearling Chinook.

A portion of the future natural adult production from Rufus Woods Lake would be combined with hatchery Chinook to reintroduce summer/fall Chinook to habitats upstream of Grand Coulee and Spokane River dams. Therefore, for summer/fall Chinook, the program will follow the ISAB recommended stepping-stone approach. See Section 5.3 for additional discussion on the management of natural-origin Chinook.

Fish production from Rufus Woods Lake would be considered an extension of the spatial distribution of Upper Columbia River summer/fall Chinook. A wider spatial distribution would increase the total capacity and productivity of the Upper Columbia summer/fall Chinook ESU.

2.4.2 Lake Roosevelt, Sanpoil River, and Spokane River Summer/Fall Chinook

Summer/fall Chinook production areas upstream of Grand Coulee Dam include the Sanpoil River, Transboundary Reach and Spokane River. Phase 1 LCM results indicated that if fish passage, habitat and reservoir survival assumptions were accurate, summer/fall Chinook adult production potential upstream of Grand Coulee Dam could exceed 44,000 adults (pre-harvest) to the mouth of the Columbia River. However, the assumptions used in modeling were based primarily on the scientific literature, outputs from other models, and results from similar systems or facilities (e.g., Baker Lake FSC, mainstem Columbia River dams). Thus, as the ISAB noted in their review of Phase 1, there is considerable uncertainty in the assumptions and therefore results regarding eventual adult summer/fall Chinook production from this area.

Juvenile Survival Rate Through Lake Roosevelt

There is concern that juvenile salmonids will not be able to successfully migrate through the 151-mile-long Lake Roosevelt. This may be the case, but this risk only applies to fish produced upstream of the lake. Salmon from the Sanpoil River and Spokane River will only have to migrate through ~25 miles and 50 miles of Lake Roosevelt, respectively. These distances are similar to the length of reservoirs in the Columbia River that fish successfully migrate through each year.

Studies will be undertaken and focused on testing critical uncertainties associated with reservoir survival, upstream and downstream fish passage survival, smolt-to-adult survival and reproductive success of hatchery-origin summer/fall Chinook adults released to the Sanpoil River, Spokane River, and Transboundary Reach. In the initial research phase, it will not be feasible to capture and tag natural-origin juvenile migrants in a cost-efficient manner. Hatchery-origin juveniles will therefore be used as surrogate research animals during these studies and the results applied to natural-origin smolts for modeling purposes.

Juvenile hatchery fish will be used to conduct survival studies throughout the Spokane River, in Lake Roosevelt and at Grand Coulee Dam and Chief Joseph dams. Enough juveniles will be released to account for mortality that occurs during outmigration, in the ocean and during the return migration to the blocked area to provide a sample size large enough to estimate smolt-to-adult survival rate, adult recruits per spawner (AR/S) and provide enough returning adults to quantify the collection efficiency of adult passage facilities at Chief Joseph hatchery ladder or dam.

Additionally, smaller numbers of hatchery juveniles will be acoustic-tagged to determine their behavior and survival as they pass Spokane River dams, Grand Coulee Dam, and Chief Joseph Dam. This information will be used for determining dam passage routing and survival, locating possible interim juvenile passage facilities, and determining required facility effectiveness to achieve passage survival rate objectives for the dams. Acoustic-tagged juveniles will also determine reach survival throughout various riverine and reservoir habitats in the blocked area. This information will be used to identify adaptive management actions that may be appropriate to increase the success of migrating juveniles through reaches where survival is low.

Fish production from upstream of Grand Coulee Dam would be considered an extension of the spatial distribution of Upper Columbia River summer/fall Chinook thereby increasing capacity and resilience of the overall ESU. These factors are likely to benefit the population by increasing population abundance and by buffering potential losses due to stochastic events and a changing climate.

2.4.3 Lake Roosevelt Sockeye Salmon

Sockeye salmon production areas modeled in Phase 1 included the Sanpoil River, Christina Lake, and Transboundary Reach. LCM results showed that total Sockeye adult production with effective fish passage may exceed 75,000 fish at the mouth of the Columbia River absent fisheries (Table 3). Even without the construction of juvenile fish passage facilities, the life cycle survival rate may be sufficient to produce many adults with continued hatchery fish supplementation (Figure 5). Adult Sockeye salmon returns will be used for testing upstream passage facilities at Grand Coulee and Chief Joseph dams.

Sockeye salmon modeling assumptions were based on the scientific literature and not empirical data collected from the system. Thus, there is considerable uncertainty around estimates of adult Sockeye salmon production, which needs to be resolved during Phase 2.

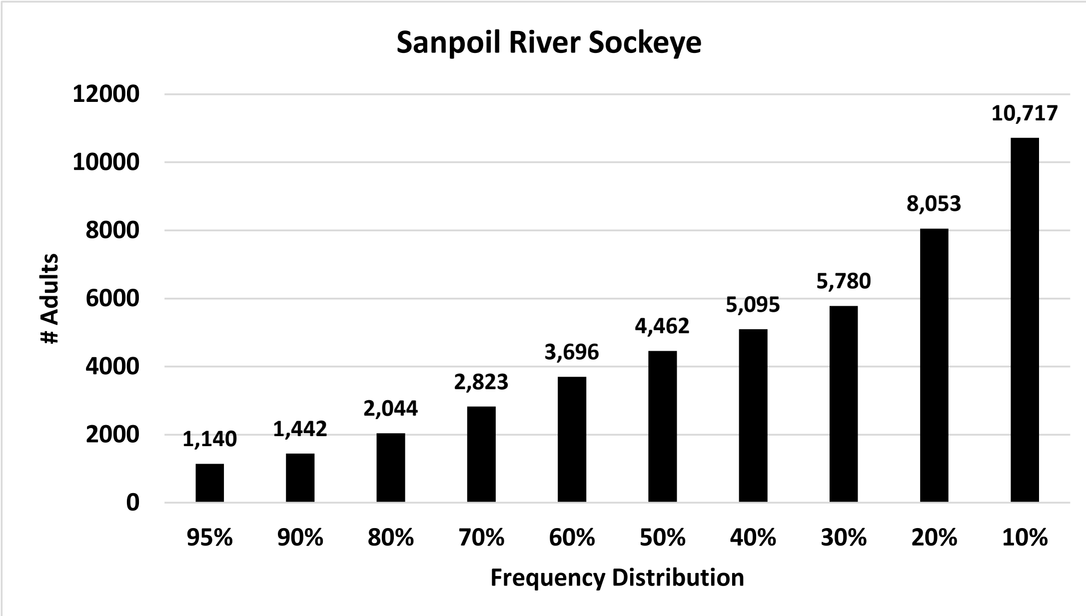


Figure 5. LCM generated 10% to 95% total adult hatchery-origin Sockeye salmon frequency distribution for the Sanpoil River without the construction of juvenile fish passage facilities. The adult numbers are based on Pacific Decadal Oscillation conditions for 1999 – 2013 and an annual release of 1,000 hatchery-origin adults. Each bar represents the frequency of model runs that were greater than the associated adult abundance value (e.g., 95% of the model runs resulted in total adult production of at least 1,140 adults). The adult numbers represent abundance at the Columbia River mouth absent ocean fisheries.

As was the case for summer/fall Chinook, the implementation strategy for Sockeye salmon will be one of experimentation. Similar studies and monitoring as described for summer/fall Chinook will be conducted for Sockeye salmon. Studies will be focused on testing critical uncertainties associated with reservoir survival, upstream and downstream fish passage survival, smolt-to-adult survival, and Sockeye salmon reproductive success.

It is proposed that Sockeye salmon from upstream of Grand Coulee Dam would be considered an extension of the spatial distribution of Okanogan River Sockeye salmon and managed accordingly to prevent possible impacts to downstream fisheries.

2.5 Phase 2 Studies

As stated earlier, Phase 2 is structured with two main steps and is projected to span over 20 years to fully implement. The adaptive management framework, however, has inherent uncertainty incorporated into it and therefore the schedule and specifics around each task are not explicit in how or when they will be implemented (see Appendix A: Phase 2 Schedule and Associated Costs for a detailed Gantt chart of the Phase 2 Implementation Plan). This is especially true the further out you project into the future of Phase 2. The flexibility in the implementation plan will allow managers to make scientific and policy decisions regarding salmon reintroduction based on the best available data. Thus, it is important to keep in mind that the Phase 2 Implementation Plan is a way to guide managers through an arduous and lengthy process and should be considered a living document.

2.5.1 Step 1: Baseline Studies (Years 1 – 6)

In years 1 through 6 (step 1), Phase 2 study priorities will focus on collecting baseline data for survival and fish passage. Juvenile salmon survival and dam passage behavior studies will be performed for Chinook (yearlings and subyearlings) and Sockeye using acoustic tags[17]. The results from survival studies will inform the sizes of subsequent juvenile releases and be used to update the life cycle model to evaluate reintroduction feasibility. Dam passage behavior and survival data is intended to inform the need for, and design of, interim juvenile passage facilities.

Moderate-scale annual releases of PIT-tagged hatchery origin yearling Chinook and subyearling Sockeye[18] (50k – 200k per species) will evaluate fish behavior, migratory survival to below Chief Joseph Dam, provide smolt-to-adult return rates (SAR), and provide local-origin adults necessary for conducting research. Returning local-origin adults will be tracked to determine survival and migratory behavior near the dams, which would inform the design of upstream passage systems, and throughout the reservoirs and to the spawning grounds. Parentage-based tagging (PBT) genetic sampling will be performed on returning adults to determine the area of origin, and thus, the success of various spawning aggregates and release groups. Detailed descriptions of initial Step 1 studies are provided in Appendices B, C, and D.

2.5.1.1 Evaluate Downstream Movement and Survival of Juvenile Summer/Fall Chinook in the Upper Columbia River Basin

This study is being undertaken to confirm juvenile summer/fall Chinook passage survival and behavior assumptions used in the LCM to estimate fish performance in the blocked area. Acoustic telemetry will be used to achieve the following study objectives:

- Estimate survival and travel time from the mouth of the Sanpoil River (rkm 987) and Kettle Falls (rkm 1121) to Grand Coulee Dam (rkm 957).

- In the Spokane River, estimate survival and travel time from Little Falls Dam (rkm 1071), Long Lake Dam (rkm 1089), Nine Mile Dam (rkm 1127), and the mouth of Hangman Creek (rkm 1145) to Grand Coulee Dam.

---

[17] Because of the difficulty in separating subyearling Chinook rearing mortality from migration mortality (Gingerich and Kahler 2020), this life stage would only be used to determine their behavior in the forebay, passage route (spill, turbines) at the dam and possibly survival through each route. This information is needed to design and test interim fish passage facilities. The details of when and how to test subyearlings will be one of the first topics of discussion for the fish passage team and fisheries managers.

[18] Subyearling Sockeye released for this study are expected to migrate out the following spring as yearlings.

- Estimate survival and travel time from Grand Coulee Dam to Chief Joseph Dam (rkm 877).
- Assess near-dam behavior and estimate route-specific passage survival at Grand Coulee Dam.
- Assess near-dam behavior and estimate route-specific passage survival at Chief Joseph Dam.
- Assess near-dam behavior and estimate route-specific passage survival at Spokane River dams.

The number of acoustic-tagged fish released at each site (75 to 200) within the study design was developed to collect baseline data on downstream passage and survival through reservoirs and dams in the blocked area at a level that balanced statistical precision requirements with anticipated funding levels. Data gathered will guide decision-making regarding the need for, and location of, juvenile fish passage facilities and resulting LCM estimates of adult production. Because survival rates through the dams and reservoirs are unknown, sample sizes were set based on high and low survival scenarios (Table 7).

Table 7. Simulated survival estimates of high and low survival scenarios, with 95% confidence intervals shown in parentheses, for specific reaches in the study area for the proposed study design.

	Survival Estimates and Confidence Intervals	
Reach	Scenario A (High)	Scenario B (Low)
Combined release to Grand Coulee Dam	0.54 (0.49–0.58)	0.43 (0.37–0.48)
Grand Coulee Dam passage survival	0.50 (0.44–0.56)	0.25 (0.19–0.31)
Grand Coulee Dam tailrace to Chief Joseph Dam forebay	0.98 (0.95–1.00)	0.97 (0.93–1.00)
Chief Joseph Dam passage survival	0.88 (0.84–0.92)	0.82 (0.75–0.89)
Grand Coulee tailrace to Chief Joseph tailrace	0.86 (0.78–0.94)	0.80 (0.70–0.89)
Kettle Falls to Chief Joseph tailrace	0.30 (0.23–0.37)	0.11 (0.06–0.15)
Upper Hangman Creek to Chief Joseph tailrace	0.06 (0.01–0.11)	0.02 (0.00–0.05)
Little Spokane River to Chief Joseph tailrace	0.12 (0.05–0.18)	0.04 (0.00–0.08)
Little Falls to Chief Joseph tailrace	0.36 (0.27–0.46)	0.15 (0.08–0.22)
Sanpoil River to Chief Joseph tailrace	0.42 (0.33–0.52)	0.19 (0.12–0.27)

The study will be repeated for three years to account for yearly environmental and project operation variability, which is expected to affect fish behavior and resultant survival rate estimates. Yearling Chinook will initially be used for testing in Step 1 as this life stage is expected to have higher survival rates through reservoirs and dams than subyearlings and it is anticipated to be the long-term rearing strategy for hatchery Chinook. The higher survival rate reduces the cost of the study while researchers test study assumptions, methods and need for additional equipment (e.g., receivers). Subyearling studies will be developed and initiated in Step 1; however, because of the difficulty in separating subyearling rearing mortality from migration mortality (Gingerich and Kahler 2020), the primary purpose of the subyearling releases will be to evaluate fish behavior and survival at the dams[19]. The details of when and how to test subyearlings will be one of the first topics of discussion for the fish passage team and fisheries managers. Some potential sources of subyearling Chinook include hatcheries (same donors as the yearling programs) or natural-origin Chinook collected from tributary traps or mainstem Columbia collection facilities downstream of Chief Joseph Dam. Each of these subyearling source options have tradeoffs in terms of availability and applicability that need further input and testing as the program moves forward. In Step 2, natural-origin Chinook juveniles may also be collected tagged and released from the interim bypass facilities in Step 2 and at traps operating in the Sanpoil River and Spokane River. This information will be useful in designing downstream passage facilities and refining their operation over time.

2.5.1.2 Evaluate Juvenile Sockeye Salmon Survival through Lake Roosevelt, Grand Coulee Dam, Rufus Woods Lake, and Chief Joseph Dam

This study is being undertaken to confirm Sockeye juvenile rearing survival and passage survival assumptions used in the LCM to estimate fish performance for production areas upstream of Grand Coulee Dam. Acoustic telemetry will be used to achieve the following study objectives:

- Estimate juvenile Sockeye salmon survival from release (in spring/summer) to migrant stage (following spring) and through Lake Roosevelt.
- Estimate juvenile Sockeye salmon survival through Grand Coulee Dam.
- Estimate juvenile Sockeye salmon survival through Rufus Woods Lake, from Grand Coulee Dam to Chief Joseph Dam.
- Estimate juvenile Sockeye salmon survival through Chief Joseph Dam.
- Assess behavior and travel route of juvenile Sockeye salmon in the forebay and through Grand Coulee Dam and Chief Joseph Dam.

[19] Subyearling Chinook are expected to migrate later in the year than yearling Chinook. Environmental conditions (river flow, temperature, project operations), and subyearling Chinook response to these conditions, are expected to be different than for yearling Chinook. These differences will likely need to be evaluated and accounted for in the development of fish passage systems.

A brief description of the study is provided below by task.

Objective 1: Estimate juvenile Sockeye salmon survival from release in the Sanpoil River to Grand Coulee Dam

Subyearling Sockeye salmon, obtained from the Okanogan National Alliance (ONA) Penticton Hatchery, will be implanted with a PIT tag and an acoustic transmitter, and released into the Sanpoil River during the spring/summer with the expectation that they will rear in Lake Roosevelt for up to a year before emigrating as yearlings the following spring. Transmitters implanted in subyearling Sockeye salmon will be programmed with a delayed start to ensure transmitters are active at the time of emigration from Lake Roosevelt, which would be expected to occur from April through early June in the subsequent year after transmitter implantation. This approach should provide the opportunity to estimate survival from release as subyearling to yearling migrant as measured at Grand Coulee Dam.

It is possible that some portion of Sockeye salmon will emigrate from Lake Roosevelt as subyearlings. Prior to implementing this study, information obtained from PIT-tagged subyearling Sockeye salmon released by the ONA upstream of Grand Coulee Dam will be evaluated to determine whether a substantial proportion of Sockeye emigrate from Lake Roosevelt as subyearlings. If so, emigration of acoustic-tagged Sockeye salmon from Lake Roosevelt as subyearlings will be monitored from June through October of the release year by programming a subset of the transmitters to be actively transmitting at the time of release.

A total of 300 Sockeye salmon subyearlings will be released to the Sanpoil River to evaluate in reservoir survival from subyearling parr to yearling smolts. The estimated precision of survival estimates is presented in

Table 8.

Objectives 2, 3, and 4: Estimate juvenile Sockeye salmon survival through Grand Coulee Dam, Rufus Woods Lake, and Chief Joseph Dam

Approximately 900 wild Sockeye salmon smolts will be collected from the smolt trap and/or purse seine efforts in the Canadian portion of the Okanagan River, implanted with a JSATS acoustic transmitter and a PIT tag, and released approximately 30 km upstream of Grand Coulee Dam. The upstream release location was selected to allow tagged fish to distribute naturally as they move downstream thereby mimicking passage by run-of-river fish. This release location will be near the confluence of the Sanpoil Arm, which will also provide a useful reach survival estimate. Tagged fish that are detected by the receiver array deployed on the upstream face of Grand Coulee Dam will form a "virtual" release group which is a grouping of fish based on detections at an array independent of when or where those fish were released (Harnish et al. 2020). A second virtual release group (V_2) will be formed of fish from the R_1 group that survive to and are detected by the receiver array deployed on the upstream face of Chief Joseph Dam. The virtual release/dead-fish correction (ViRDCt) mark-recapture model (Harnish et al. 2020) will be used to estimate dam passage survival of the V_1 and V_2 groups at Grand Coulee Dam and Chief Joseph Dam, respectively.

Table 8. Estimated precision of release-to-migration survival probability for acoustic-tagged hatchery subyearling Sockeye salmon that migrate from Lake Roosevelt as yearlings. Precision estimates assume a detection probability of 0.99 at Grand Coulee Dam, a joint probability of survival to and detection at Chief Joseph Dam of 0.45, and a subyearling emigration rate of 0.

Sample size (N)	SE	95% LCL	95% UCL
Survival probability = 0.25			
200	0.031	0.189	0.311
300	0.025	0.201	0.299
400	0.022	0.207	0.293
Survival probability = 0.36			
200	0.034	0.293	0.427
300	0.028	0.305	0.415
400	0.024	0.313	0.407

The initial power analysis suggested that releasing 900 Sockeye yearling smolts into Lake Roosevelt at its confluence with the Sanpoil Arm would yield a standard error of approximately 3.3% (Appendix C). Before implementing the study, managers will be consulted to confirm that sample sizes and resulting precision are sufficient for decision making regarding the need for fish passage facilities and estimating adult production from reintroduction.

The study will be repeated for three years to account for yearly environmental and project operation variability, which is expected to affect fish behavior and resultant survival rate estimates. If the interannual variability is high, or one or more years appears to be insufficient, then more study years may be added to the evaluation.

2.5.1.3 Evaluating Survival of Reintroduced Anadromous Salmon with Passive Integrated Transponder (PIT) Tags Upstream of the Blocked Area of the Columbia River

This study addresses assumptions associated with the feasibility of reintroducing Sockeye salmon and Chinook salmon upstream of Chief Joseph, Grand Coulee, and Spokane River dams. The information obtained from the implementation of this study will help to evaluate the factors and life stages that influence the numbers of adults returning to the upper Columbia River and inform planning and development of interim or permanent adult passage facilities at all five dams. As such, this study plan, combined with those designed to evaluate juvenile survival through the Spokane River, Lake Roosevelt, Grand Coulee Dam, Rufus Woods Lake, and Chief Joseph Dam will provide much of the information necessary to evaluate the reintroduction effort and identify areas where more detailed studies are needed.

A brief description of the study is presented below with the complete plan provided in Appendix D.

The study has 6 objectives:

- Estimate juvenile Chinook and Sockeye salmon survival from release upstream of Grand Coulee and Spokane River dams to Rocky Reach and McNary dams.
- Estimate adult Chinook and Sockeye salmon survival from Bonneville Dam to Wells Dam.
- Estimate release-to-Wells Dam smolt-to-adult return rates (SARs) of yearling Chinook salmon and subyearling Sockeye salmon.
- Estimate the Wells Dam-to-Chief Joseph Hatchery ladder conversion rate of adult Chinook and Sockeye salmon.
- Evaluate adult Chinook and Sockeye salmon behavior in the tailraces of Chief Joseph, Grand Coulee, and Spokane River dams, fallback at these dams, and survival and behavior in Rufus Woods Lake.
- Estimate adult Chinook and Sockeye salmon behavior and survival upstream of Grand Coulee Dam.

The study will use a combination of PIT tags and acoustic tags to achieve study objectives. The PIT tags will be used to estimate juvenile and adult survival rates through the Columbia River and smolt-to-adult survival rates (SAR). Adult returns from the juvenile releases will then be used to estimate the adult conversion rate from Wells Dam to the Chief Joseph Hatchery Ladder and with sufficient adult returns, behavior in the tailraces of all five dams scoped for upstream passage. The adult behavior information will be obtained by collecting adults at Wells Dam and fitting them with acoustic tags that are compatible with currently deployed receivers.

PIT tagged hatchery-origin Sockeye salmon subyearling juveniles will be released to the Sanpoil River with the expectation they will rear both in the Sanpoil River and Lake Roosevelt then migrate out the following spring.

PIT tagged hatchery-origin yearling Chinook will be released at the following locations:

- Tailrace of Grand Coulee Dam (and/or net pens in Lake Rufus Woods)
- Sanpoil River (and/or Sanpoil Arm of Lake Roosevelt)
- Spokane River (Little Falls Dam, Little Spokane River, Hangman Creek)
- Transboundary Reach

Before implementing the study, managers will be consulted to confirm that the life stages being tested, sample sizes and resulting precision are sufficient for decision making regarding the need for and effectiveness of fish passage facilities and estimating adult production from reintroduction.

The study will be repeated for three years to account for yearly environmental and project operation variability, which is expected to affect fish behavior (e.g., dam passage route and migration timing) and resultant survival rate estimates. The estimated statistical precision for yearling Chinook survival rates to Rocky Reach and McNary Dam is provided in Appendix D.

2.5.2 Step 2: Interim Passage and Supporting Studies (Years 7-21)

Step 2 focuses on the design, installation, and testing of interim fish passage systems. Step 2 is broken down into sub-steps that correspond with the installation of individual passage systems. Having sub-steps also provides some flexibility in the order and timing of installation, allowing for adaptive management of the installation and testing of interim passage facilities depending on where survival bottlenecks occur and where the most benefit may be gained.

Table 9. Estimated precision (SE and 95% CI) of release-to-Rocky Reach Dam (RRJ) and release-to-McNary Dam (MCJ) survival estimates for PIT tagged yearling Chinook salmon released into the Sanpoil River, Spokane River (below Little Falls, Below Nine Mile Dam/Little Spokane River, and below Spokane Falls/Hangman Creek), and the Transboundary Reach of the Columbia River (near Newport, WA). PIT N (Total) = total number of PIT tagged yearling Chinook salmon released (all release locations combined); SE = standard error; CI = confidence interval.

PIT N (Total)	PIT N by Release Location	Release-to-RRJ SE	Release-to-RRJ 95% CI	Release-to-MCJ SE	Release-to-MCJ 95% CI
Below Grand Coulee Dam / Rufus Woods Lake					
60,000	10,000	0.026	0.653-0.755	0.052	0.424-0.628
110,000	10,000	0.026	0.653-0.755	0.052	0.424-0.628
160,000	10,000	0.026	0.653-0.755	0.052	0.424-0.628
Sanpoil River					
60,000	13,150	0.019	0.285-0.360	0.041	0.161-0.320
110,000	26,300	0.014	0.296-0.349	0.029	0.185-0.297
160,000	39,450	0.011	0.301-0.344	0.023	0.195-0.287
Below Little Falls Dam (Spokane River)					
60,000	8,100	0.018	0.245-0.318	0.037	0.138-0.282
110,000	16,200	0.013	0.256-0.307	0.026	0.159-0.261
160,000	24,300	0.011	0.260-0.303	0.021	0.168-0.252
Below Nine Mile Dam / Little Spokane River					
60,000	5,050	0.022	0.203-0.290	0.044	0.099-0.269
110,000	10,100	0.016	0.216-0.277	0.031	0.124-0.244
160,000	15,150	0.013	0.221-0.272	0.025	0.135-0.233
Below Spokane Falls / Hangman Creek					
60,000	5,050	0.020	0.155-0.232	0.039	0.069-0.220
110,000	10,100	0.014	0.167-0.221	0.027	0.091-0.198
160,000	15,150	0.011	0.171-0.216	0.022	0.101-0.188
Transboundary Reach					
60,000	18,650	0.014	0.200-0.254	0.029	0.114-0.225
110,000	37,300	0.010	0.208-0.246	0.020	0.130-0.209
160,000	55,950	0.008	0.212-0.242	0.017	0.137-0.202

Hatchery programs from Step 1 will continue throughout Step 2 to provide a supply of juveniles and adults necessary for Phase 2 studies of the reintroduction program. Hatchery-origin juvenile chinook and Sockeye salmon will continue to be released and tagged to monitor for survival and interim passage collection efficiency. The trap-and-haul[20] program for local-origin adults from Chief Joseph Dam to upstream impoundments will continue, along with PBT sampling to assess population viability.

2.5.2.1 Step 2.1 (years 7 – 9): Grand Coulee Dam Downstream Passage + Continued Activities

Juvenile dam behavior and passage routing information from Step 1 will be used for the design and installation of interim downstream passage at Grand Coulee Dam. Collection efficiency of Chief Joseph Dam upstream passage system will also begin.

2.5.2.2 Step 2.2 (years 10 – 12): Grand Coulee Dam Upstream Passage + Continued Activities

Adult tailrace behavior information collected in Step 1 will be used for the design and installation of an interim upstream passage system at Grand Coulee Dam. Collection efficiency of the Grand Coulee Dam downstream passage system will be tested. A second trial of the multi-year juvenile survival study with yearlings and subyearlings will be conducted as downstream passage survival at Grand Coulee Dam was identified as a critical uncertainty during Phase 1.

2.5.2.3 Step 2.3 (years 13 – 15): Spokane River Upstream Passage + Continued Activities

Adult tailrace behavior information collected in Step 1 will be used for the design and installation of interim upstream passage systems at Little Falls, Long Lake, and Nine Mile dams. Collection efficiency studies of the Grand Coulee Dam upstream passage system will continue.

2.5.2.4 Step 2.4 (years 15 – 21): Downstream Passage at CJD and Spokane River Dams + Continued Activities

Assessments performed in Phase 1 indicate that successful juvenile downstream passage at these projects may be relatively high. The necessity of downstream passage at these dams will be evaluated following dam passage survival studies conducted within Step 1 and Step 2.2. Design and installation of interim downstream passage systems for CJD and Spokane River dams will occur, as necessary. Collection efficiency testing on CJD and Spokane River downstream passage systems will be performed, along with a final trial of juvenile survival studies. All relevant data will be incorporated into the life cycle model. Modeling results and decision trees will be reviewed by stakeholders for Phase 3 decision-making.

2.6 Adaptive Management of the Steps

The detailed studies presented above are the starting point to answering critical uncertainties. Phase 2 studies are largely informed by previous work, using results from earlier research to improve the next trial of a study, or used to modify the next research project. For example, survival estimates from the

[20] Trap-and-Haul: A fish passage strategy for upstream or downstream transport of individuals to overcome migration barriers. Facilities consist of a collector (downstream migrants) or trap (upstream migrants) used to collect and concentrate fish, and a means of conveyance (e.g., pipe, pneumatic tube, fish lift) or transport (e.g., tanker truck or barge).

summer/fall juvenile Chinook downstream survival study (2.5.1.1) will be used to scale the release group sizes of the subsequent PIT tag-based survival study (2.5.1.3). Results from the studies conducted in Step 1 will inform Step 2 studies and actions. For example, dam passage survival estimates will be used to inform the order in which downstream passage systems are installed.

This adaptive management approach will improve the efficiency and cost effectiveness of Phase 2 efforts. However, it also creates a degree of uncertainty. Near-term research and actions are readily apparent due to the uncertainties identified in Phase 1 and logistical considerations. Depending on the results of these near-term studies, the mid and long-term paths may change course from what is presented herein. This flexibility and uncertainty are recognized from the outset of Phase 2.

The results from fish passage survival studies will be used to update LCM inputs and generate expected fish production resulting from installation of each passage strategy. This modeling will be used to inform fisheries managers of program progress, investigate passage system improvements to increase survival, explore different levels of hatchery production and release locations, and conduct sensitivity analyses to determine the need to replicate studies to reduce uncertainty over time.

2.7 Summer/Fall Chinook Production Potential

2.7.1 Rufus Woods Lake

The adult production potential of the 17-miles of riverine habitat in Rufus Woods Lake was based on a habitat analysis completed by Hanrahan et al. (2004). This information was then used to calculate redd capacity based on four different methods (UCUT 2019). Analysis results indicated that redd capacity may range from 270 to 5,035, dependent on river flow, suitable habitat utilization and the area required for a single redd. Thus, there is considerable uncertainty around summer/fall Chinook production potential for the population.

To determine the adult Chinook production potential of Rufus Woods Lake, hatchery summer/fall Chinook adults (~1,000) will be released to the lake each year. Adult releases to the lake have already been implemented and will continue throughout Phase 2. Fish released are to be genetically sampled to perform PBT analysis of resulting adult returns to the Chief Joseph Hatchery ladder and any future adult collection facility or sampling sites (fisheries, rivers downstream of Chief Joseph Dam etc.).

The PBT analysis will allow the calculation of adult recruits per spawner (AR/S) for fish released to Rufus Woods Lake over multiple brood years. The AR/S estimate would account for all sources of mortality throughout the lifecycle; from adult release to juvenile migration through the hydrosystem, marine survival, harvest, and adult migration back through the hydrosystem to Chief Joseph Dam. Resulting estimates of AR/S will be used to guide decisions regarding the need for juvenile passage facilities, the level of hatchery supplementation, and population management (Figure 6 and Figure 7)

Adult recruits per spawner[21] AR/S is a key performance metric that is typically used to guide management decisions in fisheries. During Phase 2 however, the spawners shall be defined as the number of potential spawners and is equal to the number of adults moved into the blocked area, as the actual number of successfully spawning adults will be difficult to evaluate due to blocked area harvest, potential fallback, and the difficulty in evaluating spawning success in large river mainstem habitats. An AR/S value of ≥ 1.0 would be used as the performance metric indicating that the population is sustainable, and no additional actions are required. An AR/S value ranging from 0.25 to < 1.0 is the metric wherein either juvenile fish passage would be built to increase survival sufficiently to achieve a sustainable natural population or supplementation with hatchery juveniles would be used to achieve sufficient adult abundance to meet program goals[22]. If AR/S is less than 0.25 the program would consider if the funding and gametes utilized for the reintroduction of Chinook into Rufus Woods Lake would be better spent on a different species or locations, or simply using surplus hatchery fish to provide benefits to upstream tribes and communities. The decision will be partially based on outcomes of studies upstream of Grand Coulee and Spokane River dams and the preferred passage systems for those production areas.

Adult Recruits per Spawner (AR/S)

AR/S is used as a key performance metric as it accounts for survival from spawning to juvenile survival through the hydrosystem, marine survival, harvest, and adult migration back to Chief Joseph Dam. The higher the AR/S value the more likely reintroduction will be successful.

2.7.2 Lake Roosevelt, Sanpoil River, and Spokane River

The total miles of stream habitat that may support summer/fall Chinook in the Sanpoil River, Spokane River and Transboundary Reach are 59.6, 257.1, and 36 miles, respectively. Summer/fall Chinook production estimates for the Sanpoil River and Spokane River were based on the results of EDT habitat modeling (ICF 2017 and 2018). For the Transboundary Reach, two-dimensional habitat mapping was used to generate estimates of redd capacity at various redd sizes and river flows. Because the Chinook production estimates are based on habitat modeling outputs, there is considerable uncertainty as to production potential for each of the three production areas and therefore the outcome of reintroduction efforts upstream of Grand Coulee Dam.

---

[21] Adult Recruits per Spawner (AR/S): The number of adult salmon returning to Chief Joseph Dam produced from a given number of potential spawners released into blocked area habitats.
[22] Program goals are discussed in Section 6.

To reduce summer/fall Chinook production potential uncertainty, hatchery and/or natural-origin summer/fall Chinook adults will be released annually to each of the three production areas. The highest priority for obtaining surplus adults is the Chief Joseph Hatchery stock, but availability of surplus fish and balancing demand with other priorities (harvest and food) may require using other sources such as Wells or Entiat National Fish Hatchery. It is expected that the adult releases will occur annually throughout Phase 2.

Because the number of adults available for release to both Rufus Woods Lake and upstream of Grand Coulee Dam will be limited, releases have been initially prioritized based on LCM estimates of adult productivity. Populations with higher productivity (P) are expected to better withstand mortality associated with upstream and downstream fish passage. This strategy will also ensure that more local-origin adults are available for necessary studies.

The release location priorities and adult productivity values for summer/fall Chinook are as follows:

1. Rufus Woods Lake (P = 2.92)

2. Transboundary Reach (P = 2.13)

3. Spokane River (P = 1.47)

4. Sanpoil River (P = 1.01)

Release location priority will be adjusted based on the results of juvenile and adult passage survival studies, resulting adult return rates, and policy direction from fisheries managers, while also balancing the needs of regional tribes.

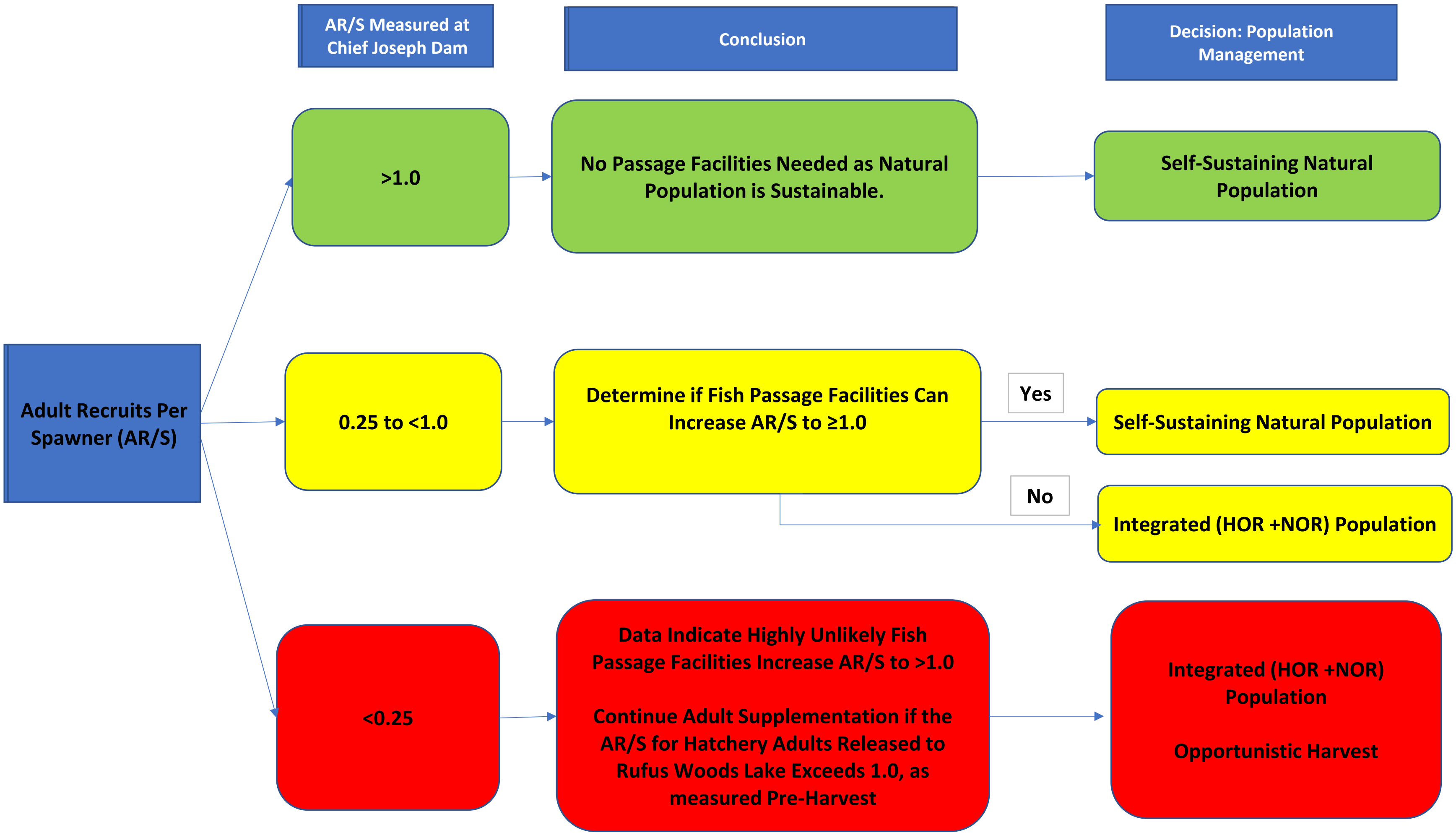


Figure 6. Decision flow chart for selecting the preferred Rufus Woods Lake population management strategy based on AR/S.

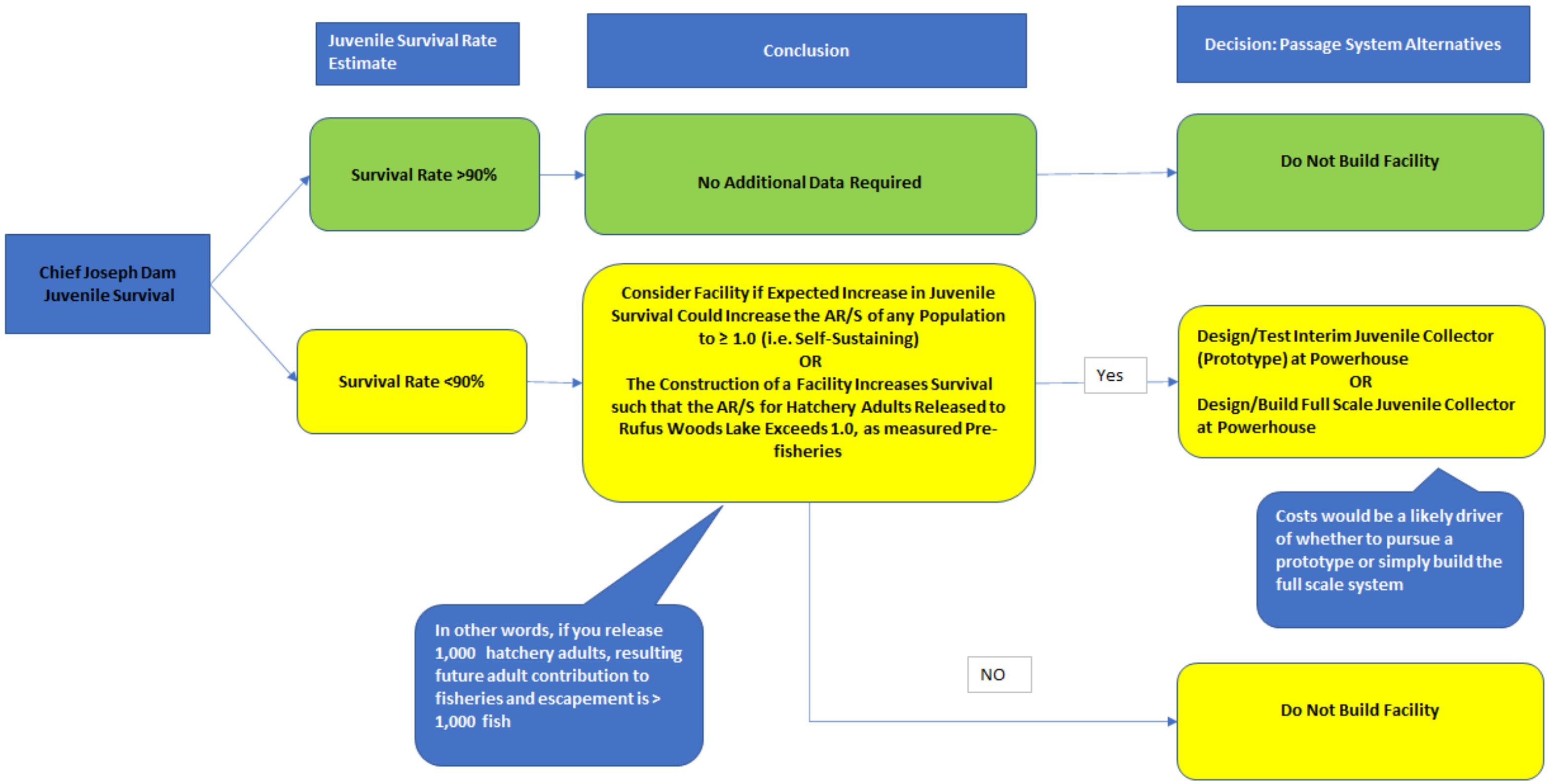


Figure 7. Decision flow chart for selecting the preferred juvenile passage system at Chief Joseph Dam based on estimated juvenile survival rate through project turbines and spill.

Adult salmon released to spawn will be genetically sampled to perform PBT analysis of resulting adult returns to the Chief Joseph Hatchery ladder and any future adult collection facility or sampling sites (fisheries, rivers downstream of Chief Joseph Dam etc.). Juvenile releases may receive PIT tags, coded-wire tags, and/or other unique markings to identify them during migration and return as adults. Marking protocols will be coordinated with the regulatory agencies to ensure they do not affect other RM&E programs.

The tags and PBT analysis will allow the calculation of AR/S for fish releases over multiple brood year. Resulting estimates of AR/S will be used to guide decisions regarding juvenile passage facilities, degree of hatchery supplementation, and population management (Figure 8).

2.8 Sockeye Salmon Production Potential

In Phase 1, Sockeye salmon production potential for stream and lake habitat upstream of Grand Coulee Dam was determined based on analyses that estimated spawner capacity for the three production areas examined, as well as the juvenile rearing capacity of Lake Roosevelt.

Estimates of adult spawner capacity were heavily influenced by assumptions regarding redd area and the percent of each habitat type used for spawning. For example, the spawner capacity estimate for the Sanpoil River ranged from 34,000 to 219,000 redds.

The smolt rearing capacity of Lake Roosevelt was determined using the Euphotic Volume (EV) model (Hume et al. 1996). This model has been used in other anadromous reintroduction feasibility evaluations in the Willamette, Yakima, and Fraser River watersheds (Bocking and Gaboury 2003, Gaboury and Bocking 2003, Bussanich et al. 2006, BOR 2007a, BOR 2007b). The results of the EV analysis indicated that smolt capacity could range from 12 million to 49 million fish (Table 10).

Because both the spawner and smolt rearing capacity estimates were not based on empirical, site-specific data, the resulting Sockeye production estimates from the LCM are highly uncertain.

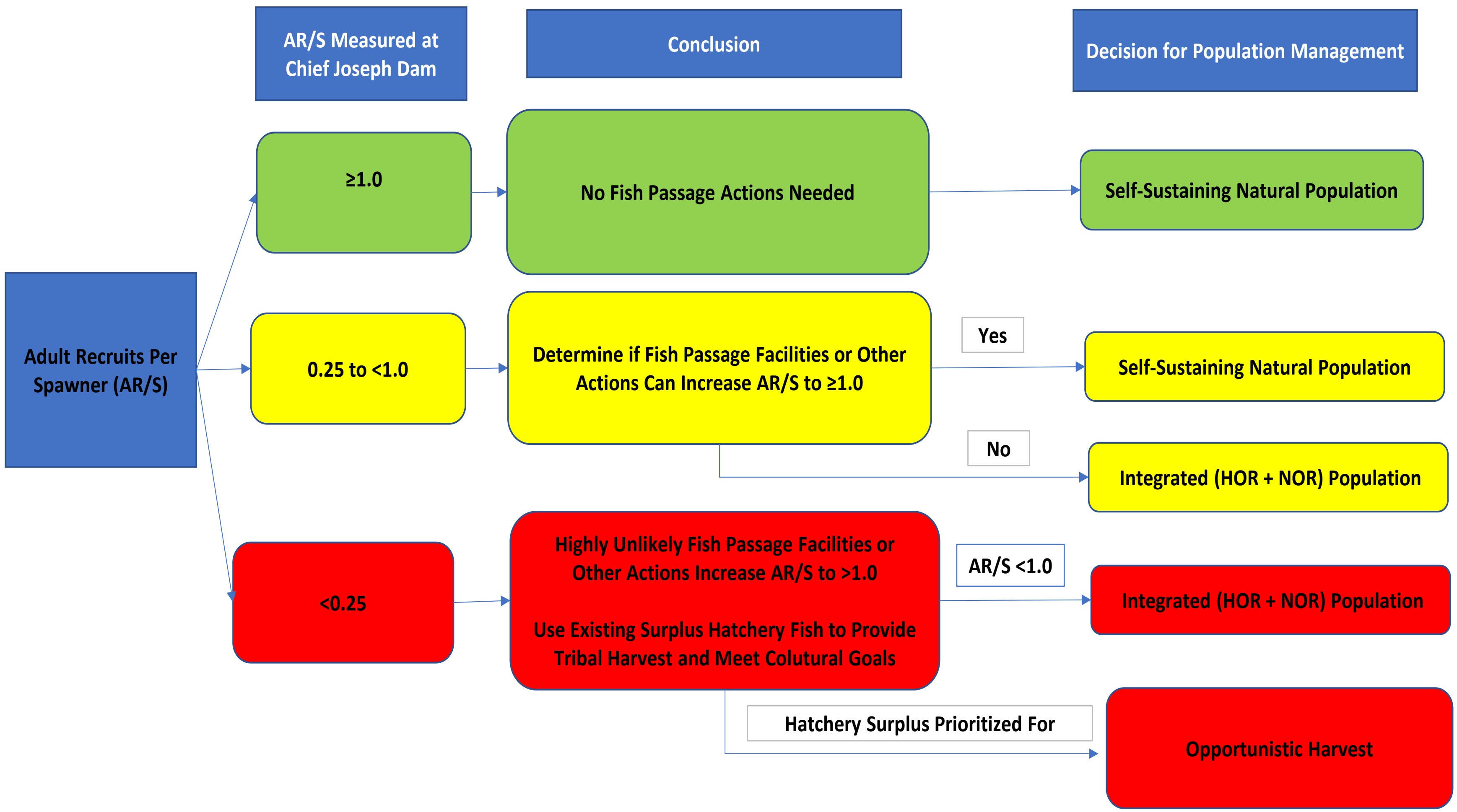


Figure 8. Decision flow chart for selecting the preferred management strategy for summer/fall Chinook and Sockeye production areas based on adult recruits per spawner (AR/S).

.

Table 10. Ten-year mean Sockeye smolt capacities for Lake Roosevelt (1997 – 2006), by month, under various assumed smolt yields per Euphotic Volume (EV) unit.

	Assumed Smolt Yield		
	Low (6,780/EV Unit)	Moderate (8,531/EV Unit)	High (10,455/EV Unit)
May	12,046,000	15,157,000	18,576,000
July	23,833,000	29,988,000	36,751,000
October	31,506,000	39,643,000	48,584,000

To better estimate Sockeye production potential, hatchery and natural-origin Sockeye salmon adults and juveniles will be released throughout Phase 2 to the Sanpoil River, Transboundary Reach, and directly into Lake Roosevelt. The fish needed for these releases may come from the following sources:

1. Eggs, fry and parr from the Okanogan Nation Alliance (ONA) hatchery facility in the Okanogan River basin.

2. Natural-origin pre-smolts or smolts from the Okanogan River.

3. Hatchery and natural-origin Sockeye salmon adults returning to the Chief Joseph Hatchery.

4. Hatchery and natural-origin adults captured live at downstream passage facilities such as Wells and Priest Rapids dams and the Colville Tribe's purse-seiner operating at the mouth of the Okanogan River.

Adult Sockeye salmon released will be genetically sampled to perform PBT analysis of resulting adult returns to the Chief Joseph Hatchery ladder and any future adult collection facility or sampling sites (fisheries, rivers downstream of Chief Joseph Dam etc.).

Within Step 1, Sockeye parr will be released to Lake Roosevelt to estimate the survival rate to yearling smolt. A portion of these parr will be acoustic and/or PIT-tagged to estimate the juvenile passage survival rate at Grand Coulee Dam, Chief Joseph Dam, and mainstem Columbia River hydro projects (See Section 2.5.1.2)

As stated earlier for summer/fall chinook, PBT analysis will allow for the calculation of adult recruits per spawner (AR/S) for Sockeye releases over multiple brood years. Resulting estimates of AR/S will be used to guide decisions regarding juvenile passage facilities, hatchery supplementation and Sockeye population management.

2.9 Implementation Strategy for Redband Trout/Steelhead

The efforts to test feasibility of reintroduction for Sockeye and Chinook offer a unique opportunity to also benefit Redband trout (*O. mykiss gairdneri)* in the blocked area. In Phase 1, it was determined that steelhead (*O. mykiss spp.*) from the extant areas were not a good candidate donor stock due to genetic and disease concerns. It was also concluded that steelhead should not be included in the feasibility testing for Phase 2 due to ESA constraints. However, Redband trout from the blocked area have been documented in the anadromous zone and evidence exists that a portion of the resident populations are expressing an anadromous life history (McLellan et al. 2021). During the implementation of Phase 2 efforts to trap-and-haul or capture salmon in interim facilities, every effort should be made to identify and transport Redband trout. If juvenile Redband trout are encountered in downstream bypass facilities within the blocked area they should be genetically sampled, PIT tagged and allowed to continue downstream. If Redband trout from the blocked area (as determined by PIT tag, genetics, stable isotopes, or other method) are encountered in adult upstream traps or interim collection facilities they should be transported to the blocked area. These fish should be subjected to similar pathogen testing protocols as the salmon in Phase 2. Initially, this will require short-term holding in quarantine while rapid qPCR tests are implemented. If the pathogen testing protocol is changed for salmon, then it should also be reconsidered for *steelhead*. However, given the likely small numbers of individuals encountered and the additional risk of intraspecific horizontal and vertical transmission, it may be prudent to implement and maintain a more stringent pathogen testing protocol until or unless volitional[23] passage is installed.

2.10 Passage System Analysis and Ongoing RM&E

The results from fish passage survival studies will be used to update LCM inputs and generate expected fish production resulting from installation of each passage strategy. This modeling will be used to inform fisheries managers of program progress, investigate passage system improvements to increase survival, explore different levels of hatchery production and release locations, and conduct sensitivity analyses to determine the need to replicate studies to reduce uncertainty over time.

Ongoing research, monitoring, and evaluation (RM&E) will be performed throughout Phase 2. Monitoring all life stages for each production area will help identify limiting factors that may be constraining the success of the reintroduction program. Adaptively managing these limiting factors, in

[23] Volitional*:* Continuously available fish passage that is performed under the power of the fish, potentially using human-built infrastructure.

addition to providing fish passage, will not only improve performance metrics over time, but also improve ecosystem conditions for other native species.

2.11 Phase 2 Study Support Programs

To support production of the juvenile salmon necessary to implement Phase 2 studies, interim rearing facilities and strategies will be developed at the beginning of Step 1. Additionally, an interim adult collection strategy at Chief Joseph Dam will be established during Step 1 as this is likely necessary to support trap-and-haul of adults to blocked area habitats. These programs will be maintained throughout the duration of Phase 2 studies and expanded upon if results from the adaptive management process deem it necessary.

2.11.1 Trap-and-Haul Programs

Adult salmon will be collected at the base of Chief Joseph Dam using either existing infrastructure at the Chief Joseph Hatchery ladder and/or new interim facilities. Depending on the numbers of returning local-origin adults, capacity of the CJH ladder or holding facilities may be overwhelmed, requiring improvements or construction of a new collection or holding facility. Adults will then be identified, sorted, and tagged based on their area of origin and the associated research objectives. Sorted adults will then be screened for pathogens, if necessary, and loaded into fish transport trucks and hauled to respective locations in blocked habitat study areas.

2.11.2 Pathogen testing

Starting in 2019, the UCUT tribes worked with WDFW to establish a Pathogen Testing Protocol to manage and reduce the risk of introducing the M-clade of IHN to the blocked area. The protocol includes holding returning adults in quarantine for several days while the WDFW fish health lab conducts a rapid qPCR test for the M-clade of IHN. Each ‘lot’ of fish are sampled at the 2% assumed pathogen prevalence level. Testing is not required for fish destined for Lake Rufus Woods because there are no wild populations of *O. mykiss* to protect between Chief Joseph and Grand Coulee Dams and the commercial triploid program in Rufus Woods is fully inoculated for IHN. This approach has proven feasible during early implementation of Cultural and Educational releases. We proposed to continue the pathogen testing during Phase 2 feasibility assessments, particularly while the numbers of returning adults and translocated surplus hatchery fish are relatively small. As the program grows during Phase 2 the logistics and cost of holding and testing large numbers (i.e., thousands) of fish will increase and likely become infeasible. As the benefits of having more salmon in the blocked area begins to outweigh the cost of exposing novel populations of *O. mykiss* to IHN, we anticipate that policy makers will work with technical staff to re-assess the cost/benefit/risk of pathogens and the reintroduction.

2.11.3 Interim Hatchery Production

The salmon reintroduction effort will require a source of both summer/fall Chinook and Sockeye to conduct studies required for evaluating rearing and migratory survival, fish passage survival, passage facilities design, and adult production potential. In Phase 1, Chief Joseph Hatchery summer/fall Chinook and Okanogan River Sockeye salmon stocks were ranked highest for use in the reintroduction program and associated testing and are therefore the preferred stocks for use in Phase 2 efforts.

The objectives of Phase 2 regarding artificial production are:

- To obtain the regulatory approvals needed to collect, rear, and release these stocks in areas upstream of Chief Joseph Dam.
- Identify existing, develop interim, and operate interim hatchery facilities required to produce the summer/fall Chinook and Sockeye salmon required for Phase 2 reintroduction studies.
- Define Phase 3 hatchery production goals and facility requirements needed to achieve salmon reintroduction goals.

The approach for artificial production in Phase 2 is to rely on local existing land-based facilities, increased net pen infrastructure, and develop acclimation facilities to culture Chinook and Sockeye salmon needed for the reintroduction effort. The use of existing facilities is the lowest cost approach for achieving hatchery production needs.

Existing facilities will be used for egg incubation and early rearing. Capacity constraints may require expansion or development of additional interim incubation and early rearing systems. For yearling production, sub-yearlings will be transferred from hatcheries to new net pens deployed in reservoirs and newly developed satellite acclimation sites to be grown until release. For sub-yearling production, fish will not be transferred to acclimation sites but directly released to various locations within the blocked area.

2.11.3.1 Land-Based Hatchery Facilities

The UCUT member tribes have identified nine existing hatchery facilities located upstream of Chief Joseph Dam (Table 11).

These facilities would be evaluated for their production capacity for each phase of the culture process. Current production goals of these facilities would also be reviewed to determine the feasibility, or mitigation required, to convert them for use in the reintroduction program.

In addition to the hatchery facilities in Table 11, the tribes will work with the owner/operators of anadromous hatchery facilities downstream of Chief Joseph Dam and their regulatory processes to quantify excess fish production and rearing space that may be available.

2.11.3.2 Net Pen Rearing

A total of 63 net pens are currently used to rear approximately 750,000 (5 fish/lb.) triploid rainbow trout each year in Lake Roosevelt (Table 12). The survival rate for triploid rainbow trout reared in the net pens from October to May has been >90% (Peone 2020). This is a strong indicator that environmental conditions are sufficient to net pen rear Chinook and Sockeye.

New net pens, dedicated to the reintroduction effort, will need to be deployed within blocked area reservoirs. Four locations (Kettle Falls, Two Rivers, Keller Ferry, and Rufus Woods) are the proposed sites as they coincide with presumed production areas of reintroduced summer/fall Chinook and Sockeye. Additional acclimation may be needed in the Sanpoil River and Spokane River watersheds as none of the existing net pens are close enough to achieve appropriate acclimation. Options such as natural off channel rearing ponds or portable circular tanks will be considered in those areas.

The major benefits of using net pens to rear program fish at existing sites include:

- Low construction cost per net pen (~$40,000).
- Low operational cost (annual cost of current trout program is ~$180,000 per year).
- Easily expandable to meet fish production goals.
- High fish rearing survival rate.
- Acclimates salmon to the conditions at corresponding release locations.

The costs of the triploid rainbow program have been maintained at low levels by using volunteer labor to maintain the net pens and perform daily feeding. This same approach will be considered for the rearing of anadromous fish.

Table 11. Land-based hatchery facilities available for rearing program fish.

Name	Waterbody	Location	Agency	Available Capacity	Comments
Spokane Tribal Hatchery	Tshimikain Creek	Ford, WA	STI	TBD	
Ford Hatchery	Tshimikain Creek	Ford, WA	WDFW	TBD	
Spokane Hatchery	Little Spokane River	Spokane, WA	WDFW	TBD	Brood facility
Sherman Creek	Sherman Creek	Kettle Falls, WA	WDFW	TBD	
Colville Fish Hatchery	Colville River	Colville, WA	Stevens Co./ Colville School District	TBD	Low flow, suitable for early rearing (up to fry)
STI Recirculating System	Off-site	STI	STI	4,200 Age 1+ (20/lb.)	
Little Falls Raceways	Spokane River	Little Falls Dam	STI	TBD	
CDAT Recirculating System	Off-site	Plummer, ID	CDAT	6,000 Age 1+ (20/lb.) - 20,000 Subs (50/lb.)	
Penticton Hatchery	Okanogan Lake	Penticton, BC	ONA	1-5 million Sockeye fry	Sockeye production only

Table 12. Location, minimum, and maximum rearing capacity and period of use for net pens used to rear triploid rainbow trout in Lake Roosevelt. *Italicized rows* correspond with juvenile release sites for Phase 2 studies.

Location	Rkm	# Pens	Min. Capacity (9k fish/pen)	Max. Capacity (15k fish/pen)	Current Use
Kettle Falls/ Sherman Creek	*1132.6*	*18*	*162,000*	*270,000*	*mid-Oct. - May*
Gifford/Hall Creek	1097.1	6	54,000	90,000	mid-Oct. - May
Hunters	1069.2	4	36,000	60,000	mid-Oct. - May
Two Rivers	*1032*	*7*	*63,000*	*105,000*	*mid-Oct. - May*
Seven Bays	1024	12	108,000	180,000	mid-Oct. - May
Lincoln	1017.7	12	108,000	180,000	mid-Oct. - May
Keller Ferry	*987*	*4*	*36,000*	*60,000*	*mid-Oct. - May*
Total		63	567,000	945,000	--

2.11.3.3 Permanent Hatchery Facilities

The Columbia Basin Partnership Task Force (CBPTF) identified Chinook and Sockeye hatchery production and adult return goals (pre-harvest) for the blocked area upstream of Chief Joseph Dam (CBPTF 2019) (Table 13). Later in Phase 2, if feasibility testing from early steps looks favorable, these numbers may be used as the initial starting point for scoping permanent hatchery facilities and their associated construction and O&M costs for Phase 3 implementation.

Table 13. Hatchery and adult production goals developed by the Task Force for the blocked area upstream of Chief Joseph Dam (CBPTF 2019).

	Hatchery Production Goals		Adult Return Goals	
Species	Low	High	Low	High
Summer/Fall Chinook	900,000	18,000,000	20,000	35,000
Sockeye	9,100,000	9,100,000	360,000	360,000

2.12 Phase 3 Decision-Making

Like the reviews performed between the steps, analyses performed throughout Phase 2 will be synthesized and used for Phase 3 decision-making. The data collected and results of interim fish facilities testing in Phase 2 will be used to develop a suite of alternatives that could be implemented in Phase 3 to fully reintroduce Chinook and Sockeye salmon upstream of Chief Joseph, Grand Coulee, and Spokane River dams. The Phase 3 alternatives will consist of combinations of permanent fish passage facilities, hatchery facilities, and hatchery production levels for each species. The alternatives would be evaluated based on the following factors:

- Ability to achieve conservation, harvest, and cultural goals for each species.
- Construction and O&M costs of fish passage and hatchery facilities.
- Effects on extant salmonid populations, including ESA-listed salmonid populations downstream of Chief Joseph Dam.
- Effects on established marine and freshwater salmon fisheries.
- Effects on dam operations.
- Effects on hatchery operations.
- Impacts to resident species and fisheries upstream of the dams.

The development and review of these alternatives will be performed in collaboration with stakeholders and presented to policy and decision-makers for a determination of a reintroduction program supported by permanent passage and production facilities.

In addition to evaluating the technical feasibility and costs, decision-makers will also have to consider the benefits of reintroduction when determining to continue to Phase 3. Activities performed throughout Phase 2 stand to incidentally support a restoration of tribal culture, local and marine ecosystems, while also contributing to fisheries in the Columbia River and Pacific Ocean.

3 FISH PASSAGE

The results of the Phase 2 studies will be used to select preferred passage strategies for Columbia and Spokane River dams, the order in which they are installed, and scoping permanent passage facilities for possible implementation in Phase 3. Both volitional and trap-and-haul systems have the potential to achieve identified passage performance metrics, although initially in Phase 2, interim adult passage will rely exclusively on trap-and-haul and the existing Chief Joseph Hatchery ladder until additional upstream passage facilities can be installed and tested (Figure 9). Salmon migrating downstream will initially be subjected to passage via spill or turbines until downstream passage facilities can be developed and tested in Step 2 (Figure 10).

> **Fish Passage**
>
> Phase 1 analysis of possible fish passage facilities at Chief Joseph Dam and Grand Coulee Dam was limited in scope. The analysis focused on floating surface collectors for juvenile collection and bypass, and innovative adult passage systems. In Phase 2, other passage systems such as turbine screens, louvers, fish ladders and lifts will also be investigated.

3.1 Development and Design

Interim facilities would have two purposes:

- Allow for the collection of adults and juveniles to conduct necessary fish survival and behavior studies.
- Act as prototype fish passage systems to determine the likely effectiveness of permanent passage systems and their design.

The development of both interim and final fish passage facilities will generally follow the approach outlined in the United States Army Corps of Engineers (USACE) *Surface Bypass Program Comprehensive Review Report* (Compendium; USACE 2007). The Compendium compiled and synthesized the knowledge base regarding surface bypass design and evaluation of juvenile passage facilities as well as lessons learned from successes and failures of these systems. From this review they produced a surface bypass development process model that consists of three phases: Preparation, Prototype, and Production. This approach is applicable to adult upstream passage systems and juvenile passage systems such as louvers or turbine screens. Additionally, fish passage criteria and design will also reference the National Marine Fisheries Service (2011) and the US Fish and Wildlife Service (2019).

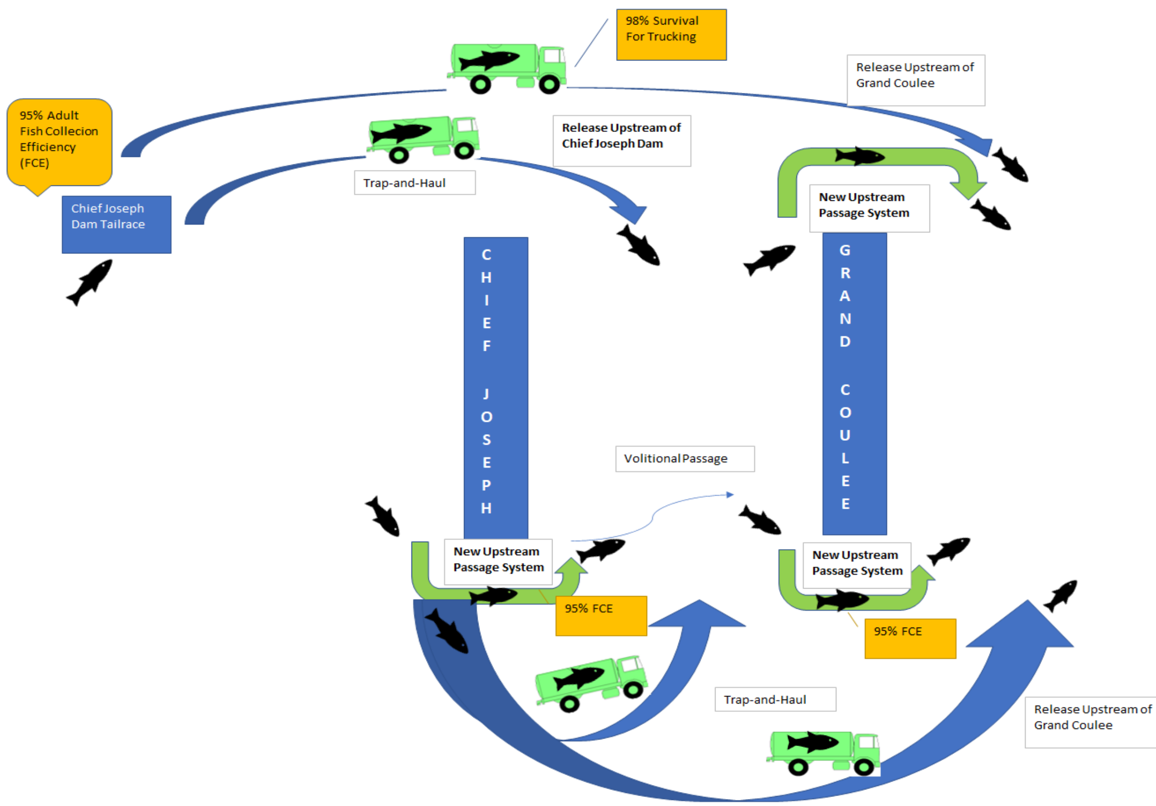


Figure 9. Schematic of volitional and trap-and-haul upstream passage systems for adult salmon at Chief Joseph Dam and Grand Coulee Dam.

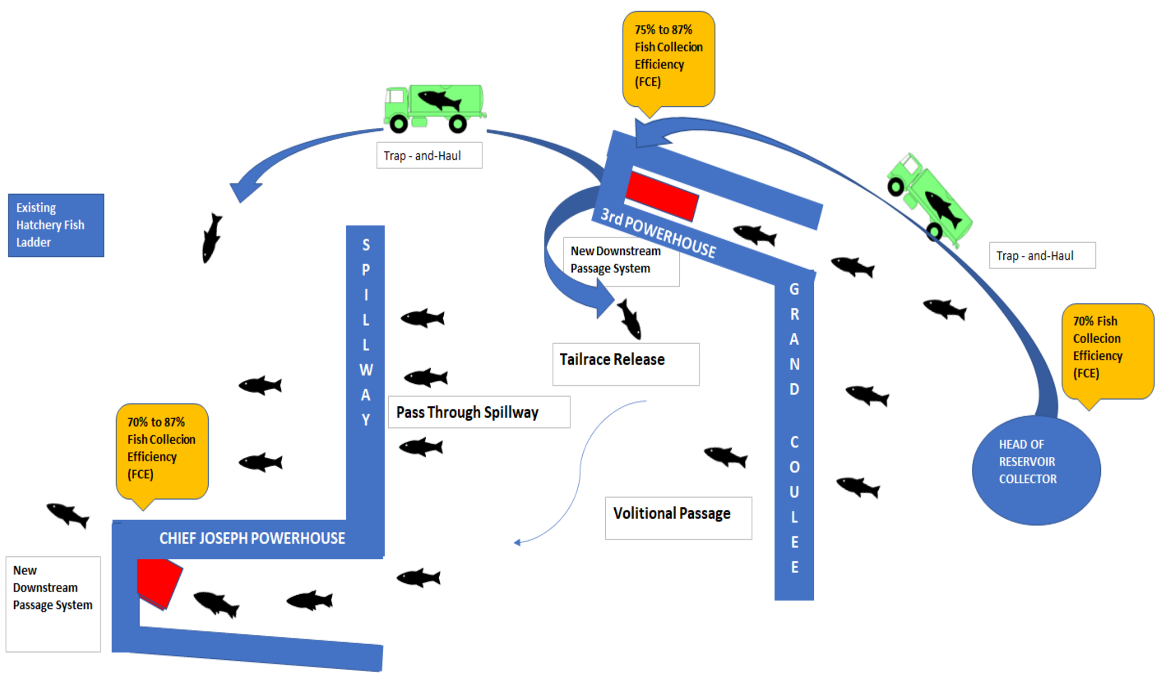


Figure 10. Schematic of a possible juvenile downstream passage strategy for Chief Joseph Dam and Grand Coulee Dam and their performance metrics.

Since 2007, multiple juvenile surface collector systems have been installed and tested for fish passage effectiveness throughout the Northwest (Kock et al. 2019). UCUT member tribes contacted the authors of this report for lessons learned from this work and incorporated it into the proposed approach.

Additionally, the UCUT member tribes have developed a tentative sequence for the testing and construction of fish passage facilities. The order of implementation will be dependent upon the results from initial studies and the decision-making processes they support. The tentative implementation sequence is as follows:

- Adult upstream passage at Chief Joseph Hatchery and/or Chief Joseph Dam.

The success of reintroduction and associated studies is highly dependent on the ability to collect returning adults with high efficiency. It is ranked higher than juvenile fish passage as juvenile fish can migrate out of the system through turbines and spill. Adult collection at CJD (or hatchery) will be used for the interim passage strategy of trap-and-haul around all five dams. This facility will also allow for the collection of data needed to calculate performance metrics critical for decision-making.

- Juvenile downstream fish passage at Grand Coulee Dam.

Most of the potential salmon production is expected from habitats upstream of this project. Higher passage survival at Grand Coulee Dam will benefit production areas in the Sanpoil and Spokane Rivers as well as the Transboundary Reach and Lake Roosevelt tributaries. The higher the juvenile passage survival rate at this project the greater the probability that reintroduction will be successful.

- Adult upstream passage at Grand Coulee Dam.

Volitional upstream passage at Grand Coulee Dam will reduce the scope of trap-and-haul operations while providing opportunities for returning local-origin adults to not be influenced by active transport. Subsequent studies of adult migratory behavior and success on fish not subject to active transport are important for evaluating the long-term feasibility of the reintroduction program. Volitional passage will also provide a means for adults that experience fallback and survive to re-ascend Grand Coulee Dam.

Passage Facility Development Priority

Adult fish passage development at Chief Joseph Dam is the highest priority for Phase 2. Unless adults can be successfully passed upstream, the construction of juvenile fish passage facilities has little value.

Juvenile passage at Grand Coulee is ranked second in priority as most of the salmon production is expected from habitats upstream of this project.

- Adult upstream passage at Little Falls, Long Lake, and Nine Mile dams.

Much of the suitable habitat in the blocked area is located upstream of these Spokane River dams. The dams are relatively small and will likely accommodate traditional or novel upstream passage systems. Volitional passage will provide an opportunity for larger numbers of adults, not constrained by hauling operations, to access the range of habitats available throughout the Spokane River watershed.

- Juvenile downstream passage at Little Falls, Long Lake, and Nine Mile Dams.

Due to the high proportion of spill that occurs during the juvenile migration period, downstream passage facilities may not be required to meet defined performance metrics. Studies early in Phase 2 will inform the need and likely effectiveness of juvenile passage at these dams.

- Juvenile passage at Chief Joseph Dam.

Based on turbine and spillway survival at similar projects, juvenile survival at this dam is expected to be >85% even without a juvenile fish passage system. This survival rate is likely sufficient for successful Chinook reintroduction into Rufus Woods Lake. Studies early in Phase 2 will inform the need for improved survival, potential benefits to production areas upstream of Grand Coulee Dam, and the sequencing of studying and implementing a juvenile passage facility.

- Head of Lake Roosevelt Juvenile Collector

It is not known at this time if juvenile salmonids from the Transboundary reach can migrate through Lake Roosevelt with high survival. If survival rates are low, this facility may be considered, developed, and tested for effectiveness at collecting juveniles.

Data collected as part of Phase 2 studies will be used to confirm the need and sequence of the fish passage facilities.

A description of each of the three phases of fish passage facility development are provided next. Much of the text for each of three sections were taken directly from the USACE 2007 (Compendium) report.

3.1.1 Preparation

The Compendium states:

The preparation phase starts with initiation of the development process and ends with a conceptual design for a prototype of the preferred alternative.

For this report, the terms prototype and interim facility are interchangeable. The steps that may be followed in Phase 2 to develop fish passage facilities are as follows:

- A project development team (Team) will be established that consists of representatives from UCUT member tribes' staff, dam owners/operators, resource agencies, and experts in the fields of biology, engineering, and hydraulics.

- Clear goals regarding salmon production, dam passage survival, and fish collection efficiency of the facilities will be established by the Team.

- Baseline biology, including species of interest, migration pathways, forebay and tailrace residence time, and vertical and horizontal distribution upstream and downstream of the dams will be assembled and described. Critical data gaps identified by the Team will be the focus of future studies.

- A brainstorming workshop will be conducted by the Team to develop an alternative matrix of potential passage facilities at each dam[24]. The Team will develop estimates of expected system performance for each species of interest.

- Depending on available resources, a computational fluid dynamics model (CFD) and physical model of the forebay and tailrace will be developed. These models refine potential facility locations and gather further data on attraction flows and fish behavior through telemetry.

- The Team will make a recommendation as to the need for a prototype system and the preferred alternative. If a protype is not required then the process moves to Phase 3, Production.

- An engineering firm will be hired to design the prototype system.

This process may need to be altered based on input from dam owners. These parties may wish to pursue their own process or tweak this process to better accommodate their needs.

3.1.2 Prototype (i.e., Interim Facility)

This phase will begin with the development of detailed design of the prototype (i.e., interim) passage facility and conclude with selection of a conceptual design for a full-scale production system (i.e., permanent system). Steps in the Prototype phase are:

- Design, build and install the prototype facility. If a decision was made to use CFD and physical models to design facilities, the Team will use these models to investigate various entrance configurations and release locations of collected and bypassed fish prior to building the prototype.

[24] Passage alternatives could be in project reservoirs or tributaries as well.

- Establish clear performance objectives for the prototype. The Team will develop the performance metrics used for evaluating the success of the prototype system. Metrics could include fish collection efficiency, ability to attract fish to specific locations, survival of collected fish etc.

- Conduct detailed biological evaluation and hydraulic modeling of the passage system. This information will be used to adjust system design until it achieves performance metrics identified for the prototype.

- Reach a decision as to whether to proceed to full scale production system. The Team will produce a report that details the results of all evaluations, the conclusions the Team has drawn from these evaluations and make a recommendation as to whether to proceed to development of the full-scale system.

3.1.3 Production

The production phase will start with concept development and finish with the construction of a highly effective fish passage system that provides safe and timely fish passage. The production phase will consist of designing, building, and evaluating the full-scale fish passage system.

3.2 Chief Joseph Dam Fish Passage Facilities

Initially, interim adult upstream passage would rely on trap-and-haul from the existing fish ladder at Chief Joseph Hatchery and downstream migrants would pass the project through turbines and spill (Figure 11).

The LCM analysis assumed that adult fish collection efficiency at Chief Joseph Dam tailrace was 95%, and juvenile survival past the dam was 88%. These assumptions were not based on empirical data collected at this dam but instead relied on survival values obtained from the literature for similar hydroelectric projects. Thus, initial assumptions are highly speculative and require conducting upstream and downstream passage studies to confirm assumptions. These juvenile survival and adult collection studies will be conducted in Step 1.

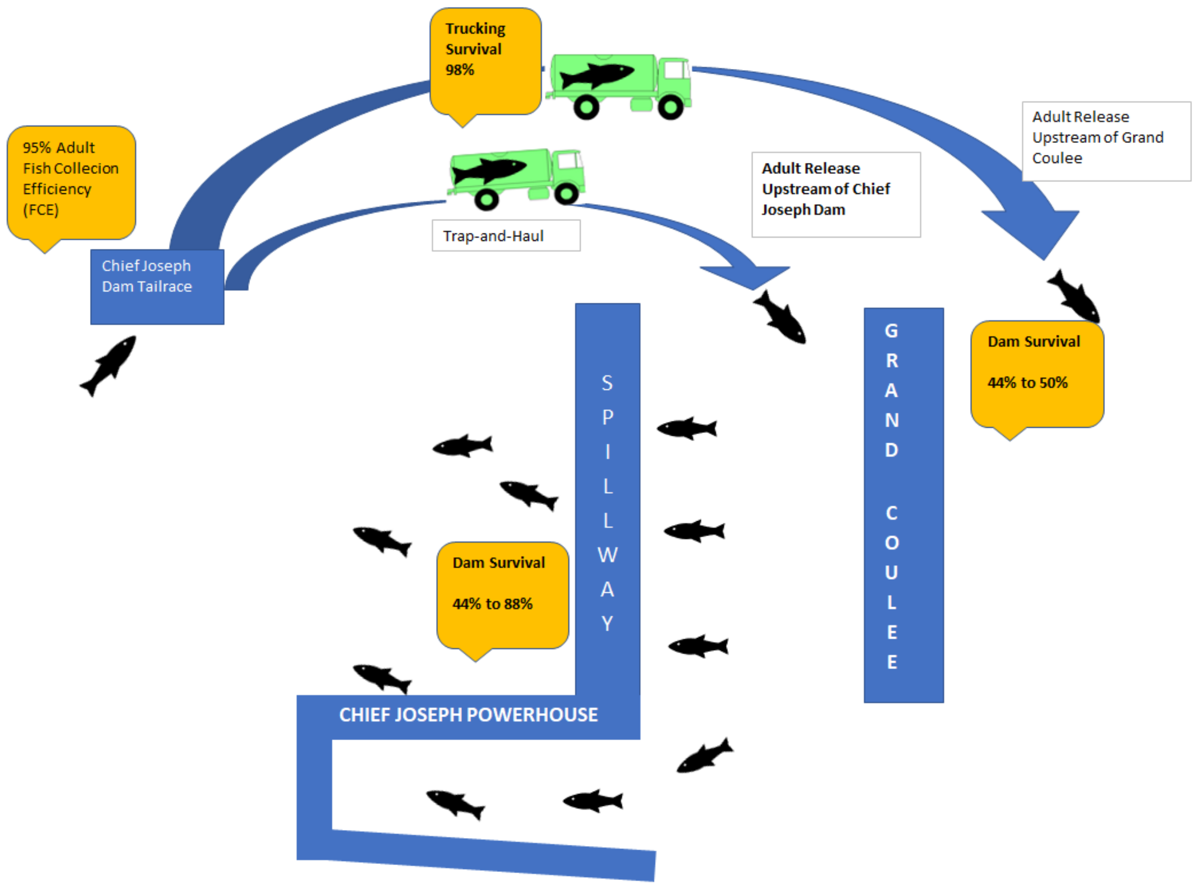


Figure 11. Upstream and downstream passage at Chief Joseph Dam. Upstream passage will initially rely on the ladder at Chief Joseph Hatchery for trap-and-haul while additional interim facilities are being designed/constructed. Juveniles to pass the project through turbines and spillways.

3.2.1 Upstream Passage

An adult collection efficiency of 95% is used as the performance metric for upstream adult passage at Chief Joseph Dam tailrace. The Chief Joseph Hatchery ladder will be used as the initial upstream collection site, but it may not be reasonable to assume that this facility has the capacity to handle upstream collections as the program grows or that it will meet the 95% efficiency goal. Therefore, work to evaluate, design and implement an additional adult collection facility should be implemented in Step 1. Studies will be implemented to evaluate the efficiency of the CJH ladder as well as fish behavior to help site/scale/refine one or more additional adult collection facilities in the CJD tailrace (Figure 12). Concepts and cost estimates will be generated for the development of a permanent adult passage facility at Chief Joseph Dam that could accommodate the larger adult returns envisioned with a successful reintroduction. These permanent facilities would then be considered for construction in Phase 3.

Additionally, any new adult passage system built at Chief Joseph Dam may have to be equipped with sorting facilities to prevent ESA-listed steelhead from migrating upstream, and/or to allow the upstream passage of *O. mykiss* that were produced in the blocked area (McLellan et al. 2021). Fish facility operations and fish handling protocols will be developed in consultation with fisheries managers as part of the facility design process.

3.2.1 Downstream Passage

The performance metric for juvenile survival past Chief Joseph Dam is currently set at 90%[25]. This plan proposes that juvenile passage facilities would not be required if this metric is achieved under the current conditions as the resultant increase in fish survival would be minor. This conclusion would be reconsidered if juvenile passage facilities at Chief Joseph Dam would substantially benefit upstream production areas of Chinook and Sockeye salmon.

The results of juvenile survival studies conducted in Step 1 to measure survival past Chief Joseph Dam through both turbines and spill would be used to determine the need for additional data collection and selection of the preferred juvenile passage system (Figure 13).

A net system designed to guide fish to a juvenile collection system or a route with higher passage survival (e.g., spillway) may be considered as a potential improvement guided by the adaptive management pathway dependent on the results of juvenile survival and behavioral studies conducted in Step 1. Hydraulic modeling of the forebay could be undertaken to determine the feasibility of net system operation over the range of river flows expected during the migration season.

[25] Survival rate through turbines and spill. Reservoir survival is not included in the metric.

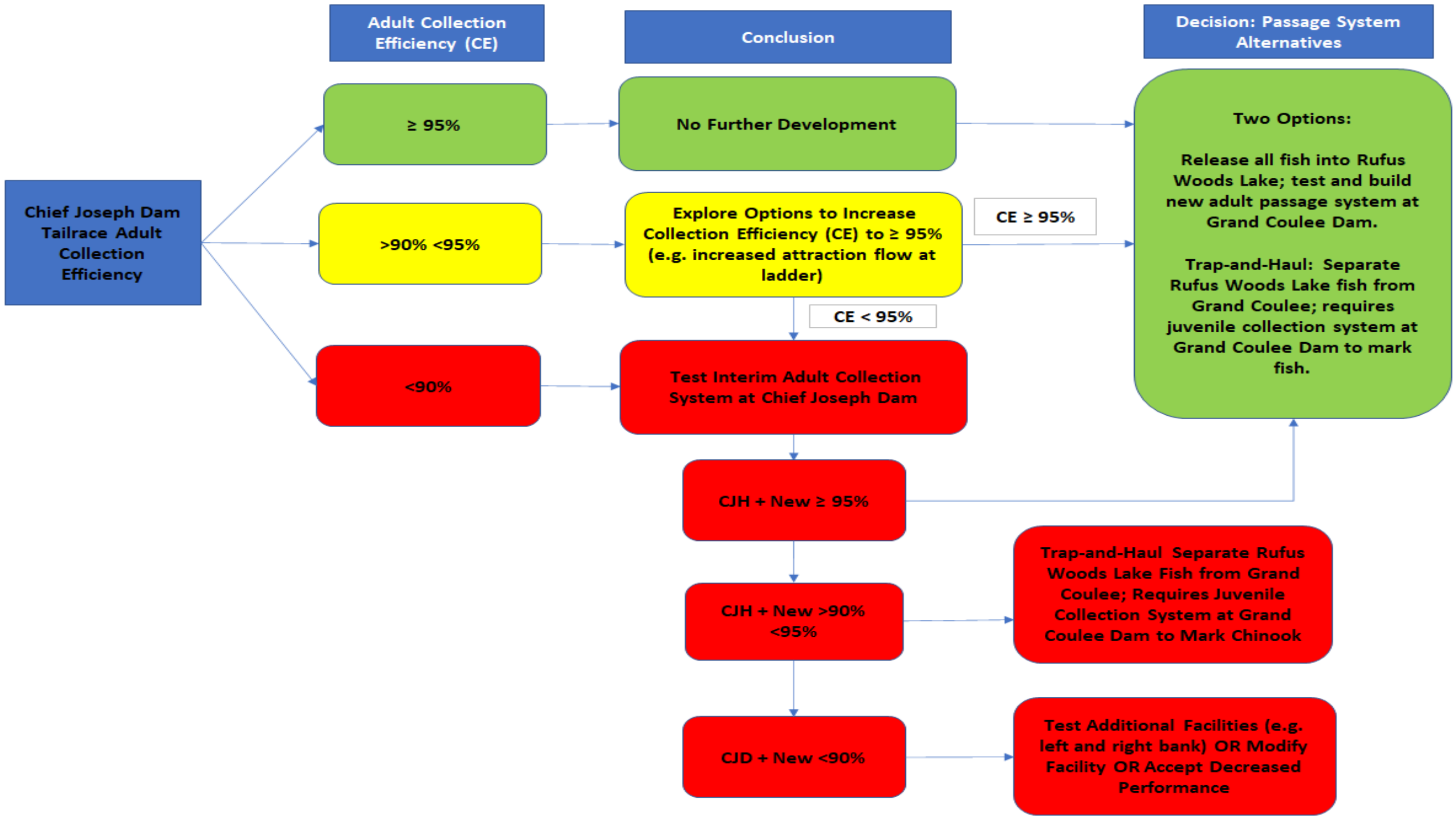


Figure 12. Decision flow chart for selecting the preferred adult interim upstream passage system for Chief Joseph Dam Tailrace.

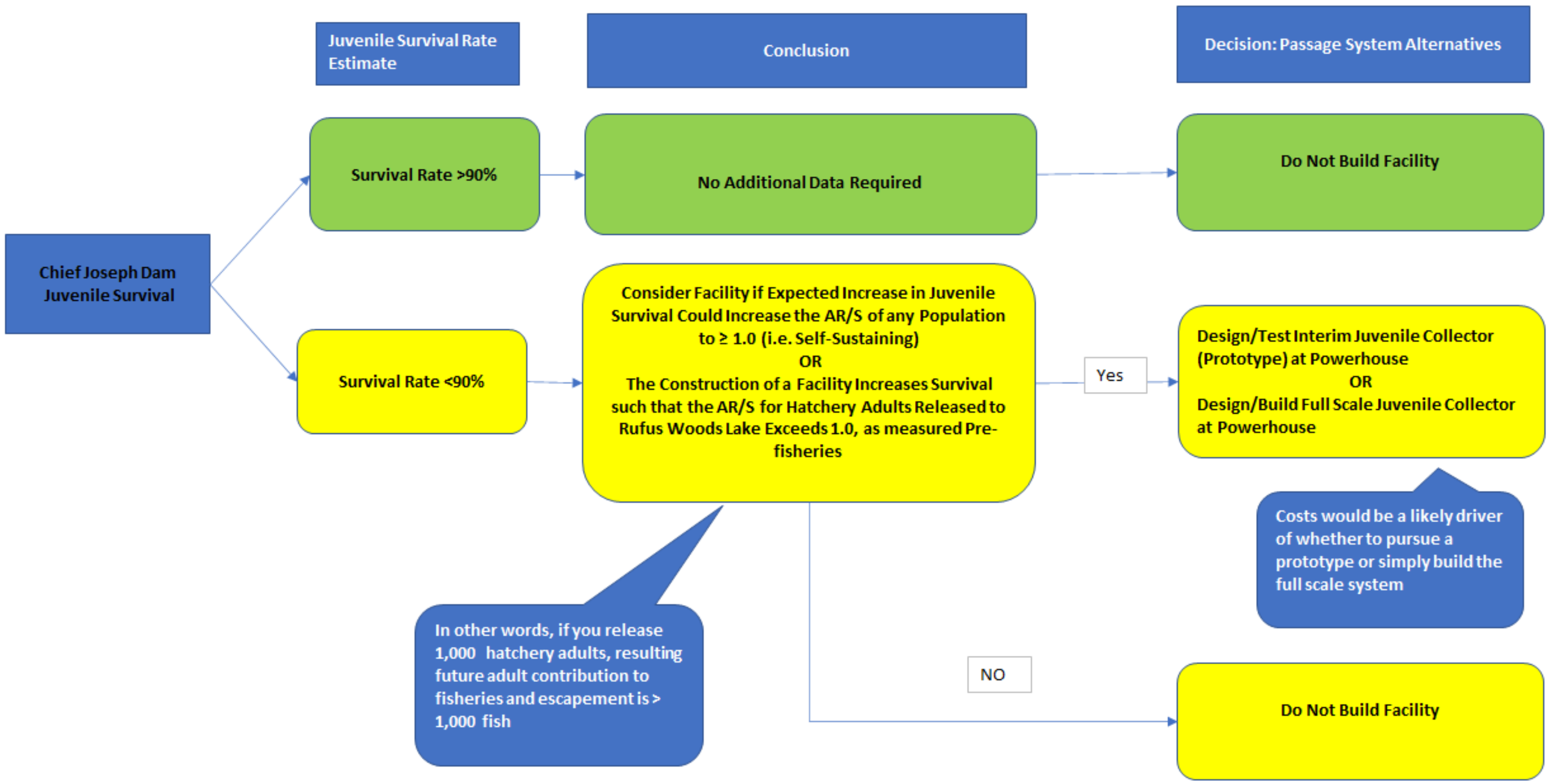


Figure 13. Decision flow chart for selecting the preferred juvenile passage system at Chief Joseph Dam based on estimated juvenile survival rate at the dam (i.e., fish passage through turbines and spillways).

3.3 Grand Coulee Dam Fish Passage Facilities

Grand Coulee Dam is not equipped with upstream or downstream fish passage facilities. Therefore, trap-and-haul from adult collection facilities downstream of Chief Joseph Dam will initially be used as the interim upstream passage method. Juvenile downstream passage will occur through turbines and spillways prior to the installation of an interim downstream passage solution (Figure 14).

3.3.1 Upstream Passage

While trap-and-haul will be used initially to provide adult fish passage, the long-term objective is to build volitional fish passage systems at each dam if study results indicate such a system would provide safe (i.e., high survival) and timely (rapid migration) fish passage.

3.3.2 Downstream Passage

LCM modeling in Phase 1 indicated that a juvenile fish passage system would be needed at Grand Coulee Dam for salmon reintroduction to achieve defined goals. This conclusion assumed that juvenile fish survival through turbines/spillways at Grand Coulee Dam and Chief Joseph Dam was <51% and ~88%, respectively. Combined survival past both dams was assumed to be approximately 45%. These survival values were not based on empirical data collected at the dams but obtained from literature on fish survival through turbines/spillways at other high head dams.

The LCM analysis also assumed that 85% of the juveniles arriving at Grand Coulee Dam could be collected at a single juvenile passage system located at the third powerhouse. This conclusion was based on the results of hydroacoustic data which showed that >85% of resident fish entrainment occurred at this location (Johnson et al. 2005). These survival and passage assumptions are speculative and require conducting studies to determine their accuracy.

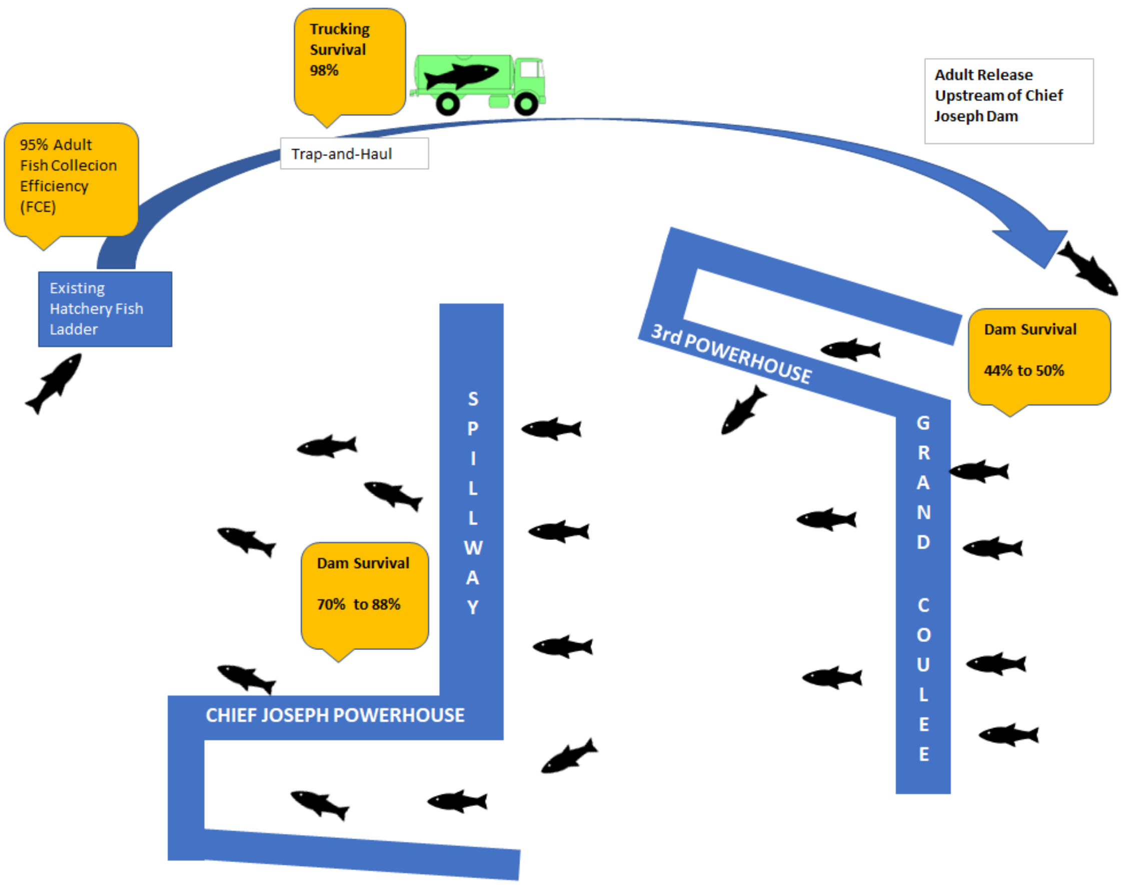


Figure 14. Initial upstream and downstream fish passage strategy for Grand Coulee production areas. Upstream passage will initially rely on Chief Joseph Dam Tailrace trap-and-haul. Juveniles to pass the dam through turbines and spillways prior to construction of interim downstream facilities.

Decision flow charts guiding how the results of each study will be used to guide juvenile fish passage facility selection and implementation are shown in Figure 15, Figure 16 and Figure 17.

The performance metric for juvenile survival past Grand Coulee Dam is 90%. Juvenile passage facilities may not be required if this metric is achieved with passage via spillways and turbines as the resultant increase in fish passage survival would be minor.

However, to determine whether to proceed with a juvenile passage or trap-and-haul system at Grand Coulee Dam requires information on the juvenile survival rate past Chief Joseph Dam and resulting AR/S values (Figure 17). Juvenile passage at Grand Coulee Dam will be justified if the combined survival rate past both dams will be high (greater than 80%) and an AR/S value of > 1.0 can be achieved.

The decision on where to build a juvenile facility at Grand Coulee Dam would be based primarily on the likely effectiveness (i.e., ability to collect fish) of the system. Therefore, results from the juvenile fish behavior studies will guide this decision. Again, the assumption is that 85% of the juveniles will pass through the third powerhouse (Figure 17). If this is not the case then several options would be considered: 1) a guidance net tested to determine if fish can be concentrated and passed at a single collector location, 2) multiple juvenile collectors at Grand Coulee Dam, 3) a juvenile passage facility built at Chief Joseph Dam to increase total survival, or 4) a combination of these options.

Engineering feasibility and design of interim juvenile collection facilities will be implemented as part of Step 2 studies. If a decision is made to proceed with full-scale operations of upstream and downstream facilities, the necessary design work would be initiated in Phase 3.

3.4 Spokane River Dams

Spokane River dams (Little Falls, Long Lake, and Nine Mile) are not equipped with upstream or downstream fish passage facilities. Therefore, trap-and-haul from adult collection facilities below Chief Joseph Dam will initially be used as the interim upstream passage method, while juvenile downstream passage will be through turbines and spillways of the dams.

3.4.1 Upstream Passage

Although trap-and-haul will initially be used to provide adult fish passage, the long-term objective is to build volitional fish passage systems at each dam if study results indicate such a system would provide safe (i.e., high survival) and timely (i.e., minimal migration delay) fish passage.

3.4.2 Downstream Passage

The interim downstream fish passage strategy for Spokane River dams will be via spillways, turbines, and the sediment bypass channel at Nine Mile Dam. Analysis conducted by Parametrix (2004) concluded that juvenile mortality through Nine Mile and Long Lake dams would range from 5% - 40% due to the high proportion of spill during the outmigration period which reduces turbine entrainment. Downstream passage mortality was not assessed for Little Falls Dam; however, fish survival is expected to be comparable to the other dams due to the small size and configuration of this project.

Survival estimates were not derived from locally collected fish passage data, but result from an analysis of flow, operations, and configuration of the Spokane River dams. These assumptions, which were applied to life cycle modeling, will be evaluated by the juvenile passage survival study early in Phase 2. Results of the study will be applied to decision flow charts to determine the need for, configuration of, and performance metrics necessary to meet downstream passage survival goals for the individual dams (Figure 18 and Figure 19.).

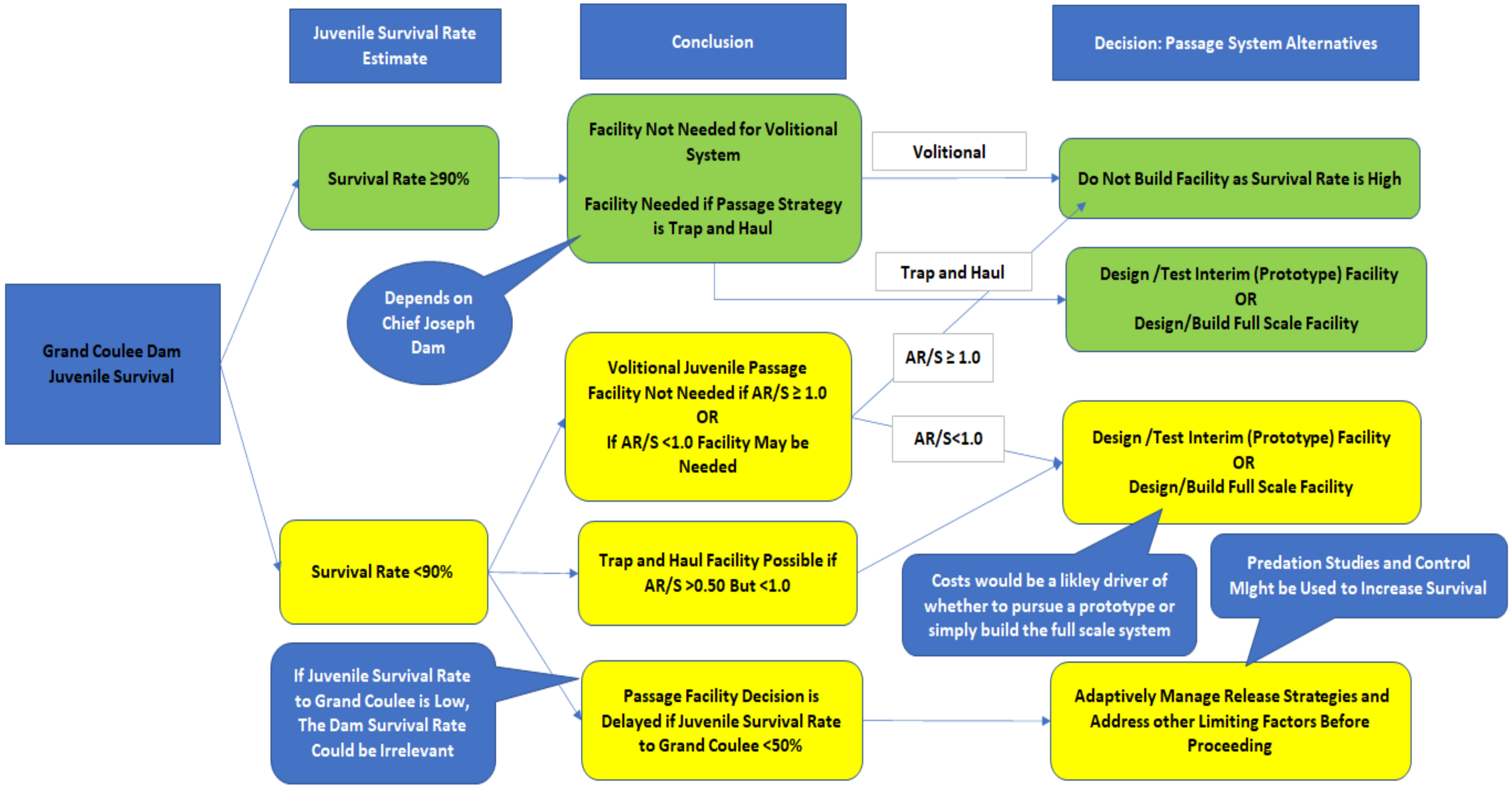


Figure 15. Decision flow chart for selecting the preferred juvenile passage system at Grand Coulee Dam based on estimated juvenile survival rate through project turbines and spillways.

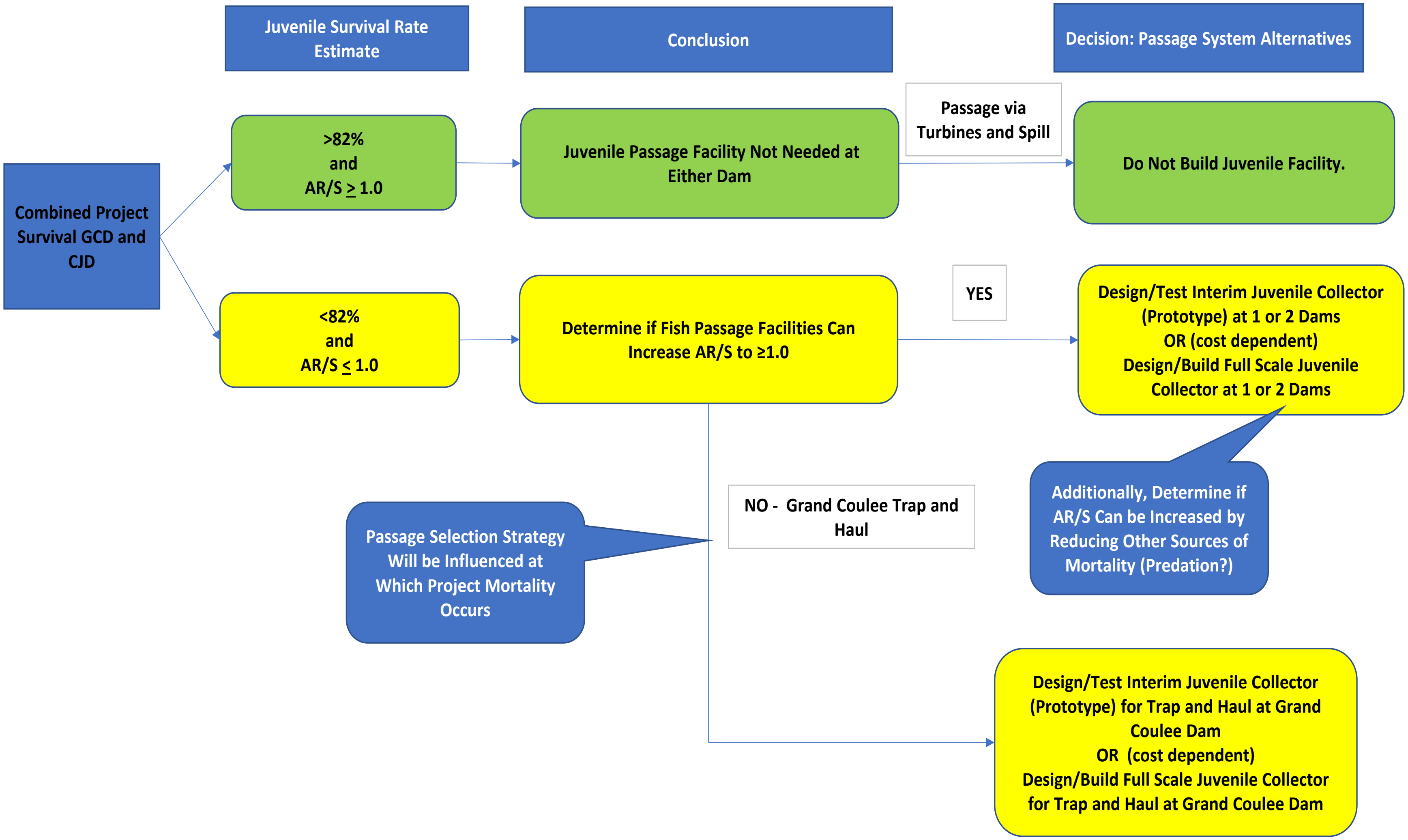


Figure 16. Decision flow chart for selecting the preferred combined juvenile passage system for both Grand Coulee Dam and Chief Joseph Dam based on total passage survival for both projects and AR/S.

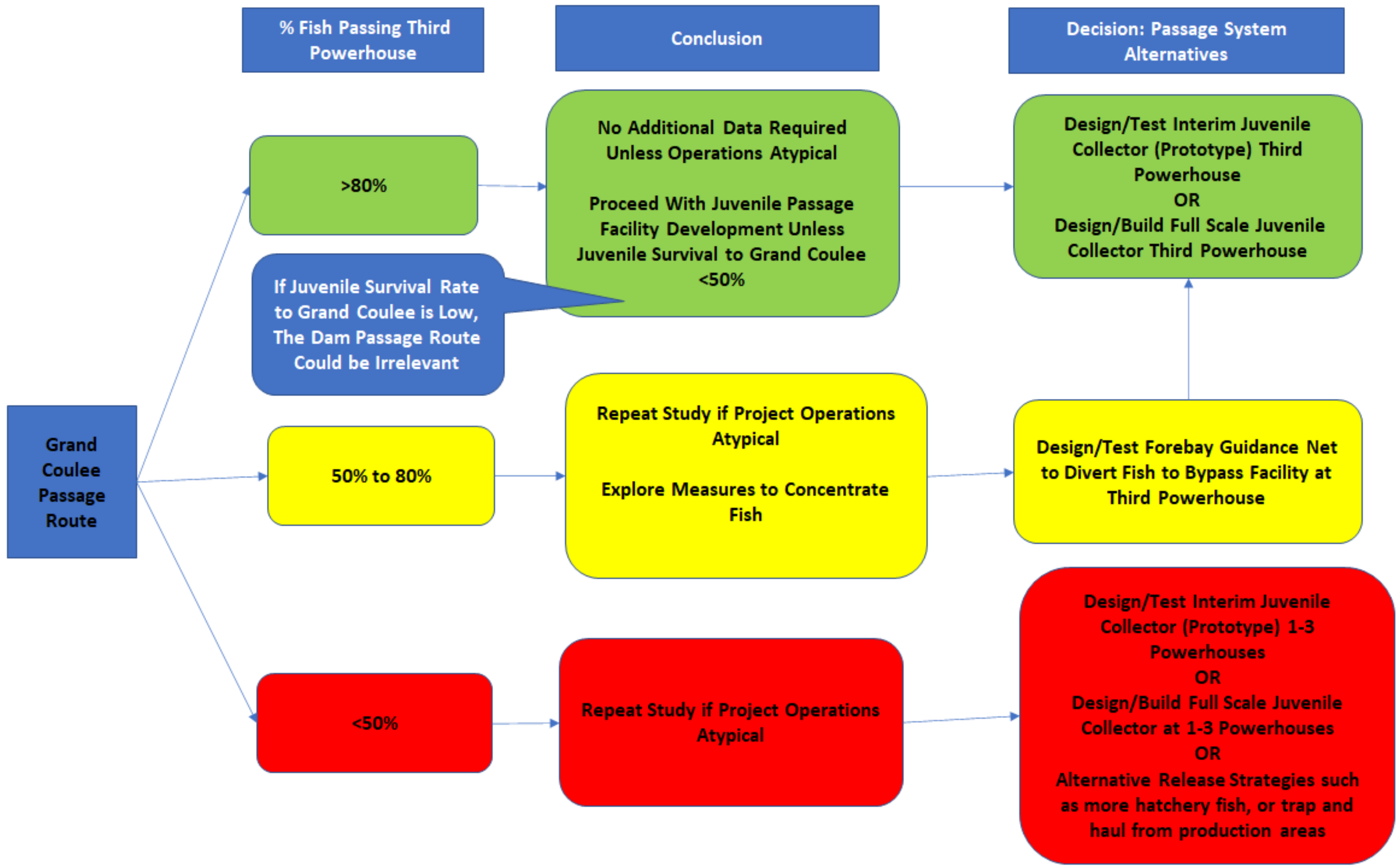


Figure 17. Decision flow chart for locating juvenile fish passage facilities at Grand Coulee Dam based on percent of juvenile migrants passing the third powerhouse.

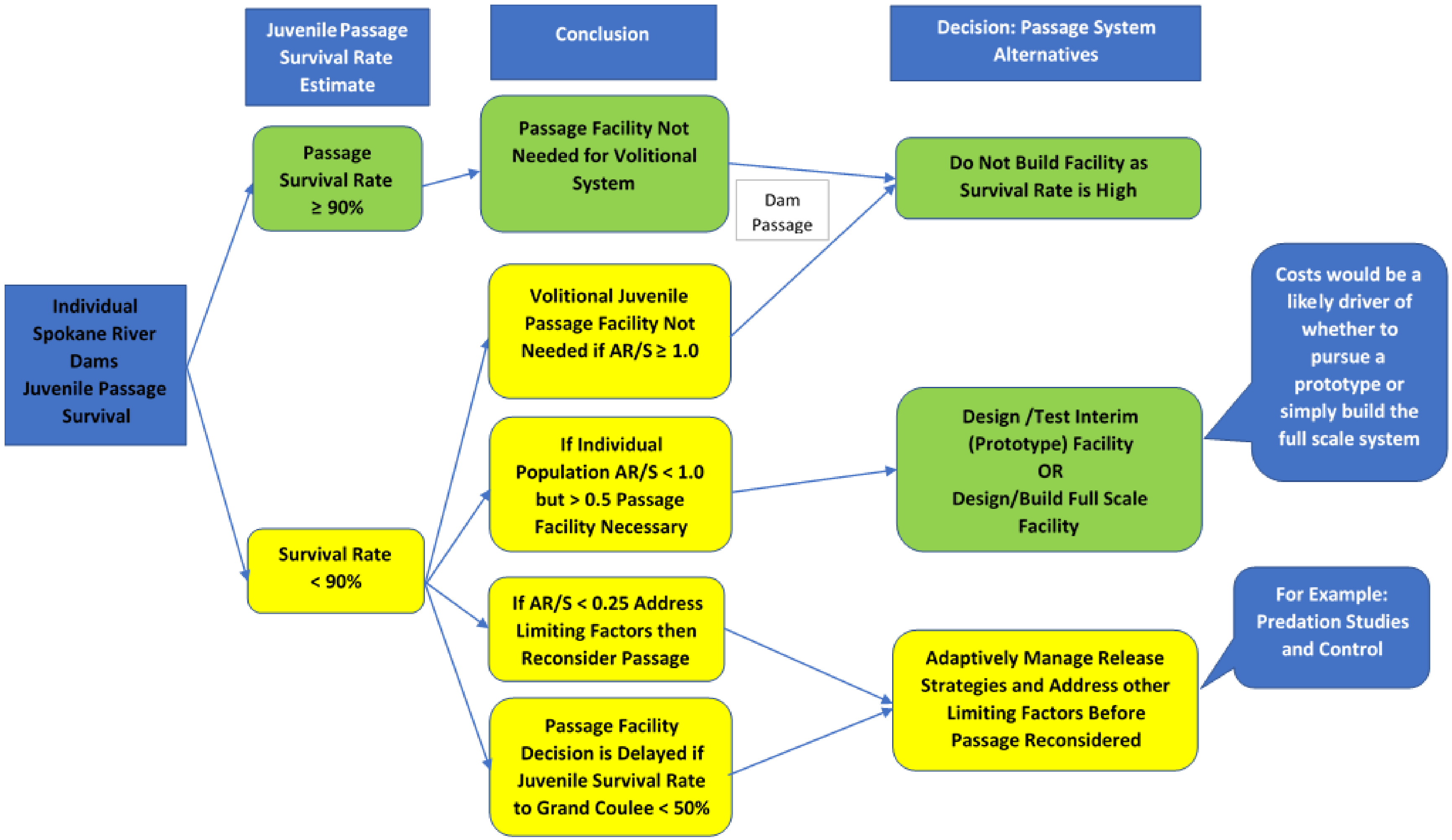


Figure 18. Decision flow chart for selecting the preferred juvenile passage strategy for each of the Spokane River dams (Nine Mile, Long Lake, and Little Falls dams) based on estimated juvenile survival rates and AR/S.

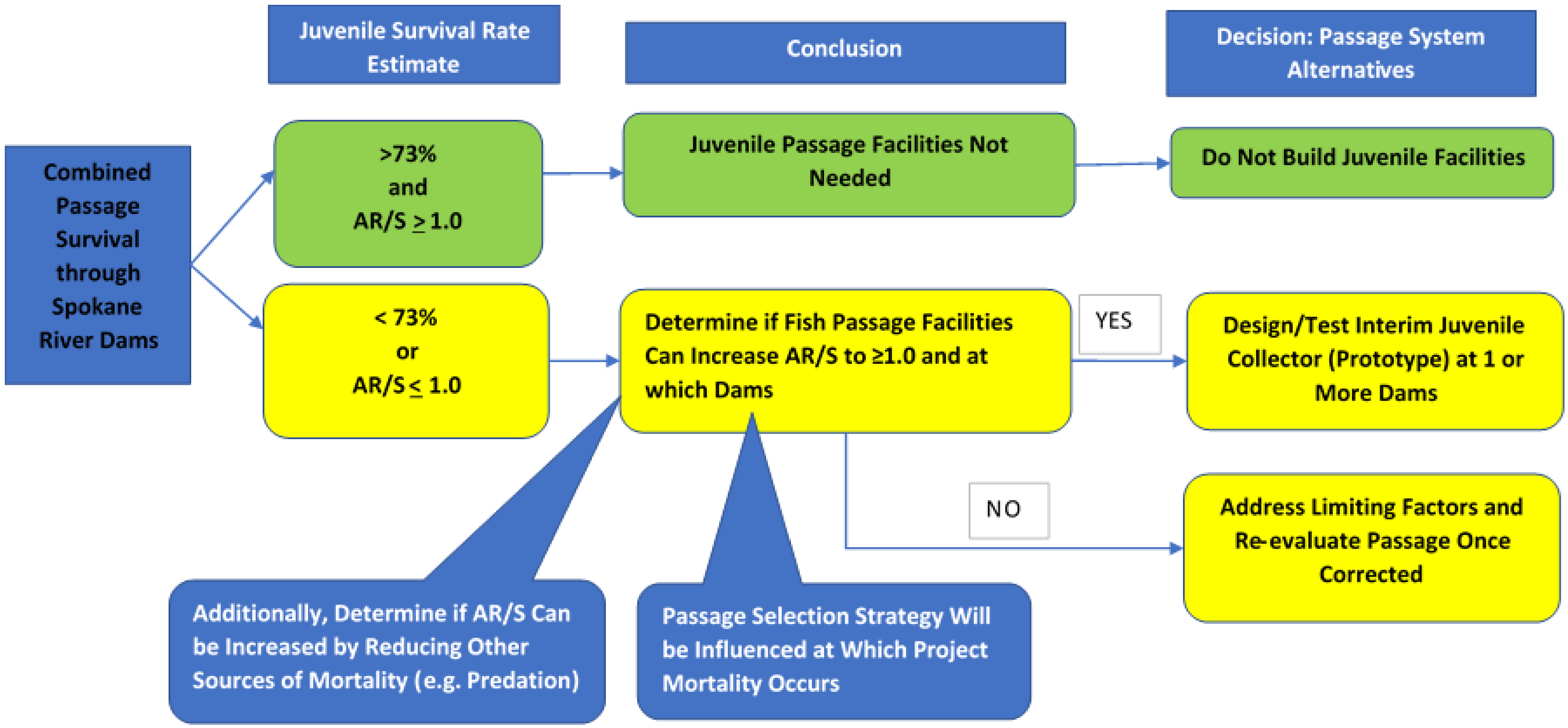


Figure 19. Decision flow chart for selecting the preferred juvenile passage strategy for the Spokane River based on AR/S and combined juvenile passage survival at Nine Mile, Long Lake, and Little Falls dams.

3.5 Production Areas Upstream of Lake Roosevelt (Transboundary Reach and Christina Lake)

A major uncertainty identified in Phase 1 was the survival rate for juveniles migrating through Lake Roosevelt. Based on juvenile survival data collected at other mainstem Columbia River Projects it was assumed that survival through Lake Roosevelt to Grand Coulee Dam would be 60% and 70% for sub-yearling and yearling migrants, respectively.

To increase juvenile survival a head of reservoir juvenile collector with a fish collection efficiency of 70%, combined with a trap-and-haul system that releases collected juveniles below Chief Joseph Dam was modeled. This passage system produced the most adults of the alternatives examined. However, due to logistical challenges (high flows, debris management, fluctuating reservoir length) associated with operating a head of reservoir collection system, it will not be considered for prototype testing until juvenile survival metrics have been confirmed and all other fish passage options have been evaluated.

4 PHASE 2 PROGRAM COSTS

Program cost estimates for Phase 2 have been developed for the framework and activities proposed herein. Estimates are based on 2020 dollars and should be adjusted for inflation and new information that becomes available and will be updated over the course of Phase 2 as the program is adaptively managed. Costs are presented below for the following categories:

- Phase 2 Studies
- Hatchery Facilities
- Fish Passage Facilities

A summary of all cost forecasts by year is included in Appendix A.

4.1 Studies

Studies are to be implemented following the two-step approach presented in Section 2.5. Cost estimates have been developed for baseline and repeated trials of juvenile survival studies, fish passage efficiency studies, and additional RM&E activities. Studies and actions addressed in Step 1 create the foundation of Phase 2. There is a relatively high degree of confidence in the scope and budgets of these early Phase 2 studies. However, studies undertaken later in Phase 2 are dependent on the results of Step 1 research, and therefore there is greater uncertainty associated with the scope of Step 2 studies and the respective cost estimates (Table 14). The cost estimates provided in Table 14 represent planning level costs and may increase or decrease as Phase 2 is adaptively managed.

Table 14. Phase 2 studies and associated costs (2022 values).

Phase 2 Steps (Associated Studies)	Estimated Cost (in millions)
Step 1 (Hatchery Review, RM&E, Baseline Survival Studies)	$23.6
Step 2.1 (RM&E, Passage Facility Evaluation)	$6.38
Step 2.2 (RM&E, Passage Eval, Survival Studies)	$14.52
Step 2.3 (RM&E, Passage Facility Evaluation)	$6.38
Step 2.4 (RM&E, Passage Eval, Survival Studies)	$28.6
Total	$79.5

4.2 Hatchery Production

Capital and O&M costs estimated for an interim artificial production strategy for egg incubation and juvenile rearing facilities, expanding Lake Roosevelt net pens and developing acclimation facilities are presented below in Table 15.

Table 15. Construction and O&M costs (in millions) for interim hatchery facilities (2020 dollars).

Interim Hatchery Facility	Facility Cost Estimates	Annual O&M
Review of Existing Facilities	$0.1	--
Early Rearing Facilities	$2.0	$0.33
Net Pens	$0.5	$0.1
Acclimation Facilities	$1.0	$0.2

4.3 Fish Passage

An initial range of possible capital and O&M costs are provided in this section for the following fish passage systems:

- Interim Upstream Adult Passage
- Interim Juvenile Downstream Passage
- Permanent Passage Solutions

The cost of these passage systems was developed based on a review of information presented in the literature for these systems throughout the Pacific Northwest and California (NPCC 2016). The only detailed study of passage costs specific to the five blocked area dams was completed by the USACE for Chief Joseph Dam in 2002 (USACE 2002).

4.3.1 Interim Adult Upstream Fish Passage

A brief description and cost estimates for possible interim adult passage systems that could be constructed at Chief Joseph, Grand Coulee, and Spokane River dams are provided in Table 16. The interim upstream passage strategy for Phase 2 will be trap-and-haul from a collector at Chief Joseph Hatchery (CJH). Initially the CJH ladder and holding facilities will be used to collect adults and sort them according to their release location as indicated by PIT tag code. Fish will be hauled to the impoundment associated with their juvenile release location and used for monitoring adult migratory behavior and survival. Additional improvements may be necessary to expand the capacity of the ladder and/or holding facilities at Chief Joseph Hatchery to accommodate the numbers of adults estimated to return throughout Phase 2. If collection efficiency is not sufficient, an additional collection facility at Chief Joseph Dam will be developed. This alternative collection facility will be informed by initial assessments performed by USACE (2002) and tailrace behavior studies performed within Step 1. Infrastructure improvements at Chief Joseph Hatchery and a possible additional upstream passage system at Chief Joseph Dam range from $1.0 million to $8 million. Trucks specific to this interim upstream passage strategy will need to be purchased early within Step 1. One truck per production area (3) should be sufficient for transport throughout Phase 2. The three trucks will be purchased early in year one and two and are estimated to cost $330,000 each.

Interim upstream passage systems will be installed in a stepwise approach proceeding upstream. The second will be at Grand Coulee, the third at Little Falls, and so on. The trap-and-haul operation from Chief Joseph Dam will be adjusted as other passage systems are in place. Following the installation of Grand Coulee Dam interim upstream passage, fish marked as destined for Lake Roosevelt will be passed at Chief Joseph Dam while marked fish destined for the Spokane River will be hauled to that watershed.

The cost of interim adult passage facilities likely ranges from $6 to $20 million per dam[26]. Passage costs are expected to be at the higher end of the range for Grand Coulee while the costs decrease for the remaining four dams as dam height and project complexity decreases.

[26] Cost depends on whether one or more upstream passage system is needed at each dam.

Table 16. Estimated capital costs of possible interim adult passage facilities (2022 dollars).

Interim Upstream Passage Facility	Facility	Cost Range	Cost Source
Trap-and-Haul from Chief Joseph Hatchery Ladder or CJD Adult Collection Facility	Chief Joseph Hatchery ladder regularly collects natural and hatchery-origin summer/fall Chinook. Including one originating from the Spokane Reservation. Use facility as interim collection system for a trap-and-haul operation. Improvements to expand capacity or an additional collection facility may be needed. Tailrace behavior of returning adults will inform location. Consultation with USACE will inform type and scale.	Trap-and-haul $0.33 million (Per year for operations) (+$1 million for trucks (3)) CJH Ladder Improvements ($1,100,000)	Based on trap-and-haul trucking distance, labor costs and expected number of fish for Step 1 (1-6 years) Costs in later years will depend on adult run size and presence of interim upstream and downstream passage systems.
Short Fish Ladder + Pneumatic Tube	Short Denil fish ladder (200 ft.) would be used to attract and collect adults from tailrace to a sorting facility where they would be piped (via pneumatic tube) over the dam or loaded on trucks and transported.	CJD Right Bank - $5.75 to $7.75 Million CJD Left Bank - $6.3 to $8.1 Million GCD Right Bank - $6.74 to $8.67 Million GCD Left Bank - $7.1 to $9.2 Million Power and Attraction Flow - $382,000 per year, per system	Estimate assumes Denil fishway costs of $37,000 to $86,000 per foot rise. Assumed flow of 25-100 cfs. (Katopodis 1992, CRWC 2000, Porcher and Larinier 2002, Appendix E.)

4.3.2 Interim Downstream Juvenile Fish Passage

It is difficult to determine the type and size of any juvenile interim facility that may be built until more is known about fish behavior and passage routes at each dam. Results from Step 1 studies will serve this purpose. Ideally, the interim facility selected for implementation would help inform the design of the full-scale system. The types of juvenile interim passage facilities or methods that will be considered for individual dams include but are not limited to:

- Merwin Traps (with or without attraction flow) (Hamilton et al. 1970)
- Portable Floating Fish Collection System (USGS 2016)
- Floating or Fixed Louver System (Ducharme 2011)
- Rocky Reach Corner Collector (USACE 2007)
- Project Spill or bypass with or without Guidance Nets

Although different types of interim juvenile fish passage systems could be built at the five dams, the assumption in Phase 1 was that surface collectors located at the powerhouse would be most successful for GCD while passage via spill may be sufficient for CJD and Spokane River dams. Surface collectors have been installed at multiple dams in the Pacific Northwest and continue to be developed at other high head dams (Kock et al. 2019, USACE 2019 and 2020). Thus, costs are readily available for these systems.

The costs of full-scale surface collectors built in the Pacific Northwest have ranged from approximately $14 million to $137 million (Table 17). Prototype downstream collectors range broadly in costs depending on the type and scale of the system. Because surface collectors have yet to be designed for blocked area dams, for planning purposes it is assumed the median cost estimate (+/- 30%) in Table 17 is a reasonable cost range of permanent juvenile fish passage at Chief Joseph Dam and Grand Coulee Dam (i.e., $41 to $77 million)[27]. Here we assume that all costs associated with an interim juvenile passage facility ($12.3 – $23.1 million per collector) will not exceed 30% of the range for a full-scale surface collector (Table 17). It is worth reiterating that not all dams will require surface collectors, while passage via spill may be sufficient at some.

[27] Surface collectors are not expected to be necessary at Spokane River dams because of operations, sizes, and configurations of those projects.

Table 17. The capital costs of full-scale surface collectors used to provide downstream passage for juvenile salmonids (2020 dollars).

Facility	Attraction Flow (cfs)	Cost (Millions)
Lower Baker	500/1,000	$59
Upper Baker	500/1,000	$59
River Mill Dam	500/700	$14
North Fork	600/1,000	$59
Cushman	250	$31
Swift	1,000	$68
Pelton/Round Butte	6,000	$137
Median Cost		$59
Range (+/- 30% of Median) of Full-Scale Collector		$41 - $77
Prototype Collector (30% of full-scale)		$12.3 - $23.1

The costs associated with the O&M of adult and juvenile passage facilities vary considerably dependent on facility size, inflow and attraction flow, and effects to power generation, etc. Estimates of O&M costs for permanent fish passage facilities within the study area were completed at Chief Joseph Dam by the USACE in 2002 (Table 18).

Table 18. Costs of full-scale permanent fish passage facilities, operations and maintenance, annual generation loss, and studies (design and permitting) in millions. Source: USACE (2002) updated to 2020 dollars.

Chief Joseph Dam Passage System	Facility Cost Range	Annual O&M Cost	Annual Generation Loss	Design
Fish Ladder	$46 - $86	$0.28	$1.3	$7.0
Bypass Channel	$73 - $137	$0.28	$0.96	$7.0
Fish Lift	$31 - $57	$1.3	$1.9	$7.0
Surface Collector	$41 - $77	$1.6	TBD	$13.0

TBD- To be determined. Based on size of collector and whether system is volitional or trap-and-haul.

4.3.3 Operation and Maintenance (O&M)

4.3.3.1 Initial Trap-and-haul

In Step 1, fish passage will be provided using trap-and-haul from Chief Joseph Hatchery or possibly an additional interim facility dependent on funding. The costs during this period are for the labor and trucks required to transport hatchery juveniles and returning adults to various locations in the basin. Approximately $330k annually is sufficient to conduct trap-and-haul activities as initial adult returns, and juvenile releases will be small.

4.3.3.2 Interim Passage Facilities

Passage during Step 2 will be provided by interim/prototype facilities as they are incrementally constructed. The costs associated with O&M are expected to be considerably less than the full-scale systems presented in Table 18.

Considering the reduced scale of the facilities, O&M costs associated with upstream and downstream interim passage have been reduced to approximately 3% of capital costs and standardized across the projects. Operations and maintenance costs for downstream passage during Phase 2 were estimated to be $0.55 million per project per year, $0.42 million per project per year for upstream passage. For the Spokane River, O&M costs for downstream passage were reduced to $0.28 million per project per year due to the smaller scale of these projects and the uncertainty of needing downstream passage or types of systems at all three projects. A relatively small amount of water may be necessary to transport juvenile fish downstream. This is likely to have negligible impacts to energy production at each facility. However, estimates of generation loss cannot be developed until an interim passage strategy is selected for each project (Table 19).

Table 19. Costs estimates (in millions) for interim fish passage strategies. Passage projects are presented in the proposed order of installation (2020 dollars).

Interim Passage Systems	Facility Construction	Annual O&M	Annual Generation Loss	Design
CJH Trap-and-Haul	$0.7 - $1.3	$0.33	TBD	$0.33
CJD Upstream	$5.9 - $9.1	$0.42	TBD	$0.55
GCD Downstream	$11.8 - $21.8	$0.55	TBD	$2.2
GCD Upstream	$5.9 - $10.9	$0.42	TBD	$0.55
Spokane Upstream (each project)	$2.8 - $5.2	$0.42	TBD	$0.77
CJD Downstream	$11.8 - $21.8	$0.55	TBD	$2.2
Spokane Downstream (each project)	$1.1 - $2.1	$0.28	TBD	$0.22
Total Costs	$40 - $72.2	$2.97	TBD	$6.8

4.4 Combined Phase 2 Cost Estimates

Implementing all components of Phase 2, as described in this plan, is estimated to cost $208 million. Cost estimates of studies, infrastructure, and O&M for each step are presented in Table 20.

These estimates were generated by applying costs associated with similar fish passage projects and research to the blocked area. Costs were scaled given the magnitude of this effort, the unique conditions of each dam, and the existing body of knowledge for the region. Given the adaptive management approach adopted for Phase 2, it should be recognized that these costs may increase or decrease as the program progresses and more is learned. There is a relatively high level of confidence in the cost estimates associated with Step 1 as the activities resolve critical uncertainties and provide the framework for carrying out necessary Phase 2 activities. Cost estimates for Step 2 are less certain, particularly the further into Phase 2 they project. However, this Implementation Plan provides a defensible framework for further investigating reintroduction of anadromous species to the blocked area.

Table 20. Total cost estimates (in millions*) for the implementation of Phase 2 (2022 dollars).

Phase 2 Step	RM&E	Infrastructure & Operations	Step Total	Cumulative Total
Step 1	$23.6	$15.2	$38.8	$38.8
Step 2.1	$6.4	$24.8	$31.2	$70
Step 2.2	$14.5	$15.3	$29.8	$100
Step 2.3	$6.4	$23.0	$29.4	$129.1
Step 2.4	$28.6	$50.3	$78.9	$208
Total	$79.5	$128.5	$208	--

*-Numbers rounded to 0.1.

5 POLICY AND REGULATORY CONSIDERATIONS

This section provides information to help facilitate Phase 2 discussions and approvals in the regulatory processes between UCUT member tribes and state and federal entities such as the Washington Department of Fish and Wildlife (WDFW), the National Marine Fisheries Service (NMFS), the United States Fish and Wildlife Service (USFWS), United States Army Corps of Engineers (USACE), and the United States Bureau of Reclamation (BOR). Additional policy and process considerations are necessary for interacting with Mid-Columbia PUD facilities and hatchery programs. Although the reintroduction effort will be substantial, it is not a new endeavor for the region. Salmon reintroduction to habitats upstream of large dams is occurring or has occurred in the Deschutes River (Oregon), Cowlitz River (Washington), Lewis River (Washington), Elwha River (Washington), White Salmon River (Washington), Lake Cle Elum (Washington), Klamath River (California) and multiple USACE owned dams in the Willamette River. Thus, the permitting and regulatory needs for such efforts are known and achievable.

5.1 Establishment of Technical and Policy Teams

The reintroduction effort is a large undertaking that will require coordination with multiple parties. These parties will have both technical and policy concerns regarding the reintroduction program and its effect on their areas of responsibility. To address these concerns the UCUT will create two teams, one to deal with policy issues, the other technical. To the extent that the regulatory requirements are understood and easily achievable (WDFW transport permits), the technical team or project implementers can simply engage the regulatory entity and obtain the necessary permit. In other instances where the path forward is not as clear (ESA permits, NEPA, *U.S. v. OR*), the policy team may engage in a process or ongoing dialogue to develop an appropriate path forward. The Policy team will be responsible for identifying all permits and authorities required to initiate and complete the Phase 2 activities as described in this report. Some examples include:

County:

- Land use authorization/permits (shoreline and/or building permits, short plat, or subdivisions, etc.)

Washington State:

- Fish transfer permits (WDFW)
- Fish Health Screening (WDFW)Scientific Collection Permits (WDFW)
- Water rights (WDOE)

Federal:

- Endangered Species Act Permits and Authorizations (could include amendments to existing HGMPs, new HGMPs, or a letter of 'not likely to adversely affect')
- National Environmental Policy Act Review
- Congressional Authority for USACE and BOR facilities (e.g., fish passage authority)
- National Pollutant Discharge Elimination System (NPDES) Permit; CWA Section 404 Permit
- Access to and Utilization of other Facilities (Chief Joseph Dam, Grand Coulee Dam, Chief Joseph Hatchery etc.)
- Importation permits for transboundary transport of eggs/smolts (USFWS)

Mid-Columbia PUD (or their respective relicensing committees):

- Access to brood (via the annual broodstock management plan)
- Surplus hatchery fish (via the tribal surplus hatchery fish sharing plan for each entity)
- Access to dams or other facilities (e.g., facility use agreements)

Tribal:

- Land use authorizations/permits
- Animal importation permits (CTCR)
- Water rights (e.g., CTCR Environmental Trust Program)

Other:

- *U.S. v. OR*

The Technical Team will be responsible for assisting in study identification, methods, implementation, and analyses. They will make recommendations to the Policy Team as to the program changes required to meet objectives based on monitoring and evaluation results (i.e., adaptive management). The Policy Team will then determine the policy and regulatory processes and permits and determine how specifically to engage in each process by working directly with the appropriate entities.

Note: In 2021-2022, as this Implementation Plan was being drafted, reviewed, and revised, an interagency policy group was formed to bring together state, federal and tribal representatives to discuss the reintroduction effort. This group is the Upper Columbia Blocked Area Anadromous Fish Working Group (Upper Columbia BAAFWG). The Upper Columbia BAAFWG consists of a plenary policy group and has several work teams to delve into technical, policy and regulatory considerations. Once this Implementation Plan is finalized, the Upper Columbia Blocked Area Anadromous Work Group could fill the role of the needed policy and technical teams, or it could serve as a good starting point to establish the necessary coordination teams envisioned in this plan.

5.2 Obtaining Juvenile Salmon for RM&E

The release of juvenile salmon into the blocked area is important for several reasons, and will meet one or more of the following objectives:

1) Evaluating smolt migration through the hydrosystem and generating returning adults that are acclimated to the blocked area for testing upstream passage facilities.

2) Education and outreach purposes, such as salmon in the classroom.

3) Ceremonies, providing an opportunity for celebrations, religious gatherings, and harvest opportunities.

4) Experiments to answer specific critical uncertainties such as reach survival or behavior near a dam (generally acoustic tag studies).

In general, 2-4 above would require relatively small sample sizes of several hundred to several thousand juveniles. For specific examples of potential sample sizes of acoustic tagging studies please see Appendices B and C. Number 1 (above) will likely involve sample sizes of tens of thousands to hundreds of thousands depending on the number of release sites evaluated, the severity of mortality incurred and the statistical rigor of the study. Appendix D outlines an approach for the PIT tag studies and evaluated release sizes of up to 75,000 Sockeye and 160,000 Chinook. Due to uncertainties in survival and study results, it is possible that the Phase 2 studies could require somewhat larger release groups of juvenile salmon.

UCUT member tribes have committed to implementing cultural, educational, and Phase 2 experimental releases using non-ESA listed stocks. Summer Chinook and Sockeye salmon are the primary focus as their runs are productive and healthy in areas immediately downstream of the blocked area. They were also the most highly ranked in donor stock assessments (Warnock et al. 2016, Hardiman et al. 2017). However, there is interest in performing some of the studies using spring Chinook, as recommended by the ISAB in their review of the Phase 1 report (ISAB 2019). Spring Chinook could be used for some Phase 2 studies but only when appropriate donor stocks (those not constrained by ESA) are available.

There are four options through which juvenile Chinook salmon may be obtained to support experimental or cultural releases of salmon in the blocked area.

1) Part of existing production programs

2) Within the +10% of existing program production goals

3) Surplus juveniles from existing programs

4) New production

5.2.1 Part of Existing Production Programs

In this option, juvenile salmon from one or more of the existing hatchery programs would be released in the blocked area to meet the juvenile release objectives listed above.

Presumably, this option would have the least risk to downstream extant ESA-listed species because of the reduced survival that would be expected from releases upstream of Chief Joseph and Grand Coulee dams. Regulatory agencies, such as the National Marine Fisheries Service and the United States Fish and Wildlife Service have already consulted on these existing programs and evaluated their effects to ESA-listed extant populations. The release location of a portion of the program, the tag and mark strategy, and possibly the life-stage (yearling vs. subyearling Chinook) would need to be considered for reintroduction. In the long-term, this option would likely not be acceptable to fish managers as it may undermine their existing mitigation production obligations. However, in the short-term it may provide a means to get started on meeting some of the objectives for juvenile releases and, assuming the release numbers are small (< 50,000), the effects on returning adults would be minimal. Additional constraints associated with each existing program will need to be considered. For example, the use of CJH fish in the blocked area is not currently supported by the Federal Action Agencies due to their interpretation of language in the record of decision that authorizes funding for that facility. Resolution to this issue, and the use of CJH fish for the reintroduction program is of high importance to the UCUT tribes.

5.2.2 Within the +10% of Existing Programs' Production Goals

Hatchery programs are generally permitted to rear and release up to 10% more smolts than the production goal. This allows some flexibility during years when survival at one or more life stages is better than expected. Utilizing the +10% juvenile fish would offer a middle ground between already-permitted release numbers and the mitigation obligations of the program. Like the option that uses part of existing program production, regulatory agencies have already consulted on these programs and evaluated their effects on ESA-listed populations in the extant habitat, the differences that would need to be considered are the release location of a portion of the program, the tag and mark strategy, and possibly the life-stage of releases (yearling vs. subyearling).

There are two options within this pathway to supply juveniles to the reintroduction work. First, it could be opportunistic, whereas if a program happens to be between 100-110% of production goals, those fish become available to meet release objectives in the blocked area. This option would not be reliable because in any given year there may not be any programs that are over 100% of production. Second, specific programs could be requested to collect extra broodstock to achieve additional production of up to 110%. Although the numbers would be relatively small, intentionally collecting extra brood to achieve >100% of program would likely involve additional analyses by NOAA/NMFS and U.S. Fish & Wildlife Service and would require an adjustment to the broodstock protocols.

5.2.3 Surplus Juveniles from Existing Programs

When a hatchery is over production goals (>110%), the excess fish generally cannot be released at their intended location; however, state law prohibits the destruction of viable salmon eggs at hatcheries managed by WDFW (WAC 220-304-020 and RCW 77.95.210). Therefore, surplus fish (eggs, fry, or smolts) are either sent to another facility that is short of their production goal or released into non-anadromous waters to support recreational fisheries (e.g., Alta Lake, Rock Lake, Banks Lake).

Regulatory agencies may not have previously consulted on the effects of surplus production if/when they enter the anadromous zone; therefore, depending on the release numbers and location, additional analyses from NMFS/USFWS may be necessary to permit the releases of these fish in the blocked area. Access to fish in this option would be opportunistic and difficult to plan around. However, if surplus juveniles are available from a preferred donor source it seems logical to utilize them to benefit the blocked area objectives.

5.2.4 New Production

This option would use a downstream hatchery to collect brood for a new program dedicated to reintroduction efforts in the blocked area. The program would need to collect additional brood congruent to existing programs for at least 5-10 years, perhaps longer if blocked area adult collection facilities are inefficient. New production could be utilized to meet the juvenile release objectives at any of the scales listed above but is probably most appropriate for the highest level of production identified to meet Phase 2 experimental needs.

Regulatory agencies have not consulted on the effects of these fish to native fish populations if/when they enter the anadromous zone, nor the impacts of collecting the additional brood necessary. Depending on the release numbers and locations, additional effects analyses will be necessary to permit the collection of additional broodstock and the use of their progeny as part of blocked area reintroduction. This option is likely a long-term strategy as the required permitting and analyses will take significant time and effort to complete.

5.2.5 Phase 2 Release and Marking Strategies

There are multiple watersheds where populations historically persisted and will be the focus of Phase 2 studies. Release sites will coincide with these assumed populations, which are supported by Phase 1 evaluations. Additional release sites at hydroelectric dams will be necessary to assess dam passage survival. In total there are expected to be approximately 14 release sites distributed across the blocked area, nine assumed populations and five paired-release sites (Table 21).

Within the fourth objective of juvenile releases is to produce local origin returning adults necessary for adult migration, behavior, and survival studies. Ensuring adequate numbers of adults and the ability to sort these fish for passage upstream will be challenging. To resolve these challenges the UCUT member tribes are investigating an adipose fin present, coded-wire tag (CWT), and/or PIT tag marking strategy.

The presence of an adipose fin will reduce potential losses incurred through mark-selective fisheries, increasing the number of returning adults for use in passage studies.

Detection of CWTs (in combination with ad-present) or PIT tag will indicate blocked area origin for summer Chinook[28]. The PIT tag will also allow managers to determine the release group that the fish belongs to, informing management actions and enable the calculation of release group-specific metrics.

The same marking strategy can be used for Sockeye so long as fish are released at sufficient size. Because no upper Columbia River Sockeye are adipose fin-clipped, this mark could be used for identifying reintroduction fish at fish ladders, hatcheries, sport fisheries and the spawning grounds.

---

[28] Adipose present, CWT is a mark strategy used for conservation hatchery programs of spring Chinook and steelhead. This tag and mark strategy is also being used for fall Chinook from the Priest Rapids Hatchery.

Table 21. Release sites proposed for Phase 2 feasibility studies and the purpose of each site.

Release Site	Site Purpose
Hangman Creek	Assumed Population (Hangman Creel Watershed)
Spokane River	Assumed Population (Mainstem Spokane River)
Little Spokane River	Assumed Population (Little Spokane River Watershed)
Nine Mile Dam	Dam Passage Survival
Long Lake Dam	Dam Passage Survival
Little Falls Dam	Dam Passage Survival
Two Rivers Marina	Assumed Population (Lower Spokane River/Lake Roosevelt)
Spokane Subbasin Total	7
Transboundary Reach	Assumed Population (Mainstem Columbia River)
Sherman Creek	Assumed Population (Lake Roosevelt Tributaries)
Kettle River	Assumed Population (Lake Roosevelt Tributaries & Christina Lake)
Sanpoil River	Assumed Population (Sanpoil River Watershed)
Lake Roosevelt Total	4
Grand Coulee Dam	Dam Passage Survival
Lake Rufus Woods	Assumed Population (Mainstem Columbia River)
Chief Joseph Dam	Dam Passage Survival
Lake Rufus Woods Total	3
Total Release Sites	14

Parentage-based-tagging (PBT), based on genetic sampling, could also be used to identify all returns from program fish releases. This approach would work best for a new production program as it would be easier to link the broodstock used to the juveniles produced. For an existing program, eggs and juveniles for the reintroduction program would need to be kept separate from the production fish which would complicate hatchery operations.

5.3 Population Management

Natural-origin summer/fall Chinook from the Wenatchee River, Methow River, and Okanogan River are assumed present in the CJD tailrace each year. Current hatchery management requires that natural-origin fish collected at the CJH ladder be released to the river so these fish can return to their stream of origin.

With the implementation of reintroduction, natural-origin fish from upstream of Chief Joseph Dam will be collected at the hatchery ladder and other interim collection facilities. Since natural-origin fish are unmarked, it will not be possible to distinguish blocked area natural-origin fish from extant area natural-origin fish. A subsample of natural-origin fish transported will be genetically sampled to determine their origin. A post-hoc analysis will be conducted to determine if the potential impact to downstream populations is within acceptable limits. Fisheries managers will need to determine an acceptable level of demographic loss of natural-origin adults that stray to CJD and get incorporated in the translocation program. Adult tracking studies will be conducted to determine the fate (survival, fall back, and destination) of fish transported upstream of each dam within the study area.

The reintroduction program initially proposes to treat summer/fall Chinook that pass CJD as a single population with multiple production areas (i.e., Rufus Woods Lake, Sanpoil River, Spokane River, Transboundary Reach).

6 Phase 3 Decision Making

Like the reviews performed between the steps, analyses performed throughout Phase 2 will be synthesized and used for Phase 3 decision-making. Abundance goals for each species have not been pre-determined in Phase 1, instead we propose to develop the goals based on information obtained regarding feasibility and cost during Phase 2. The data collected and results of interim fish facilities testing in Phase 2 will be used to develop a suite of alternatives that could be implemented in Phase 3 to fully reintroduce Chinook and Sockeye salmon upstream of Chief Joseph, Grand Coulee, and Spokane River dams. The alternatives will consist of combinations of fish passage facilities, hatchery facilities and hatchery production levels for each species. The alternatives would be evaluated based on the following factors:

- Ability to achieve conservation, harvest, and cultural goals for each species.
- Construction and O&M costs of fish passage and hatchery facilities.
- Effects on extant salmonid populations, including ESA-listed salmonid populations downstream of Chief Joseph Dam.
- Effects on established marine and freshwater salmon fisheries.
- Effects on dam operations.
- Effects on hatchery operations.
- Impacts to resident species and fisheries upstream of the dams.

The development and review of these alternatives, and the associated goals for a permanent program will be performed in collaboration with stakeholders and presented to policy and decision-makers for a determination of a reintroduction program supported by permanent passage and production facilities.

7 References

Baldwin, C., and B. Bellgraph. 2017. Untitled Technical Memorandum. Update to Hanrahan et al. (2004) Chinook spawning habitat assessment in Rufus Woods Reservoir.

Baldwin, C. 2018. Unpublished Data. Assessment of Sockeye spawning habitat within the Sanpoil Subbasin.

Bellgraph, B.J., Baldwin, C., Garavelli, L., Haque, Z., Perkins, W., Richmond, M., Howell, M. and McLellan, J., 2020. Estimates of Chinook Salmon Spawning Habitat in a Blocked Reach of the Columbia River Upstream of Grand Coulee Dam. *Northwest Science*, *94*(2), pp.99-110.

Bocking, R.C. and M.N. Gaboury. 2003. Feasibility of reintroducing Sockeye and other species of pacific salmon in the Coquitlam Reservoir BC. Prepared for the BC Hydro Bridge Coastal Fish and Wildlife Restoration program. BCRP Report 04. Co.03. LGL Limited. 105p.

Bureau of Reclamation (BOR). 2007a. Assessment of Sockeye Salmon Production Potential in the Cle Elum River Basin, Storage Dam Fish Passage Study, Yakima Project, Washington, Technical Series No. PN-YDFP-008, Bureau of Reclamation, Boise, Idaho, March 2007.

BOR. 2007b. Assessment of Sockeye Salmon Production Potential in the Bumping River Basin, Storage Dam Fish Passage Study, Yakima Project, Washington, Technical Series No. PN-YDFP-010, Bureau of Reclamation, Boise, Idaho, March 2007.

Bussanich, R., Bocking, R., Field, K., Nordin, R., Banner-Martin, K., Perga, M. and Mazumder, A., 2006. Assessment of rearing capacity for consideration of reintroducing Sockeye Salmon to the Coquitlam reservoir. BCRP Report No. #05. Co.13. July 2006.

Chapman, D.W. 1986. Salmon and Steelhead Abundance in the Columbia River in the Nineteenth Century. *Transactions of the American Fisheries Society*. 115:5, 662-670.

City of Spokane (CS). 2014. A Resolution Supporting Anadromous Fish Reintroduction Above Grand Coulee Dam. Resolution No. 2014-0070. July 7, 2014. Spokane City Council. Spokane, WA. https://my.spokanecity.org/citycouncil/meetings/2014/07/07/legislative-meeting/

Columbia Basin Partnership Task Force (CBPTF). 2019. A Vision for Salmon and Steelhead: Goals to Restore Thriving Salmon and Steelhead to the Columbia River Basin: Phase 1 Report of the Columbia Basin Partnership Task Force of the Marine Fisheries Advisory Committee.

Columbia Basin Partnership Task Force (CBPTF). 2020. A Vision for Salmon and Steelhead: Goals to Restore Thriving Salmon and Steelhead to the Columbia River Basin: Phase 2 Report of the Columbia Basin Partnership Task Force of the Marine Fisheries Advisory Committee. October 2020.

https://www.fisheries.noaa.gov/vision-salmon-and-steelhead-goals-restore-thriving-salmon-and-steelhead-columbia-river-basin

Columbia Basin Tribes & First Nations (CBTFN). 2015. Fish Passage and Reintroduction into the U.S. and Canadian Upper Columbia Basin.

Connecticut River Watershed Council, Inc. 2000. Providing fish passage around dams in the Northeast: a fishway for your stream. The Connecticut River Watershed Council, Inc., Easthampton, Massachusetts. Visit http://www.ctriver.org/ to order copies of this publication. See as well http://www.edc.uri.edu/restoration/html/tech_sci/socio/costs.htm

Ducharme L. 2011. An Application of Louver Deflectors for Guiding Atlantic Salmon (*Salmo salar*) Smolts from Power Turbines. Journal of Fisheries Research Board of Canada. 29(10):1397-1404: DOI: 10.1139/f72-217

Gaboury, M.N., and R.C. Bocking 2004. Feasibility of reintroducing Sockeye and other species of Pacific salmon in the Alouette Reservoir, BC. Prepared for Alouette River Management River Society.

Gingerich and Kahler. 2020. Wells Project Subyearling Chinook Life-History Study – 2011 to 2013 Final Report. Wells Hydroelectric Project. FERC No.2149.

Giorgi, C. 2018. Identification of Potential Habitats for Blocked Area Reintroduction. Prepared for Bureau of Reclamation, Agreement No. R16AP00169. June 2018.

Giorgi, C. and A. Kain. 2018. Lake Roosevelt Sockeye Salmon Rearing Capacity. Spokane Tribal Fisheries, Wellpinit, WA. March 2018.

Golder Associates. 2016. Chinook Salmon Spawning Habitat Availability in the Lower Columbia River. Report No. 1538622-001-R-Rev0. Prepared for Canadian Columbia River Inter-Tribal Fisheries Commission, Cranbrook, BC. April 2016.

Golder Associates. 2017. Chinook Salmon Spawning Habitat Availability in the Lower Columbia River, Year 2. Report No. 1659612-001-R-Rev0. Prepared for Canadian Columbia River Inter-Tribal Fisheries Commission, Cranbrook, BC. March 2017.

Hamilton J., L. Rothfus, M. Erho and J. Remington. 1970. Use of a Hydroelectric Reservoir for the Rearing of Coho Salmon.

Harnish R, J Skalski, R Townsend, and K Ham. 2020. In search of a cost-effective approach for estimating dam passage survival. North American Journal of Fisheries Management 40(4):865–882.

Hardiman, J.M., Breyta, R.B., Haskell, C.A., Ostberg, C.O., Hatten, J.R., and Connolly, P.J., 2017, Risk assessment for the reintroduction of anadromous salmonids upstream of Chief Joseph and Grand Coulee Dams, northeastern Washington: U.S. Geological Survey Open-File Report 2017–1113, 87 p., https://doi.org/10.3133/ofr20171113.

Hanrahan, T. P., Dauble, D. D., and D. R. Geist. 2004. An estimate of chinook salmon (*Oncorhynchus tshawytscha*) spawning habitat and redd capacity upstream of a migration barrier in the upper Columbia River. Canadian Journal of Fisheries and Aquatic Science. 61: 23-33.

Hume, J.M., Shortreed, K.S., and K. Morton. 1996. Juvenile Sockeye rearing capacity of three lakes in the Fraser River system. Canadian Journal of Fisheries and Aquatic Science. 53: 719-733.

ICF 2017. Anadromous Reintroduction Potential for The Sanpoil River and Select Upper Columbia Tributaries on The Colville Reservation Using the Ecosystem Diagnosis and Treatment Model.

ICF 2018. Anadromous Reintroduction Potential for the Spokane Basin and Select Tributaries to Lake Roosevelt Using the Ecosystem Diagnosis and Treatment Model. Project # 2016-003-00.

Independent Scientific Advisory Board (ISAB). 2019. Review of the Upper Columbia United Tribes' *Fish Passage and Reintroduction Phase 1 Report: Investigations Upstream of Chief Joseph and Grand Coulee Dams* (Reintroduction Report). ISAB 2019-3, Northwest Power and Conservation Council, Portland, OR. November 1, 2019.

Johnson R., C. McKinstry, C. Cook, D. Tano, D. Faber, S. Francis, S. Simmons, C. Simmons, R. Brown, S. Thorsten, R. LeCaire. 2005. Strobe light deterrent efficiency test and fish behavior determination at Grand Coulee Dam and Third Power Plant Forebay. Battelle Northwest National Library.

Katopodis C. 1992. Introduction to Fishway Design. Freshwater Institute Central and Arctic Region, Department of Fisheries and Oceans.

Kock T, N. Verretto, N. Ackerman, R. Perry, J. Beeman, M. Garello and S. Fielding. 2019. Assessment of Operational and Structural Factors Influencing Performance of Fish Collectors in Forebays of High-Head Dams. Transactions of the American Fisheries Society 148:464-479, 2019.

McLellan, H.J., A. W. Child, A. Nelson. 2021. Resident Fish Research Monitoring and Evaluation Project, 2020 Annual Report. Colville Confederated Tribes. Bonneville Power Administration Report P184253.

National Marine Fisheries Service (NMFS). 2011. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon. https://repository.library.noaa.gov/view/noaa/23894

Northwest Power and Conservation Council (NPCC). 2014. Columbia River Basin Fish and Wildlife Program. Portland, OR. https://www.nwcouncil.org/fw/program/2014-12/program.

Northwest Power and Conservation Council (NPCC). 2016. Staff Paper: Review of Fish Passage Technologies at High Head Dams.

Northwest Power and Conservation Council (NPCC). 2020. 2020 Addendum to the 2014 Columbia River Basin Fish and Wildlife Program. October 2020. Council document 2020-9. Portland, OR. https://www.nwcouncil.org/reports/2020-9.

Northwest Power Planning Council (NPPC). 1987. Appendix E: Numerical Estimates of Hydropower-Related Losses, *in* NPPC 1987 Columbia River Basin Fish and Wildlife Program. Portland, OR.

Parametrix. 2004. Entrainment Evaluation. Spokane River Hydroelectric Report. Final Report. Doc. No. 2004-0319. Prepared for Avista Corporation, Spokane, WA. Parametrix, Kirkland, WA. August 2004.

Peone, T. 2020. Spokane Tribal Hatchery Operation and Maintenance Non-Technical Annual Progress Report: January 1, 2019 – December 31, 2019. BPA Project No. 1991-046-00.

Porcher J.P., and M. Larinier. 2002. Designing Fishways, Supervision of Construction, Costs, Hydraulic Model Studies.

Southern Resident Orca Task Force (SROTF). 2019. Final Report and Recommendations. November 2019. https://www.governor.wa.gov/sites/default/files/OrcaTaskForce_FinalReport andRecommendations_11.07.19.pdf.

Upper Columbia United Tribes (UCUT). 2019. Fish Passage and Reintroduction Phase 1 Report: Investigations Upstream of Chief Joseph and Grand Coulee Dams.

U.S. Army Corps of Engineers (USACE). 2002. Chief Joseph Dam Preliminary Investigation of Fish Passage Alternatives. Surface Bypass Program Comprehensive Review Report.

USACE. 2007. Surface Bypass Program Comprehensive Review Report. Report No. 09000-399-0409. U.S. Army Corps of Engineers, Portland Office. December 31, 2007.

USACE. 2019. Draft Environmental Assessment: Cougar Dam Downstream Passage, Willamette River Basin, South Fork McKenzie River, Oregon.

USACE. 2020. Cougar Dam High Head Fish Bypass 100% Engineering Design Report (Final EDR); Prepared by Alden, AECOM and BioAnalysts for USACE, Portland District.

U.S. Fish and Wildlife Service (USFWS). 2019. Fish Passage Engineering Design Criteria. USFWS, Northwest Region R5, Hadley, Massachusetts. https://www.fws.gov/northeast/fisheries/pdf/USFWS-R5-2019-Fish-Passage-Engineering-Design-Criteria-190622.pdf

United States Geological Survey (USGS). 2016. Evaluation of the Biological and Hydraulic Performance of the Portable Floating Fish Collector at Cougar Reservoir and Dam, Oregon, 2014.

Warnock, W.G., Stroud, D.H.P, and J.E. Merz. 2016. Donor stock selection of Chinook Salmon for reintroduction to the Transboundary Reach of the Columbia River. Report prepared for the Canadian Columbia River Inter-Tribal Fisheries Commission. 153 pp.

Washington State Governor's Office (WSGO). 2018. Southern Resident Killer Whale Recovery and Task Force. Executive Order 18-02. March 14, 2018. Olympia, WA. https://www.governor.wa.gov/sites/default/files/exe_order/eo_18-02_1.pdf.

WSGO. 2021. Governor's Salmon Strategy Update, Securing a future for people and salmon in Washington. 2021. Olympia, WA. https://rco.wa.gov/wp-content/uploads/2021/12/GSRO-GovSalmonStrategy-2021.pdf.

8 Appendices

Appendix A: Phase 2 Schedule and Associated Costs

P2IP Schedule and Cost Estimates (in millions of dollars)	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	Activity Totals
Phase 2 Reintroduction Activities	Step 1 (Years 1 - 6)						Step 2.1 (Years 7 - 9)			Step 2.2 (Years 10 - 12)			Step 2.3 (Years 13 - 15)			Step 2.4 (Years 16 - 21)						
Downstream Behavior and Survival (yr)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Acoustic Tags Survival and Behavior Chinook	$ 0.99	$ 1.21	$ 1.21							$ 0.88	$ 0.88									$ 0.88	$ 0.88	$6.93
Acoustic Tags Survival and Behavior Sockeye		$ 1.21	$ 1.21	$ 1.21						$ 1.21	$ 1.21									$ 1.21	$ 1.21	$8.47
Juvenile PIT Releases (Chinook)(tag + labor)	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$11.55
Juvenile PIT Releases (Sockeye)(tag + labor)		$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$6.60
Upstream Passage Studies (yr)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	--
Chief Joseph Hatchery Ladder				$ 0.55	$ 0.55	$ 0.55																$1.65
Grand Coulee (Sanpoil, Transboundary)				$ 0.55	$ 0.55	$ 0.55																$1.65
Spokane River				$ 0.55	$ 0.55	$ 0.55																$1.65
Interim Upstream/Downstream Design/Build (yr)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	--
Agency Preparation to Develop Interim Facilities (permitting)	<--<--<--<--<--<--<--<--<--<--<--<--<--<--<--<--<--<--<--<--<--<--<-- NEPA, ESA (HGMP), FERC, and other processes and permitting -->																					--
Adult Trap and Haul - Trucks	$ 0.33	$ 0.72																				$1.05
Operation	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$6.93
Chief Joseph Dam Upstream Passage- Design/Build					$ 0.55	$ 7.70																$8.25
Operation							$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$6.27
Grand Coulee Downstream Passage - Design/Build							$ 2.20	$15.40	$ 3.39													$20.99
Operation									$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$ 0.55	$7.15
Grand Coulee Upstream Passage - Design/Build										$ 0.55	$ 7.70	$ 1.69										$9.94
Operation												$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$ 0.42	$4.18
Spokane River Dam Upstream Passage - Design/Build													$ 2.20	$11.00	$ 2.42							$15.62
Operation															$ 1.25	$ 1.25	$ 1.25	$ 1.25	$ 1.25	$ 1.25	$ 1.25	$8.75
Chief Joseph Dam Downstream Passage - Design/Build																$ 2.20	$ 15.40	$ 3.39				$20.99
Operation																		$ 0.55	$ 0.55	$ 0.55	$ 0.55	$2.20
Spokane River Dam Downstream Passage - Design/Build																			$ 0.55	$ 4.40	$ 0.97	$5.92
Operation																					$ 0.83	$0.83
Interim Downstream Facilities Testing (yr)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	--
Grand Coulee																						--
Fish Collection Efficiency and Behavior - Chinook										$ 1.10	$ 1.10											$2.20
Fish Collection Efficiency and Behavior - Sockeye										$ 1.10	$ 1.10											$2.20
Chief Joseph																						--
Fish Collection Efficiency and Behavior - Chinook																			$ 2.20	$ 2.20		$4.40
Fish Collection Efficiency and Behavior - Sockeye																			$ 2.20	$ 2.20		$4.40
Spokane River																						--
Fish Collection Efficiency and Behavior - Chinook																				$ 1.65	$ 1.65	$3.30
Interim Upstream Passage Facilities Testing (yr)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	--
Chief Joseph Dam							$ 0.22	$ 0.22														$0.44
Grand Coulee													$ 0.22	$ 0.22								$0.44
Spokane River																$ 0.22	$ 0.22					$0.44
RM&E - Spawning, AR/S, PBT, Reproductive Succes	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$ 1.10	$23.10
Interim Hatchery Facilities (yr)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	--
Review Exisiting Facilities for Program Use	$ 0.06																					$0.06
Expand Interim Early Rearing Facilities and Net Pens	$ 0.55	$ 1.43																				$1.98
Operate Interim Hatchery Facilities	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$ 0.33	$6.93
Develop Conceptual Designs for Phase 3 Hatchery Facilities																	$ 0.28	$ 0.28				$0.55

Annual Costs by Activity Type (in millions $) (yr)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
Research, Monitoring, and Evaluation Sub-Total	$2.70	$4.40	$4.40	$4.84	$3.63	$3.63	$2.20	$2.20	$1.98	$6.27	$6.27	$1.98	$2.20	$2.20	$1.98	$2.20	$2.20	$1.98	$6.38	$10.12	$5.72	**$79.48**
Infrastructure & Operations Sub-Total	$1.54	$2.81	$0.66	$0.66	$1.21	$8.36	$3.28	$16.48	$5.02	$2.18	$9.33	$3.74	$4.25	$13.05	$5.72	$5.50	$18.97	$7.51	$4.40	$8.25	$5.64	**$128.52**
Annual Totals	**$4.24**	**$7.21**	**$5.06**	**$5.50**	**$4.84**	**$11.99**	**$5.48**	**$18.68**	**$7.00**	**$8.45**	**$15.60**	**$5.72**	**$6.45**	**$15.25**	**$7.70**	**$7.70**	**$21.17**	**$9.49**	**$10.78**	**$18.37**	**$11.36**	**$207.99**
Cumulative Totals	**$4.24**	**$11.44**	**$16.50**	**$22.00**	**$26.84**	**$38.83**	**$44.31**	**$62.99**	**$69.98**	**$78.43**	**$94.03**	**$99.75**	**$106.19**	**$121.44**	**$129.14**	**$136.83**	**$158.00**	**$167.49**	**$178.27**	**$196.63**	**$207.99**	--

Phase 2 Stepwise Implementation Summary (in millions $)	RM&E	Infrastructure & Ops.	Cumulative Total
Year 1-6 (Studies, Hatcheries, CJD Up)	$23.6	$15.2	$38.8
Year 1-9 (Studies, Hatcheries, CJD Up, GCD Down)	$30.0	$40.0	$70.0
Year 1-12 (Studies, Hatcheries, CJD Up, GCD Down, GCD Up)	$44.5	$55.3	$99.7
Year 1-15 (Studies, Hatcheries, CJD Up, GCD Up & Down, Spo. Up)	$50.9	$78.3	$129.1
All Studies and Interim Facilities	**$79.5**	**$128.5**	**$208.0**

= Infrastructure Design and Build
= Research and Infrastructure Evaluation
= Operation and Maintenance of Infrastructure
= Federal Authorities to be Addressed
= Contingency Year to Allow Flexibility

Appendix B: Study Design to Evaluate Downstream Movement and Survival of Juvenile Summer/Fall Chinook Salmon in the Upper Columbia River Basin

--Research Proposal--

A Pilot Study Design to Evaluate Downstream Movement and Survival of Juvenile Salmon in the Upper Columbia River Basin

December 22, 2020

Preface

This document describes a pilot study that was developed to address issues relevant to the reintroduction of anadromous fish to the blocked areas of the Upper Columbia River. It was developed collaboratively by staff of the USGS Western Fisheries Research Center (USGS), Pacific Northwest National Laboratory (PNNL), and Coeur d'Alene, Colville, and Spokane tribes, including representatives from the Upper Columbia United Tribes (UCUT). Tribal staff ensured that the study design addressed the most pertinent assumptions identified in Phase 1, that the goals and objectives were consistent with frameworks previously developed, and that it is geographically comprehensive enough to include major areas of potential habitat in the Upper Columbia River basin and jurisdictions of the various Tribes. Staff from USGS and PNNL provided technical guidance about the most appropriate tools and techniques to address the assumptions put forth. Together, the team developed a cost-effective approach using well-accepted technologies to estimate juvenile salmon survival, travel time and behavior through various river reaches and dams of the Upper Columbia River basin. Results from the pilot study will further inform feasibility, be used to update life-cycle models with better data than was available in Phase 1 and help to design more intensive juvenile salmon survival and passage studies expected later in Phase 2.

Introduction

Columbia basin tribes and First Nations (CBTFN) are leading efforts to reintroduce anadromous fish into the Upper Columbia River basin (CBTFN 2015; Warnock et al. 2016; UCUT 2019), a region which historically supported anadromy prior to the construction of large, impassable dams such as Grand Coulee and Chief Joseph (Figure 1). In a recent report (CBTFN 2015), a phased approach was outlined for restoring anadromous fish populations upstream of Chief Joseph and Grand Coulee dams which included:

Phase 1: Pre-assessment planning for reintroduction and fish passage

Phase 2: Experimental, pilot-scale salmon reintroductions and interim passage facilities

Phase 3: Construction of permanent juvenile and adult passage facilities and supporting propagation facilities. Implementing priority habitat improvements

Phase 4: Monitoring, evaluation, and adaptive management. Continuing needed habitat improvements

The UCUT (Coeur d'Alene Tribe of Indians, Confederated Tribes of the Colville Reservation, Kalispel Tribe of Indians, Kootenai Tribe of Idaho, and Spokane Tribe of Indians) initiated extensive, multiyear investigations into the reintroduction of anadromous fish upstream of Chief Joseph Dam in 2016. These included an assessment of available habitat in the United States; a review of appropriate and available donor stocks; consideration of reintroduction risk to resident fish species; and reviews of fish survival, life cycle modeling, potential passage technologies, and current dam operations. The report synthesizing Phase 1 investigations was completed in 2019 (UCUT 2019). The UCUT and their partners are ready to proceed with implementing Phase 2 activities which focus on addressing several key assumptions identified in the Phase 1 report (UCUT 2019). These assumptions include:

- Juvenile migration survival rate in Lake Roosevelt and Rufus Woods: 0.15% to 0.25% loss per km of reservoir, with larger fish having higher survival.
- Turbine/spillway survival: 44% to 50% at Grand Coulee Dam which assumes minimal spill, 44% to 88% at Chief Joseph Dam with highest values occurring during spring when spill occurs.
- Chief Joseph Dam to Bonneville Dam juvenile survival: 27% to 46% for summer/fall Chinook salmon with larger smolts having higher survival rates, 41% for yearling sockeye salmon.

- Bonneville Dam to Chief Joseph Dam adult survival: 83% for summer/fall Chinook salmon, 76% for sockeye salmon.
- Rufus Woods and Lake Roosevelt adult survival: 95% to 99% for summer/fall Chinook salmon and sockeye salmon.
- Collection efficiency of floating surface collectors for juveniles (1,000 cfs inflow): 70% to 87% with the lower value for system with no net guidance system.

A comprehensive and sustained research program is needed to further inform the feasibility of successful fish passage and reintroduction in the Columbia, Sanpoil, and Spokane rivers upstream of Chief Joseph Dam. This pilot study will help to determine reintroduction feasibility. Information must be collected to document reservoir survival, migration travel time, migration success, and dam passage survival of both juvenile and adult salmonids. Additionally, identifying where fish concentrate near dams is important for siting collectors that will likely be required to effectively pass fish at high-head dams in the system.

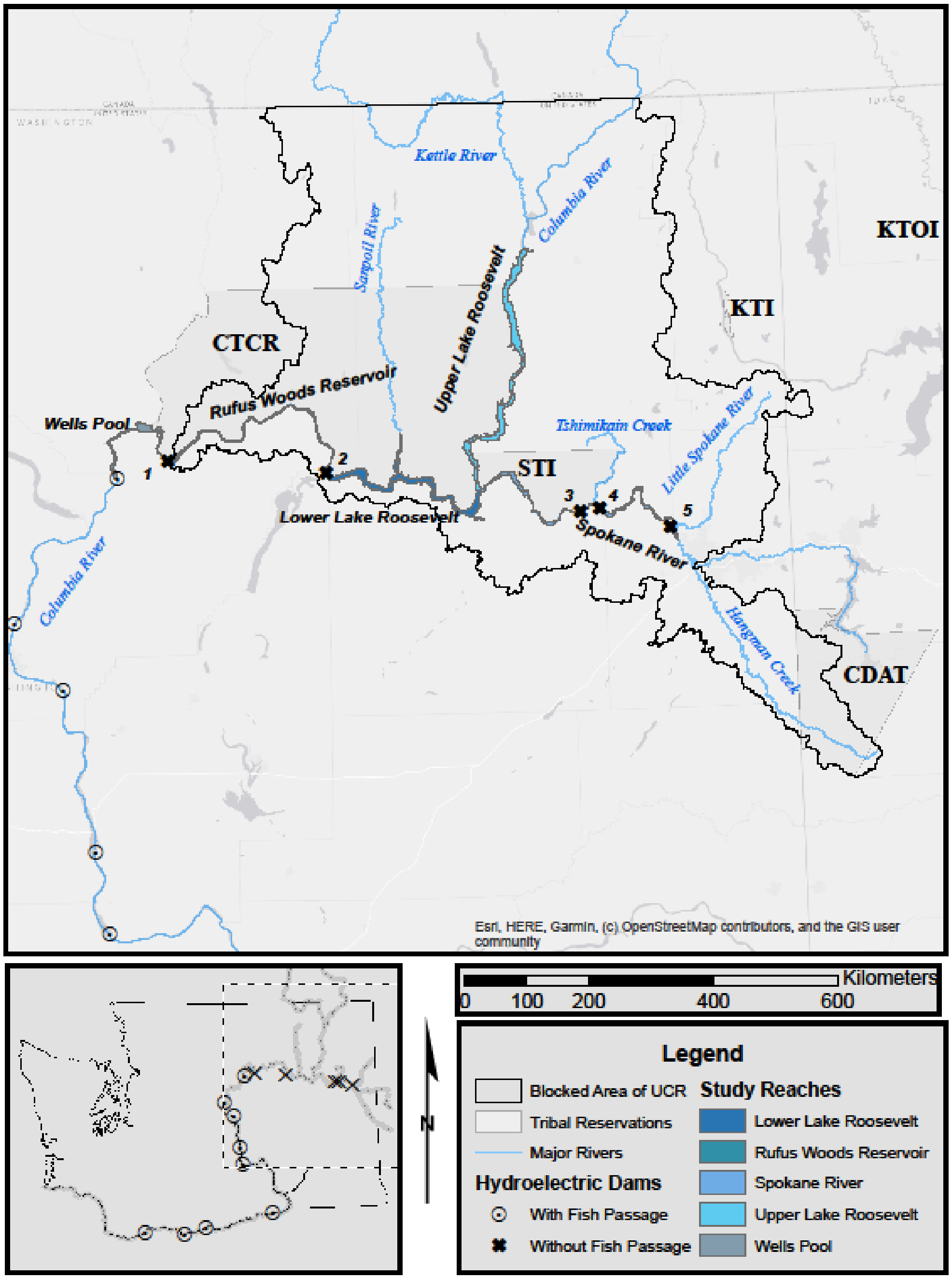


Figure 1. Map of the Upper Columbia River basin showing locations of major rivers, study reaches, dams (1 = Chief Joseph Dam; 2 = Grand Coulee Dam; 3 = Little Falls Dam; 4 = Long Lake Dam; 5 = Nine Mile Dam) and tribal reservations (Confederated Tribes of the Colville Reservation (CTCR), the Spokane Tribe of Indians (STI), the Coeur d'Alene Tribe (CDAT), the Kalispell Tribe of Indians (KTI), and the Kootenai Tribe of Idaho (KTOI).

Purpose

This document describes a pilot study design, including estimated costs of implementation, to refine smolt migration and passage survival assumptions used in Phase 1 Life Cycle Modeling (LCM). Results from the LCM were used to conclude that anadromous fish reintroduction upstream of Chief Joseph Dam and Grand Coulee Dam may be feasible. However, the values used for LCM assumptions were based on literature values for downstream populations and were not collected using empirically based site-specific studies. The purpose of the proposed pilot study is to reduce modeling uncertainty by collecting site-specific migration and passage survival data to update LCM inputs and to confirm resultant conclusions regarding anadromous reintroduction feasibility and success. Additionally, the precision of resulting survival estimates generated from the pilot study may be sufficient to guide decision making regarding the need for, and location of, juvenile fish passage facilities at Chief Joseph Dam and Grand Coulee Dam. If the precision of the resulting survival estimates is not adequate to guide decision making, the study will provide the data necessary to determine the scale, scope, and sample sizes of future Phase 2 studies that will meet precision requirements.

Study Elements

Recommended Technology

Most studies that evaluate fish movement and survival rely on the use of passive integrated transponder (PIT) tags or active transmitters (radio or acoustic) to collect data (Muir et al. 2001; Hockersmith et al. 2003; McMichael et al. 2010; Skalski et al. 2016). Some sites, such as large reservoirs and dams without juvenile bypass systems, are not conducive to PIT tag studies because tagged fish must be very close to the detection array to be detected. Active transmitters provide advantages which include the ability to detect fish at greater distances, describe two-dimensional or three-dimensional fish tracks, and determine route-of-passage at dams (Deng et al. 2011; Beeman et al. 2016). We propose to use the Juvenile Salmon Acoustic Telemetry System (JSATS; McMichael et al. 2010) during the pilot study for several reasons: (1) transmitters are small enough (15.0 x 3.4 mm, 215 mg) to allow for tagging of yearling- or some subyearling-sized juvenile salmon (>85mm); (2) the expected operating life (~70 d) of the transmitters is sufficient to monitor fish as they outmigrate through the entire planned study area; and (3) JSATS receivers can be adaptively positioned across the face of dams in the study area to provide information about where fish congregate and which passage routes they use. While this proposal primarily focuses on acoustic-tagged fish, we recommend double tagging with PIT tags as well. This will allow for additional data to be collected downstream of CJD as smolts outmigrate and when they return as adults.

Species, Life Stage and Fish Source

We developed the proposed pilot study to focus on juvenile summer/fall Chinook salmon as these stocks were identified as the most readily available and are one of the preferred reintroduction species for Phase 2 studies in the Phase 1 report (Hardiman et al. 2017; UCUT 2019). Yearling Chinook salmon are the most likely fish to be tagged for the pilot study based on availability from hatcheries in the region. However, any species of juvenile salmonid could be tagged and monitored if the fish are large enough (≥85 mm) for acoustic tagging. The exact source of fish for this pilot study has yet to be determined.

Objectives

The proposed pilot study was developed to address multiple research objectives across a large study area (Table 1). These objectives are focused on estimating juvenile survival in reservoirs; estimating passage survival at Chief Joseph, Grand Coulee, and Spokane River dams; and determining travel times through reaches in the study area. Piscivorous fish populations are robust in Lake Roosevelt, and to a lesser extent in Rufus Woods Reservoir (Baldwin and Polacek 2002; Baldwin et al. 2003), so predation rates on juvenile salmonids are assumed to be high. Additionally, passage survival at Grand Coulee Dam may be particularly low (≤60%) since spill occurs infrequently during the expected outmigration period. Thus, most outmigrants are expected to pass via turbines. Given these considerations, it will be important to empirically document juvenile travel times and survival rates in the upper Columbia River basin. Specifically, the pilot study will help to refine more intensive and long-term research studies that are planned for Phase 2.

Cultural and educational fish releases performed by UCUT tribes have provided a limited amount of information on migration and survival of juvenile salmonids within the study area which is useful for designing some aspects of the pilot study. The Coeur d'Alene and Spokane tribes conducted paired releases of PIT-tagged yearling Chinook salmon at Upper Hangman Creek (river kilometer [rkm] 1199; n = 1,453 fish) and in the Lower Spokane River at Little Falls Dam (rkm 1071; n = 765 fish) during spring 2020. A total of 3.9% (58 fish) of the Upper Hangman-released fish and 11.1% (85 fish) of the Lower Spokane River-released fish survived and were detected on PIT-tag antennas at Rocky Reach Dam. Median travel times from release to Rocky Reach Dam were 57.5 d and 50.0 d, respectively. These results are not definitive due to small sample sizes and a single year of data but are informative for planning this acoustic telemetry study.

Table 1. Pilot study research objectives for juvenile salmonid behavior and survival in the upper Columbia River basin. Objective codes are taken from Phase 2 planning documents produced by the UCUT fish committee.

Objective code	Description
GCD 1.1	Estimate survival and travel time from the mouth of the Sanpoil River (rkm 987) and Kettle Falls (rkm 1121) to Grand Coulee Dam (rkm 957).
SPO 1.1	Estimate survival and travel time from Little Falls Dam (rkm 1071), Long Lake Dam (rkm 1089), Nine Mile Dam (rkm 1127), and Upper Hangman Creek (rkm 1199) to Grand Coulee Dam.
CJD 1.1	Estimate survival and travel time from Grand Coulee Dam to Chief Joseph Dam (rkm 877).
GCD 1.2	Assess near-dam behavior and estimate route-specific passage survival at Grand Coulee Dam.
CJD 1.2	Assess near-dam behavior and estimate route-specific passage survival at Chief Joseph Dam.

Study Design Rationale

Given the number and basic nature of the assumptions that currently exist in the upper Columbia River basin, we developed the pilot study to: (1) collect initial information for juvenile survival and passage assumptions; (2) potentially provide results rigorous enough to reduce or eliminate some assumptions; and (3) provide foundational information necessary for designing subsequent studies to address remaining assumptions (see UCUT Phase 2 Strategic Implementation Plan). To describe how these factors would be addressed, a basic overview of the study area is necessary. For the pilot study, the study area is divided into seven general reaches as follows (Figure 1):

(1) **Upper Lake Roosevelt** which extends downstream from Kettle Falls to the mouth of the Spokane River. This reach spans 90 rkm and does not have any dams present.

(2) **the Spokane River** which extends downstream from Upper Hangman Creek to the river’s confluence with the Columbia River. This reach spans 179 rkm and includes three hydroelectric projects, Nine Mile Dam, Long Lake Dam, and Little Falls Dam.

(3) **Lower Lake Roosevelt** which extends downstream from the mouth of the Spokane River to Grand Coulee Dam (rkm 1029). This reach spans 74 rkm, contains no dams,

includes inflow from the Sanpoil River at rkm 987, a major tributary in the upper Columbia River.

(4) **Grand Coulee Dam** which is a large (167 m tall, 1,592 m wide) hydroelectric dam with 3 powerhouses, 1 spillway and a water withdrawal unit that supplies water to Banks Lake.

(5) **Rufus Woods Reservoir** which extends downstream from Grand Coulee Dam to Chief Joseph Dam. This reach spans 80 rkm and contains no dams or major tributaries;

(6) **Chief Joseph Dam** which is a large (72 m tall, 1,817 m wide) hydroelectric dam with 1 powerhouse and 1 spillway.

(7) **the Wells Pool** which extends 47 rkm downstream from Chief Joseph Dam to Wells Dam and includes no dams and two major tributaries, the Okanogan and Methow rivers. Data may also be opportunistically collected in the Columbia River downstream of the Wells Pool if enough tagged fish survive and migrate through downstream reaches within the expected operating life of the acoustic transmitters.

Given these reaches and proposed telemetry receiver locations, the following assumptions will be assessed for juvenile anadromous salmonids from the blocked area of the upper Columbia River:

(1) Travel time and migration survival through Upper Lake Roosevelt.
(2) Travel time and migration survival through the Spokane River.
(3) Travel time and migration survival through Lower Lake Roosevelt.
(4) Locations where fish concentrate in the forebay of, passage route distributions through, and dam passage survival at Grand Coulee and Chief Joseph dams.

Several analytical approaches are available for addressing assumptions related to fish survival. For example, the single-release-recapture model (Skalski et al. 1998) could be adapted to include two release sites, at Kettle Falls and at Upper Hangman Creek, which would establish tagged populations of juvenile salmon at the upstream ends of Lake Roosevelt and the Spokane River. Fish would then be monitored as they outmigrate and detections at receivers located throughout the study area could be used to estimate survival in reservoir reaches and at dams, and to determine where fish congregate in the forebay of dams. While this approach is a viable alternative, it includes a level of risk because it assumes that survival rates within the study area will be high enough that a substantial proportion of tagged fish from the upriver release sites will survive and outmigrate through the entire study area, providing information on survival and travel rates in each reach.

Given the uncertainties related to reservoir survival and dam passage survival in the upper Columbia River basin, we propose to use a combination of survival models. We propose to release tagged fish at multiple locations and use a combination of single-release and paired-release (Burnham et al. 1987; Skalski et al. 2009) survival models to assess fish migration and dam passage survival for the pilot study. This will ensure that information is collected in each study reach and provide the opportunity to assess multiple survival models to gain insights into assumptions and differential responses by release groups throughout the study area.

For the pilot study, we propose to release a total of 750 fish across seven locations (Table 2) throughout the study area to ensure that enough fish are present within each study reach to provide meaningful results. Releasing fish at multiple locations upstream of Grand Coulee Dam is intended to provide information about survival in Upper Lake Roosevelt, the Spokane River, and Lower Lake Roosevelt and also increase the probability that a sufficient number of fish survive to Grand Coulee Dam to yield information about where fish concentrate near the dam, and how they distribute through passage routes at the dam. Tagged fish that arrive in the forebay of Grand Coulee Dam from different upstream release sites can be virtually grouped and used to estimate single-release survival estimates in downstream reaches. Releasing fish in the tailraces of Grand Coulee and Chief Joseph dams enables paired-release estimation of dam passage survival and supplements tagged fish numbers in lower reaches of the study area to ensure that data are collected in those reaches. Single-release and paired-release estimates can be compared to provide inferences about uncertainty and potential violations of assumptions in the study designs.

Table 2.—Summary of proposed release locations and number of fish to be released for a proposed pilot study to evaluate outmigration behavior and survival of juvenile salmon in the upper Columbia River basin.

Release location	Number of fish
Kettle Falls	200
Upper Hangman Creek	100
Little Spokane River/Nine Mile Dam tailrace	100
Little Falls Dam	100
Sanpoil River	100
Grand Coulee Dam tailrace	75
Chief Joseph Dam tailrace	75
Total	750

A series of monitoring sites are proposed to detect tagged fish outmigrating from the upper Columbia River basin (Table 3). In total 52 receivers would be required which includes receivers located in the forebays and tailraces of Spokane River dams; mid-reservoir sites in Lake Roosevelt, Rufus Woods Reservoir, and the Wells Pool; and forebay, at-dam, and tailrace sites on Grand Coulee and Chief Joseph dams, and in the Wells Dam forebay. This deployment provides the ability to estimate dam passage survival at Nine Mile Dam, Long Lake Dam, Little Falls Dam, Grand Coulee Dam and Chief Joseph Dam; to describe juvenile approach behavior at Grand Coulee and Chief Joseph dams; and estimate survival through Spokane River impoundments and in two reaches apiece in Lake Roosevelt and Rufus Woods Reservoir.

To assess expected precision in survival estimates we used the SampleSize (Version 3.2.23; Lockhart et al. 2019) program to generate juvenile survival estimates and associated confidence intervals through several reaches of the proposed study area using the sample sizes proposed for the study (Table 4). We considered two survival scenarios: Scenario A was a higher survival scenario with 70% survival in Lake Roosevelt, 50% passage survival at Grand Coulee Dam, 98% survival in Rufus Woods Reservoir, and 88% passage survival at Chief Joseph Dam; Scenario B was a lower survival scenario with 55% juvenile survival in Lake Roosevelt, 25% passage survival at Grand Coulee Dam, 97% survival in Rufus Woods Reservoir, and 82% passage survival at Chief Joseph Dam. This exercise demonstrated that the approach outlined here would yield survival estimates with moderate levels of uncertainty (95% confidence intervals of 6–19%) across the range of survival scenarios and in the various study reaches (Table 4).

Table 3.—Summary of proposed monitoring receiver locations and number of receivers to be deployed for a pilot study to evaluate outmigration behavior and survival of juvenile salmon in the upper Columbia River basin.

Location	Number of receivers
Nine Mile Falls Dam forebay	1
Nine Mile Falls Dam tailrace	1
Long Lake Dam forebay	1
Long Lake Dam tailrace	1
Little Falls Dam forebay	1
Little Falls Dam tailrace	1
Spokane River, immediately upstream of Columbia River confluence	2
Lake Roosevelt near Bissell Island	3
Lake Roosevelt, immediately upstream of the Spokane River mouth	4
Grand Coulee Dam forebay entrance	7
Grand Coulee Dam	10
Grand Coulee Dam tailrace	2
Rufus Wood Reservoir, mid-reservoir	2
Chief Joseph Dam forebay entrance	2
Chief Joseph Dam	6
Chief Joseph Dam tailrace	2
Lake Pateros, mid-reservoir	2
Wells Dam	4
Total	52

Table 4.—Simulated survival estimates, with 95% confidence intervals shown in parentheses, for specific reaches in the study area for the proposed pilot study design.

Reach	**Survival estimates and confidence intervals**	
	Scenario A	**Scenario B**
Combined release to Grand Coulee Dam	0.54 (0.49–0.58)	0.43 (0.37–0.48)
Grand Coulee Dam passage survival	0.50 (0.44–0.56)	0.25 (0.19–0.31)
Grand Coulee Dam tailrace to Chief Joseph Dam forebay	0.98 (0.95–1.00)	0.97 (0.93–1.00)
Chief Joseph Dam passage survival	0.88 (0.84–0.92)	0.82 (0.75–0.89)
Kettle Falls to Chief Joseph tailrace	0.30 (0.23–0.37)	0.11 (0.06–0.15)
Upper Hangman Creek to Chief Joseph tailrace	0.06 (0.01–0.11)	0.02 (0.00–0.05)
Little Spokane River to Chief Joseph tailrace	0.12 (0.05–0.18)	0.04 (0.00–0.08)
Little Falls to Chief Joseph tailrace	0.36 (0.27–0.46)	0.15 (0.08–0.22)
Sanpoil River to Chief Joseph tailrace	0.42 (0.33–0.52)	0.19 (0.12–0.27)
Grand Coulee tailrace to Chief Joseph tailrace	0.86 (0.78–0.94)	0.80 (0.70–0.89)

Release timing

Tagged fish would be released one time at each location with release timing designed to target arrival timing in the Chief Joseph Dam tailrace on or about April 15. This timing is intended to align outmigration periods for tagged fish in other monitoring programs located downstream of Chief Joseph Dam and would allow study fish to experience similar migratory conditions to those fish during outmigration through the Columbia River. Unfortunately, we do not have data available to estimate migration timing from the various release points proposed to downstream of Chief Joseph Dam. However, we do have PIT tag data for migration rates from release points in the Spokane River to the Rocky Reach juvenile bypass system. We also have migration rates of Chief Joseph Hatchery summer Chinook yearlings (released at the base of Chief Joseph Dam) to Rocky Reach Dam. We will use these two sources of information (or any updated information that is available closer to the time of implementing the study) to calculate the appropriate release date for each release site. Tailrace releases will be timed to match arrival timing of fish from the upstream release sites. This pilot study, or future Phase 2 studies, could easily be adapted to capture survival patterns across a broader temporal range by increasing the number of tagged fish that are released and replicating the proposed release strategy to multiple release periods in a given year.

Estimated Costs

The costs associated with conducting acoustic telemetry studies can range broadly and are largely influenced by the number of fish tagged, number of receivers operated, and type of data desired (e.g., presence/absence, two-dimensional tracks). Acoustic transmitters cost approximately $250 apiece so even moderate increases in sample size can result in substantial cost increases to a study. Similarly, new acoustic receivers cost approximately $4,000 each and additional equipment (e.g., mounting hardware, acoustic releases, anchors) is required to properly deploy these to maximize detection performance and protect them from conditions experienced in the field (e.g., damage from debris, high flows). Furthermore, to minimize data loss, each site must be equipped with the necessary electronics to allow for remote downloading or the sites must be visited at least every three weeks to change batteries. Labor associated with maintaining the sites and downloading the data can be substantial. Finally, advanced data analysis such as describing two-dimensional movements of tagged fish near a dam can increase costs due to the rigor required in continuously monitoring the position of each receiver, processing data, and summarizing results. However, two-dimensional tracking is not a component of this study design.

Estimated costs to conduct the pilot study are shown in Table 5. The overall cost for the proposed pilot study totals $610,000 which includes a one-time purchase of 52 acoustic telemetry receivers ($198,380). This adds a substantial cost to the pilot study but provides the opportunity to conduct a broad range of telemetry evaluations in the future. The JSATS telemetry system is reliable and robust and can be used to evaluate movement and survival of a variety of species and life stages. For example, Phase 1 investigations identified the need to evaluate several aspects of adult salmon behavior upstream of Chief Joseph Dam. These studies, when implemented, could utilize equipment purchased during the proposed pilot study. While this one-time equipment purchase adds to the total cost of the pilot study described here, it could provide cost savings for other studies that will likely be conducted in the future.

Table 5.—Estimated costs for tags, receivers, and equipment to conduct a pilot study to evaluate outmigration behavior and survival of juvenile salmon in the upper Columbia River basin.

Item description	No. units	Cost/unit	Total cost
Model SS400 acoustic transmitter	750	$250	$176,250
Model SR3017 acoustic receiver	52	$3,815	$198,380
PIT tags	750	$7	$5,250
Miscellaneous tagging, release, and deployment equipment			$25,000
Labor for tagging, release, setup, analysis and reporting			$205,000
Total cost for the pilot study			**$610,000**

Summary

Conducting the pilot study described here will be an important step towards restoring anadromous fish upstream of Chief Joseph Dam by providing required data and helping to define rigorous, long-term research in the future. It is important to the UCUT to gather needed information in a cost-effective manner to increase the chances for successful reintroduction upstream of Chief Joseph and Grand Coulee dams. The precision of survival estimates generated from the pilot study should be tight enough to, at a minimum, guide initial management actions and inform continued research. This pilot study also provides valuable information that can be used to facilitate planning that occurs while regulatory issues associated with releasing large numbers of hatchery fish required for large-scale Phase 2 studies are being resolved among action agencies in the current anadromous zone. While the estimated cost of conducting this research are significant, the potential advances that it will stimulate will be invaluable for returning salmon and steelhead to the blocked area of the upper Columbia River.

References

Columbia Basin Tribes and First Nations [CBTFN]. 2015. Fish passage & reintroduction into the U.S. and Canadian Upper Columba Basin. 36 p. Available at: https://ucut.org/wp-content/uploads/2016/09/Fish_Passage_and_Reintroduction_into_the_US_And_Canadian_Upper_Columbia_River4-1.pdf

Baldwin, C., and M. Polacek. 2002. Evaluation of limiting factors for stocked kokanee and rainbow trout in Lake Roosevelt, Washington, 1999. Report by the Washington Department of Fish and Wildlife to the U.S. Department of Energy, Bonneville Power Administration, Portland, Oregon. BPA Contract Number 94BI32148.

Baldwin, C.M., J.G. McLellan, M.C. Polacek, K. Underwood. 2003. Walleye predation on hatchery releases of kokanees and rainbow trout in Lake Roosevelt, Washington. North American Journal of Fisheries Management 23:660–67.

Beeman, J.B., Evans, S.D., Haner, P.V., Hansel, H.C., Hansen, A.C., Hansen, G.S., Hatton, T.W., Kofoot, E.E., and Sprando, J.M., 2016, Evaluation of the biological and hydraulic performance of the portable floating fish collector at Cougar Reservoir and Dam, Oregon, September 2015–January 2016: U.S. Geological Survey Open-File Report 2016–1197, 98 p., https://doi.org/10.3133/ofr20161197.

Burnham, K.P., D.R. Anderson, G.C. White, C. Brownie and K. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. American Fisheries Society, Monograph 5, Bethesda, Maryland.

Deng, D.Z., M.A. Weiland, T. Fu, T.A. Seim, B.L. LaMarche, E.Y. Choi, T.J. Carlson, and M.B. Eppard. 2011. A cabled acoustic telemetry system for detecting and tracking juvenile salmon: part 2. Three-dimensional tracking and passage outcomes. Sensors 11:5661–5676.

Hardiman, J.M., Breyta, R.B., Haskell, C.A., Ostberg, C.O., Hatten, J.R., and Connolly, P.J., 2017, Risk assessment for the reintroduction of anadromous salmonids upstream of Chief Joseph and Grand Coulee Dams, northeastern Washington: U.S. Geological Survey Open-File Report 2017–1113, 87 p., https://doi.org/10.3133/ofr20171113.

Hockersmith, E.E., W.D. Muir, S.G. Smith, B.P. Sandford, R.W. Perry, N.S. Adams, and D.W. Rondorf. 2003. Comparison of migration rate and survival between radio-tagged and PIT-tagged migrant yearling Chinook salmon in the Snake and Columbia rivers. North American Journal of Fisheries Management 23: 404–413.

Lockhart, T., J. Lady, and J.R. Skalski. 2019. Program SampleSize 3: sample size calculations for fish and wildlife studies. Columbia Basin Research, University of Washington, 40 p.

McMichael, G.A., M.B. Eppard, T.J. Carlson, J.A. Carter, B.D. Ebberts, R.S. Brown, M. Weiland, G.R. Ploskey, R.A. Harnish, and Z.D. Deng. 2010. The juvenile salmon acoustic telemetry system: a new tool. Fisheries 35: 9–22.

Muir, W.D., S.G. Smith, J.G. Williams, E.E. Hockersmith, and J.R. Skalski. 2001. Survival estimates for migrant yearling Chinook salmon and steelhead tagged with passive integrated transponders in the lower Snake and lower Columbia rivers, 1993–1998. North American Journal of Fisheries Management 21: 269–282.

Skalski, J.R., M.A. Weiland, K.D. Ham, G.R. Ploskey, G.A. McMichael, A.H. Colotelo, T.J. Carlson, C.M. Woodley, M.B. Eppard, and E.E. Hockersmith. 2016. Status after 5 years of survival compliance testing in the Federal Columbia River Power System (FCRPS). North American Journal of Fisheries Management 36: 720–730.

Skalski, J.R., R.A. Buchanan, R.L. Townsend, T.W. Steig, and S. Hemstrom. 2009. A multiple-release model to estimate route-specific and dam passage survival at a hydroelectric project. North American Journal of Fisheries Management 29:670–679.

Skalski, J.R., S.G. Smith, R.N. Iwamoto, J.G. Williams, and A. Hoffman. 1998. Use of passive integrated transponder tags to estimate survival of migrant juvenile salmonids in the Snake and Columbia rivers. Canadian Journal of Fisheries and Aquatic Sciences 55:1484–1493.

Steig, T.W., J.R. Skalski, and B.H. Ransom. 2003. Comparison of acoustic and PIT tagged juvenile Chinook, steelhead, and sockeye salmon (*Oncorhynchus*, spp.) passing dams on the Columbia River, USA. Proceedings of the Fifth Conference on Fish Telemetry, Ustica, Italy. 9–13 June 2003.

Upper Columbia United Tribes [UCUT]. 2019. Fish passage and reintroduction phase 1 report: investigations upstream of Chief Joseph and Grand Coulee Dams. 154 p. Available at: https://ucut.org/habitat/fish-passage-and-reintroduction-phase-1-report/

Warnock, W.G., Stroud, D.H.P, and Merz, J.E. 2016. Donor stock selection of Chinook salmon for reintroduction to the Transboundary reach of the Columbia River. 165 p. Available at: http://ccrifc.org/cms/wp-content/uploads/2015/10/Warnock-et-al.-2016_Chinook-donor-stock-assessment-in-Transboundary-Reach.pdf

Appendix C: Study Plan for Evaluating Juvenile Sockeye Salmon Survival Through Lake Roosevelt, Grand Coulee Dam, Rufus Woods Lake, and Chief Joseph Dam

Study Plan for Evaluating Juvenile Sockeye Salmon Survival through Lake Roosevelt, Grand Coulee Dam, Rufus Woods Lake, and Chief Joseph Dam

Authors: Ryan A. Harnish[1], Casey Baldwin[2], Kevin Malone[3], Conor Giorgi[4], Thomas Biladeau[5], Brian J. Bellgraph[1]

[1]Pacific Northwest National Laboratory; [2]Confederated Tribes of the Colville Reservation; [3]Malone Environmental; [4]Spokane Tribe of Indians; [5]Coeur d'Alene Tribe

This document describes a research study plan, including ballpark-estimated costs of implementation, to address assumptions associated with the feasibility of reintroducing sockeye salmon upstream of Chief Joseph and Grand Coulee Dams. The information obtained from the implementation of this study plan will help to evaluate the factors and life stages that influence the numbers of adults returning to the upper Columbia River and inform planning and development of interim or permanent juvenile passage facilities at Chief Joseph and Grand Coulee Dams. As such, this study plan, combined with those designed to evaluate smolt-to-adult return rate and adult behavior and survival, will provide much of the information necessary to evaluate the reintroduction effort and identify research areas where more detailed studies are needed. These study plans were developed collaboratively by staff of the Pacific Northwest National Laboratory (PNNL), the Coeur d'Alene, Colville, and Spokane tribes, including representatives from the Upper Columbia United Tribes; and U.S. Geological Survey Western Fisheries Research Center. Through this collaborative effort, cost efficiencies were identified among the study plans. For example, the Juvenile Salmon Acoustic Telemetry (JSATS) receivers described in this study plan are the same receivers that would be purchased for the acoustic telemetry study of Chinook salmon smolt survival. Additional cost-savings could be achieved if juvenile and adult studies that use JSATS receivers are conducted concurrently, which would save labor associated with receiver testing, deployment, servicing, and recovery as well as data management and analysis.

1. Objectives

1. Estimate juvenile sockeye salmon survival from release (in spring/summer) to migrant stage (following spring) and through Lake Roosevelt.
2. Estimate juvenile sockeye salmon survival through Grand Coulee Dam.
3. Estimate juvenile sockeye salmon survival through Rufus Woods Lake, from Grand Coulee Dam to Chief Joseph Dam.
4. Estimate juvenile sockeye salmon survival through Chief Joseph Dam.
5. Assess the behavior and travel route of juvenile sockeye salmon in the forebay and through Grand Coulee Dam and Chief Joseph Dam.

1.1 Objective 1: Estimate Juvenile Sockeye Salmon Survival from Release in the Sanpoil River to Grand Coulee Dam

Subyearling sockeye salmon, obtained from the Okanogan National Alliance (ONA) Penticton Hatchery,[1] will be implanted with a passive integrated transponder (PIT) tag and an acoustic transmitter and released into the Sanpoil River[2] during the spring/summer with the expectation that they will rear in Lake Roosevelt for a year before emigrating as yearlings the following spring. Because of the relatively small expected size (7–9 g) of these fish at the time of tagging, a small acoustic transmitter, such as those of the JSATS, is required to avoid altering the behavior or survival of tagged fish. However, transmitter size is a function of battery size; therefore, a small acoustic tag that transmits continuously cannot provide the tag life necessary to monitor survival for a full year. As such, transmitters implanted in subyearling sockeye salmon released will be programmed with a delayed start to ensure that the transmitters are active at the time of emigration from Lake Roosevelt, which would be expected to occur from April through early June in the subsequent year after transmitter implantation.

It is possible that some portion of sockeye salmon will emigrate from Lake Roosevelt as subyearlings. Prior to implementing this study, information obtained from PIT-tagged subyearling sockeye salmon released by the ONA upstream of Grand Coulee Dam will be evaluated to determine whether or not a substantial proportion of sockeye emigrate from Lake Roosevelt as subyearlings. If so, emigration of acoustic-tagged sockeye salmon from Lake Roosevelt as subyearlings will be monitored from June through October of the release year by programming a subset of the transmitters to be actively transmitting at the time of release. Detections of these fish at and downstream of Grand Coulee Dam would be used to estimate the joint probability of subyearling emigration × survival to Grand Coulee Dam. This estimate will be used to adjust the survival estimate of the delayed start group to account for emigration that occurred prior to the onset of the active transmission period. A receiver array will also be deployed in Lake Roosevelt near the mouth of the Sanpoil Arm to monitor the timing of emigration from the Sanpoil River.

Commercially available JSATS transmitters that are sufficiently small to implant in subyearling sockeye salmon have a tag life that is insufficient to monitor for survival over a four-month period. However, engineers at PNNL have developed a JSATS transmitter that measures 15 mm in length and weighs 0.216 g and achieves a substantially longer tag life – after a 6-month delay (transmitter not pinging), the transmitters could last 5 additional months at 11-s pulse rate interval [PRI] or 6 additional months at 17-s PRI. Although faster PRI's are ideal to improve detection probability, higher PRI's can be compensated for by deploying extra receivers in detection areas to improve the detection probability. Assuming a detection range of receivers of 150m, and a PRI of 24-s, a fish would have to be traveling >22.5 km/h to pass through that detection zone in 24 s, which is faster than some of the fastest rates of juvenile salmon emigration detected through the Columbia River estuary.

Using detections of acoustic transmission on arrays of acoustic telemetry receivers deployed on the upstream face of Grand Coulee Dam and downstream of Grand Coulee Dam, survival will be estimated from release to Grand Coulee Dam using the Cormack-Jolly-Seber (CJS) single-release model (Cormack 1964; Jolly 1965; Seber 1965). In general, the CJS model estimates survival as

[1] Initial discussions with Okanagan Nation Alliance have occurred, but formal agreements to collect and transport fish still need to be developed.

[2] Initial releases would occur in the Sanpoil River. Other tributaries, such as the Little Spokane River, may be evaluated in future years.

$$S = \frac{\left(\frac{n_{10} + n_{11}}{N}\right)}{\left(\frac{n_{11}}{n_{11} + n_{01}}\right)} \quad (1)$$

where n_{10} is the number of fish detected at Grand Coulee Dam but not downstream, n_{11} is the number of fish detected at and downstream of Grand Coulee Dam, N is the total number of fish released, and n_{01} is the number of fish detected downstream of Grand Coulee Dam but not at the dam itself. As such, the CJS model is the proportion detected $(n_{10} + n_{11})/N$ divided by the detection probability $n_{11}/(n_{11} + n_{01})$.

If some portion of the acoustic-tagged subyearling sockeye salmon are released with actively transmitting tags, the survival of fish that emigrate as yearlings will be estimated from release to Grand Coulee Dam as

$$\hat{S}_{\text{rel-to-GCD}} = \hat{S}_{\text{delay}} \times \left(1 - \hat{S}_{\text{active}}\right)$$

with a variance (Goodman 1960) of

$$\text{Var}\left(\hat{S}_{\text{rel-to-GCD}}\right) = \hat{S}_{\text{rel-to-GCD}}^{\;2} \times \left[\text{CV}\left(\hat{S}_{\text{delay}}\right)^2 + \text{CV}\left(\hat{S}_{\text{active}}\right)^2\right]$$

where $\hat{S}_{\text{delay}}$ is the CJS estimate of survival from release to Grand Coulee Dam for the delayed start release group and $\hat{S}_{\text{active}}$ is the CJS estimate of migration × survival of the actively transmitting release group.

A representative subsample of acoustic tags will be retained for use in a tag-life study that will occur concurrently with the field study. A total of at least 60 tags will be retained and monitored for tag life. Tag-life transmitters will be programmed the same as those used in the field. That is, if some sockeye salmon are released with actively transmitting tags then half of the tags used in the tag-life study will be programmed to begin transmitting at the same time sockeye salmon are to be tagged and the other half of the tag-life study tags will be programmed with a delayed start. If no fish are released with actively transmitting tags then all tag-life transmitters will be programmed with a delayed start that mimics the tags implanted in fish. Tag-life study tags will be soaked in ambient river water and monitored from activation to tag failure in continuous time. Failure times from each tag group will be fit to Weibull 2-parameter (Lawless 1982; Lee 1992), Weibull 3-parameter (Elandt-Johnson and Johnson 1980), and the 4-parameter vitality model (Li and Anderson 2009). The best-fitting model will be used to estimate tag-life probabilities at each detection array. Survival estimates will be adjusted for the probability of tag failure using the methods of Townsend et al. (2006) and the results of the tag-life study.

Sample size analyses were performed to determine the number of acoustic-tagged subyearling sockeye salmon that would need to be released in Lake Roosevelt to achieve survival estimates with adequate precision to guide management actions and inform continued research. Precision was estimated for multiple sample sizes and two different release-to-Chief Joseph Dam survival probabilities (Table 1).

Table 1. Estimated precision of release-to-migration survival probability for acoustic-tagged hatchery subyearling sockeye salmon that emigrate from Lake Roosevelt as yearlings. Precision estimates assume a detection probability of 0.99 at Grand Coulee Dam, a joint probability of survival to and detection at Chief Joseph Dam of 0.45, and a subyearling emigration rate of 0.

Sample Size (N)	SE	95% LCL	95% UCL
Survival Probability = 0.25			
200	0.031	0.189	0.311
300	0.025	0.201	0.299
400	0.022	0.207	0.293
Survival Probability = 0.36			
200	0.034	0.293	0.427
300	0.028	0.305	0.415
400	0.024	0.313	0.407

2.1 Objectives 2, 3, and 4: Estimate Juvenile Sockeye Salmon Survival through Grand Coulee Dam, Rufus Woods Lake, and Chief Joseph Dam

Wild sockeye salmon smolts will be collected from the smolt trap and/or purse seine efforts in the Canadian Okanagan,[1] implanted with a JSATS acoustic transmitter (15 mm in length, 216 mg in air, 3-s PRI) and a PIT tag, and released in the Grand Coulee Dam forebay about 30 km upstream of the dam (R_1;Figure 1) to allow them to distribute throughout the water column to ensure that their distribution at the time of Grand Coulee Dam passage mimics that of run-of-river fish. This release location will be near the confluence of the Sanpoil Arm, which will also provide a useful reach survival rate. Tagged fish that are detected by the receiver array deployed on the upstream face of Grand Coulee Dam will form a "virtual" release group (V_1), which is a grouping of fish based on detections at an array independent of when or where those fish were released (Buchanan et al. 2009; Skalski et al. 2009; Harnish et al. 2020). A second virtual release group (V_2) will be formed of fish from the R_1 group that survive to and are detected by the receiver array deployed on the upstream face of Chief Joseph Dam. The virtual release/dead-fish correction (ViRDCt) mark-recapture model (Harnish et al. 2020) will be used to estimate dam passage survival of the V_1 and V_2 groups at Grand Coulee Dam and Chief Joseph Dam, respectively.

Using the ViRDCt model, a tailrace detection array located 1–2 km downstream of the dam will record detections of fish from the virtual release group, including those that die during dam passage and drift far enough downstream to be detected. Dead-tagged fish are released at the dam, and detections of these fish on the tailrace array are used to correct the bias that occurs when detecting fish from the virtual release group that died during dam passage. Because of the proximity of the tailrace detection array to the dam, the ViRDCt model does not require the tailrace release(s) of the paired release-recapture (Burnham et al. 1987) or virtual/paired-release (Skalski et al. 2010) models because corrections for mortality that occurs beyond the tailrace are not needed. As such, the ViRDCt model provides substantial cost-savings compared to the virtual/paired-release model (Harnish et al. 2020).

[1] Initial discussions with Okanagan Nation Alliance have occurred, but formal agreements to collect and transport fish still need to be developed.

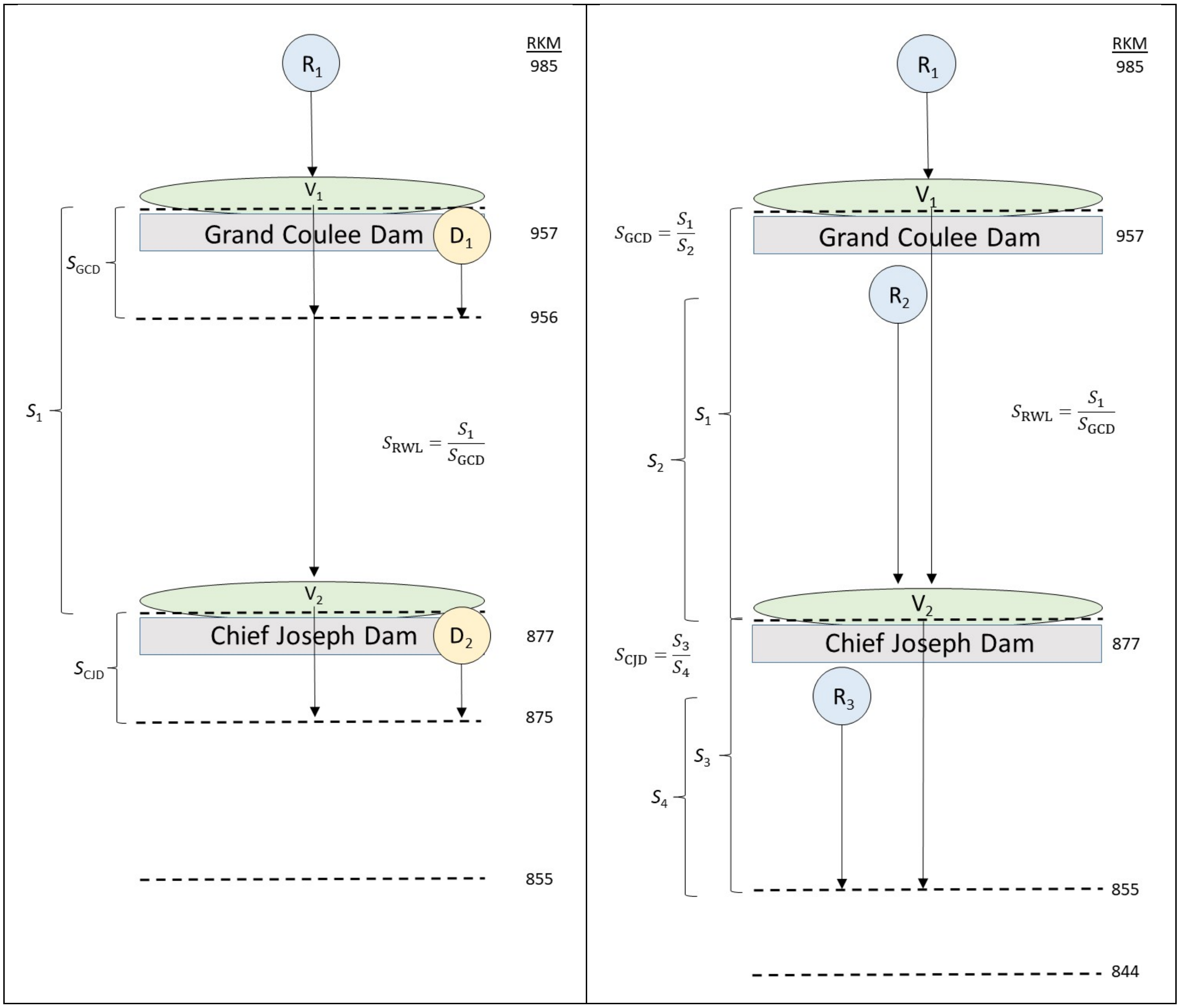


Figure 1. Diagrams depicting two study design options for estimating Grand Coulee dam passage survival (S_{GCD}), Rufus Woods Lake survival (S_{RWL}), and Chief Joseph dam passage survival (S_{CJD}). Dam passage survival is estimated using either the virtual release/dead-fish correction (ViRDCt) model (left) or the paired-release model (right). Blue circles represent release locations of live-tagged sockeye salmon (R_1, R_2, R_3), orange circles indicate dead-tagged fish releases at Grand Coulee (D_1) and Chief Joseph (D_2) dams, and dashed lines represent receiver array locations.

The paired release-recapture approach (Figure 1) will not be used to estimate dam passage survival because of concerns that this design may produce positively biased estimates because of differential expression of post-release handling mortality (Skalski et al. 2010; Harnish et al. 2020). Because the R_1 group will be released far enough upstream of the dam to allow those fish to distribute as run-of-river fish, they have time to express or recover from any potential handling or tagging effects before their inclusion in the virtual release group. In contrast, the tailrace release group would be composed of freshly tagged and released fish that do not have enough time in-river to express or recover from the effects of handling and tagging.

In addition to the release of live-tagged fish into the Grand Coulee Dam forebay described above, the ViRDCt model requires the release of dead-tagged fish from Grand Coulee and Chief Joseph Dams to correct the bias that occurs because of misidentifying dead fish as being alive at the tailrace arrays. Fish that are to be released dead may be of hatchery origin and can consist of a surrogate species, if necessary. A key assumption of the ViRDCt model is that the probabilities of dead fish arriving at the tailrace array and being detected are representative of the probabilities of arrival and detection of fish from the virtual release group that die during dam passage. For this reason, detections of R_1 fish on the Grand Coulee and Chief Joseph dam face arrays will be monitored throughout the study and used to match the spatial (i.e., spillway vs. powerhouse) and temporal distribution of the dead-tagged fish releases to distributions of the V_1 and V_2 groups. The representativeness of the dead-tagged fish releases will be evaluated and adjusted, if necessary, using the methods of Harnish et al. (2020).

Two alternative ViRDCt maximum likelihood models are available. The first model is the full model that allows for detection of dead-released fish on the tailrace and downstream arrays. The second model, which provides greater precision when valid, is the reduced model that allows for detection of dead-released fish on only the tailrace array.

For the full model, with possible dead-fish detections at two downstream arrays, the likelihood can be written as follows:

$$\begin{aligned} L = &\binom{V}{\vec{n}} (S_D p_0 \lambda + (1 - S_D)\omega p_D \Psi)^{n_{11}} \\ &\cdot (S_D(1 - p_0)\lambda + (1 - S_D)\omega(1 - p_D)\Psi)^{n_{01}} \\ &\cdot \left(S_D p_0(1 - \lambda) + (1 - S_D)\omega p_D(1 - \Psi)\right)^{n_{10}} \\ &\cdot \left[S_D(1 - p_0)(1 - \lambda) + (1 - S_D)\left((1 - \omega) + \omega(1 - p_D)(1 - \Psi)\right)\right]^{n_{00}} \\ &\cdot \binom{D}{\vec{d}} (\omega p_D \Psi)^{d_{11}} (\omega(1 - p_D)\Psi)^{d_{01}} \\ &\cdot \left(\omega p_D(1 - \Psi)\right)^{d_{10}} \left((1 - \omega) + \omega(1 - p_D)(1 - \Psi)\right)^{d_{00}}. \end{aligned} \tag{2}$$

where

V	=	number of alive fish in the virtual release at the upstream dam face,
D	=	number of dead-tagged fish released at the dam,
n_{ij}	=	number of V1 fish with capture history ij (i = 0 or 1 for detection at the tailrace array, j = 0 or 1 for detection at the tailwater #1 array),
d_{ij}	=	number of dead-released fish (D) with capture history ij (i = 0 or 1 for detection at the tailrace array, j = 0 or 1 for detection at the tailwater #1 array),
S_D	=	dam passage survival,
p_0	=	probability of an alive V fish being detected at the tailrace array,
λ	=	joint probability of survival between the tailrace array and the tailwater #1 array, and being detected at the tailwater #1 array,
ω	=	probability of a dead fish from D arriving at the tailrace array,
p_D	=	probability of detecting a dead fish at the tailrace array, and
Ψ	=	joint probability that a dead fish is washed down to the tailwater #1 array from the tailrace array and is detected at the tailwater #1 array.

The model has six parameters and six minimum sufficient statistics. Program USER (http://www.cbr.washington.edu/analysis/apps/user) will be used to estimate the model parameters and associated variances. No attempt will be made to adjust for tag life because travel times are expected to be short.

For the reduced model with dead-released fish detected only at the tailrace array, the joint likelihood model can be written as follows:

$$
\begin{aligned}
L = \binom{V}{\vec{n}} & (S_D p_o \lambda)^{n_{11}} (S_D(1-p_o)\lambda)^{n_{01}} \\
& \cdot (S_D p_o(1-\lambda)+(1-S_D)\phi)^{n_{10}} \\
& \cdot \left(S_D(1-p_o)(1-\lambda)+(1-S_D)(1-\phi)\right)^{n_{00}} \\
& \cdot \binom{D}{\vec{d}} \phi^d (1-\phi)^{D-d}
\end{aligned}
\tag{3}
$$

where

$\phi =$ joint probability of a dead-released fish (*D*) arriving at the tailrace array and being detected at that array;

$d =$ number of dead-released fish detected at the tailrace array.

The model has four parameters and four minimum sufficient statistics. This reduced model (3) has the same basic assumptions as its full model (2) counterpart, except the additional assumption that dead-tagged fish do not drift as far downstream as the first tailwater array. The placement of this downstream array has much to do with meeting this additional model assumption. In addition, a sufficient sample size of dead-tagged fish is necessary to help assure this additional model assumption is correct. Releasing just a small group of dead-tagged fish and not observing any detections downstream is no guarantee of assumption compliance. On the other hand, if 200 dead-tagged fish are released and none are detected downstream at an array having a detection probability of $P = 1.0$, then you can be 95% certain that the actual drift probability is no greater than 0.013 (i.e., $P(\omega \le 0.013) = 0.95$) (Skalski 1981).

Model (3) has a closed form estimator of dam passage survival where

$$
\hat{S}_D = \frac{\left(\left(\frac{n_{11}+n_{10}}{V}\right) - \frac{d}{\mathrm{D}}\right)}{\left(\frac{n_{11}}{(n_{11}+n_{01})} - \frac{d}{D}\right)}. \tag{4}
$$

As described above, tagged fish released into the tailrace of Grand Coulee Dam may not provide an unbiased estimate of Rufus Woods Lake survival because they do not have time in-river to express or recover from the effects of handling and tagging. Therefore, survival in Rufus Woods Lake, from the tailrace of Grand Coulee Dam to the forebay of Chief Joseph Dam, will be estimated as

$$
\hat{S}_{RWL} = \frac{\hat{S}_1}{\hat{S}_{\mathrm{GCD}}}
$$

with an associated variance (Goodman 1960) of

$$\mathrm{Var}(\hat{S}_{RWL}) = \left(\frac{\hat{S}_1}{\hat{S}_{\mathrm{GCD}}}\right)^2 \times \left[\mathrm{CV}(\hat{S}_1)^2 + \mathrm{CV}(\hat{S}_{\mathrm{GCD}})^2\right]$$

where $\hat{S}_{RWL}$ is the estimated survival from the tailrace of Grand Coulee Dam to the immediate forebay of Chief Joseph Dam, $\hat{S}_1$ is the single-release CJS estimate of survival from the immediate forebay of Grand Coulee Dam to the immediate forebay of Chief Joseph Dam, and $\hat{S}_{\mathrm{GCD}}$ is the ViRDCt estimate of Grand Coulee Dam passage survival.

Sample size analyses were performed to determine the number of acoustic-tagged sockeye salmon smolts that would need to be released in the Grand Coulee Dam forebay for estimating dam passage survival at Grand Coulee and Chief Joseph Dams using the ViRDCt model. Poor passage survival at Grand Coulee Dam would necessitate installation of a juvenile collection system at Grand Coulee Dam. Therefore, Grand Coulee Dam passage survival was prioritized in sample size analyses to achieve adequate precision to guide management actions. No additional fish will be released for the evaluation of Chief Joseph Dam passage survival conducted using the ViRDCt model. Fish from the R_1 release group that survive to and are detected at Chief Joseph Dam will be used for estimating Chief Joseph Dam passage survival. The precision of Grand Coulee Dam and Chief Joseph Dam passage survival rates was estimated for multiple live- and dead-tagged fish sample sizes (Table 2). Although the paired release-recapture model is not recommended for dam passage survival estimation, the precision of Grand Coulee Dam and Chief Joseph Dam passage survival rate was also estimated for multiple sample sizes using this approach, whereby virtual release groups are paired with a release of fish in the tailrace of Grand Coulee (R_2) and Chief Joseph (R_3) dams (Table 3; Figure 1).

Table 2. Estimated precision (SE and 95% CI) of Grand Coulee Dam and Chief Joseph Dam passage survival probabilities (S_{GCD} and S_{CJD}) estimated using the reduced ViRDCt model and of Rufus Woods Lake survival probability (S_{RWL}) for acoustic-tagged wild sockeye salmon smolts. Precision estimates assume a release-to-Grand Coulee Dam survival probability of 0.971, Grand Coulee Dam passage survival probability of 0.5, Chief Joseph Dam passage survival probability of 0.88, a detection probability of 0.99 at all arrays, a Rufus Woods Lake survival probability of 0.92, a Chief Joseph Dam tailrace-to-Brewster survival probability of 0.96, and a dead-tagged fish detection rate (ϕ) of 0.2 at Grand Coulee Dam and 0.3 at Chief Joseph Dam.

R_1 N	Total Tags N	S_{GCD} SE	S_{GCD} 95% CI	S_{RWL} SE	S_{RWL} 95% CI	S_{CJD} SE	S_{CJD} 95% CI
				D_{GCD} = 200 = D_{CJD}			
250	650	0.043	0.42-0.58	0.102	0.72-1.00	0.069	0.74-1.00
500	900	0.033	0.43-0.57	0.076	0.77-1.00	0.052	0.78-0.98
750	1,150	0.029	0.44-0.56	0.065	0.79-1.00	0.044	0.79-0.97
				D_{GCD} = 100 = D_{CJD}			
500	700	0.046	0.41-0.59	0.095	0.73-1.00	0.057	0.77-0.99
750	950	0.042	0.42-0.58	0.085	0.75-1.00	0.050	0.78-0.98
1,000	1,200	0.040	0.42-0.58	0.080	0.76-1.00	0.046	0.79-0.97

R1 N = number of live-released acoustic-tagged smolts released in the Grand Coulee Dam forebay, DGCD = number of dead-released acoustic-tagged fish released at Grand Coulee Dam, DCJD = number of dead-released acoustic-

R_1 N	Total Tags N	S_{GCD} SE	S_{GCD} 95% CI	S_{RWL} SE	S_{RWL} 95% CI	S_{CJD} SE	S_{CJD} 95% CI

tagged fish released at Chief Joseph Dam, Total tags N = total number of live- and dead-tagged fish released, SE = standard error, and CI = confidence interval.

Table 3. Estimated precision (SE and 95% CI) of Grand Coulee Dam and Chief Joseph Dam passage survival probabilities (S_{GCD} and S_{CJD}) estimated using the paired-release model and of Rufus Woods Lake survival probability (S_{RWL}) for acoustic-tagged wild sockeye salmon smolts. Precision estimates assume a dam passage survival probability of 0.5 at Grand Coulee Dam and 0.88 at Chief Joseph Dam, a detection probability of 0.99 at all arrays, a Rufus Woods Lake survival probability of 0.92, and a Chief Joseph Dam tailrace-to-Brewster survival probability of 0.95.

R_1 / R_2 / R_3 N	Total Tags N	S_{GCD} SE	S_{GCD} 95% CI	S_{RWL} SE	S_{RWL} 95% CI	S_{CJD} SE	S_{CJD} 95% CI
200 / 50 / 50	300	0.040	0.42-0.58	0.103	0.72-1.00	0.041	0.80-0.96
400 / 100 / 100	600	0.028	0.44-0.56	0.073	0.78-1.00	0.029	0.82-0.94
600 / 150 / 150	900	0.023	0.45-0.55	0.059	0.80-1.00	0.024	0.83-0.93

R1 N = number of live-released acoustic-tagged smolts released in the Grand Coulee Dam forebay, R2 = number of live-released acoustic-tagged fish released in the Grand Coulee Dam tailrace, R3 = number of live-released acoustic-tagged fish released in the Chief Joseph Dam tailrace, Total tags N = total number of live-tagged fish released, SE = standard error, and CI = confidence interval.

3.1 Objective 5: Assess Behavior and Travel Route of Juvenile Sockeye Salmon in the Forebay and through Grand Coulee Dam and Chief Joseph Dam

Hydrophones deployed on the upstream face of Grand Coulee and Chief Joseph Dams will be used to evaluate smolt behavior in the immediate forebay and dam passage routing. The lower cost approach (not three dimensional tracking) will be implemented whereby detections of acoustic transmissions at each hydrophone are evaluated separately. Assuming equal detectability among hydrophones, it is assumed that transmissions are received by the nearest hydrophone. As such, the temporal sequence of detections can be used to gain a rough estimate of tagged fish movements in the immediate forebay to their ultimate route of dam passage. Movement and passage routing information will be assessed for wild sockeye salmon smolts (from Objectives 2–4) at Grand Coulee and Chief Joseph Dams. These data will be used to estimate route-specific survival of tagged fish and to identify the best location and possible configurations for interim juvenile collection facilities the dams. Route-specific survival will be estimated using the same methodology described above except that virtual release and dead-tagged fish groups will include only those fish assigned to the passage route for which survival is being estimated.

If the data are not adequate or the analysis is too uncertain to move forward with implementation of juvenile collection facilities, then the more in-depth and costly approach of three-dimensional tracking will need to be implemented. Three-dimensional tracking uses more hydrophones and considerably more post-processing of received transmissions. Using this approach, hydrophones can be deployed at dams to track the three-dimensional movements of acoustic-tagged fish as they approach and pass through dams (Deng et al. 2011). Three-dimensional tracking is based on time-of-arrival differences of acoustic transmissions among different hydrophones (Watkins and Schevill 1972). Using the JSATS

(McMichael et al. 2010), the movements of tagged fish can be tracked several hundred of meters from the dam, which allows for thorough evaluations of approach and passage behaviors.

4.1 Coordination with Canada

This study plan does not address research needs for sockeye in the transboundary reach or in Canada. We assume that evaluations of Sockeye coming from Canadian lakes will be initiated by entities in Canada and that there will be opportunities and mutual benefits to collaborate to answer similar questions for those populations. However, it is pre-mature to develop transboundary sockeye studies at this time and we recommend adding that to the overall implementation plan through an adaptive management process at a later date.

5.1 Rough cost estimates

The initial ballpark cost estimate is $1.1 million, with the following assumptions and nuances:

- Table 1. tags=300 and 0.25 survival probability
- Table 2. tags=900 and DGCD (dead fish w/ tags) = 200
- About $400k for purchases including the acoustic tags needed for the study, which would need to be manufactured at PNNL because they are not yet commercially available; this cost also assumes that UCUT would direct purchase to avoid PNNL overhead
- Does NOT include installation and upkeep of JSATS receiver system, as these costs are in the USGS pilot study estimate and we assume these would occur in the same year
- ViRDCt survival model
- PNNL serving as advisor role on each task w/ significant support from UCUT
- About $75k is travel budget and does not yet include PNNL overhead burdening (we are keeping as-is as we assume that a majority of travel would be done locally by UCUT)
- This cost assumes that the two studies within the plan would be conducted in back-to-back years and this estimate includes both studies.
- The main cost elements/tasks are: 1. Management, 2. Tagging and Release Deployment/Demobilization, 3. Collection/Tagging/Release, 4. Data Management/Analysis, 5. Reporting, 6. Travel for all, including tasks with labor assumed from Spokane Tribe, and 7. Purchases/Procurements including tags

A more refined budget and narrative will need to be developed within 1 year of implementation, which will require a concerted effort to detail the exact tasks and roles and responsibilities of each entity involved in executing the studies.

2. References

Buchanan RA, J Skalski, and GA McMichael. 2009. Differentiating mortality from delayed migration in subyearling fall Chinook Salmon (*Oncorhynchus tshawytscha*). *Canadian Journal of Fisheries and Aquatic Sciences* 66:2243–2255.

Burnham KP, DR Anderson, GC White, C Brownie, and KH Pollock. 1987. *Design and analysis methods for fish survival experiments based on release–recapture.* American Fisheries Society Monograph Number 5.

Cormack RM. 1964. Estimates of survival from the sighting of marked animals. *Biometrika*. 51(3-4):429–438.

Deng ZD, MA Weiland, T Fu, TA Seim, BL Lamarche, EY Choi, TJ Carlson, and MB Eppard. 2011. A cabled acoustic telemetry system for detecting and tracking juvenile salmon: part 2. Three-dimensional tracking and passage outcomes. *Sensors* 11:5661–5676.

Elandt-Johnson RC, and NL Johnson. 1980. *Survival Models and Data Analysis.* John Wiley & Sons, New York, NY, USA.

Goodman LA. 1960. On the exact variance of products. *Journal of the American Statistical Association* 55:708–713.

Harnish R, J Skalski, R Townsend, and K Ham. 2020. In search of a cost-effective approach for estimating dam passage survival. *North American Journal of Fisheries Management* 40(4):865–882.

Jolly GM. 1965. Explicit estimates from capture-recapture data with both death and immigration-stochastic model. *Biometrika.* 52(1-2):225–248.

Lawless JF. 1992. *Statistical Models and Methods for Lifetime Data.* John Wiley & Sons, New York, NY, USA.

Lee ET. 1992. *Statistical Models and Methods for Lifetime Data.* John Wiley & Sons, New York, NY, USA, second edition.

Li T, and JJ Anderson. 2009. The vitality model: a way to understand population survival and demographic heterogeneity. *Theoretical Population Biology* 76:118–131.

McMichael GA, MB Eppard, TJ Carlson, JA Carter, BD Ebberts, RS Brown, M Weiland, GR Ploskey, RA Harnish, and ZD Deng. 2010. The Juvenile Salmon Acoustic Telemetry System: a new tool. *Fisheries* 35:9–22.

Seber GAF. 1965. A note on the multiple-recapture census. *Biometrika*. 52(1-2):249–260.

Skalski JR. 1981. Statistical inconsistencies in the use of no-observed effect levels in toxicity testing. Aquatic toxicology and hazard assessment: Fourth conference, ASTM STP 737, DR Branson and KL Dickerson, Eds. *American Society for Testing Materials*:377–387.

Skalski JR, RA Buchanan, RL Townsend, TW Steig, and S Hemstrom. 2009. A multiple-release model to estimate route-specific and dam passage survival at a hydroelectric project. *North American Journal of Fisheries Management* 29:670–679.

Skalski JR, RL Townsend, TW Steig, and S Hemstrom. 2010. Comparison of two alternative approaches for estimating dam passage survival of salmon smolts. *North American Journal of Fisheries Management* 30:831–839.

Townsend RL, JR Skalski, P Dillingham, and TW Steig. 2006. Correcting bias in survival estimation resulting from tag failure in acoustic and radio telemetry studies. *Journal of Agricultural, Biological, and Environmental Statistics.* 11(2):1–14.

Watkins WA, and WE Schevill. 1972. Sound source location by arrival-times on a non-rigid three-dimensional hydrophone array. *Deep-Sea Research and Oceanographic Abstracts* 19:691–706.

Appendix D: Implementation Plan for Evaluating Survival of Reintroduced Anadromous Salmon with Passive Integrated Transponder Tags Upstream of the Blocked Area of the Columbia River

Implementation Plan for Evaluating Survival of Reintroduced Anadromous Salmon with Passive Integrated Transponder Tags Upstream of the Blocked Area of the Columbia River

Authors: Ryan A. Harnish[1], Casey Baldwin[2], Kevin Malone[3], Conor Giorgi[4], Thomas Biladeau[5], Brian J. Bellgraph[1]

[1]Pacific Northwest National Laboratory; [2]Confederated Tribes of the Colville Reservation; [3]Malone Environmental; [4]Spokane Tribe of Indians; [5]Coeur d'Alene Tribe

This document describes a study plan, including ballpark-estimated costs of implementation, for addressing assumptions associated with the feasibility of reintroducing Sockeye and Chinook salmon upstream of Chief Joseph and Grand Coulee Dams. The information obtained from the implementation of this study plan will help to evaluate the factors and life stages that influence the numbers of adults returning to the upper Columbia River and inform planning and development of interim or permanent adult passage facilities at the five dams. As such, this study plan, combined with those designed to evaluate juvenile survival through the Spokane River, Lake Roosevelt, Grand Coulee Dam, Rufus Woods Lake, and Chief Joseph Dam, will provide much of the information necessary to evaluate the reintroduction effort and identify research areas where more detailed studies are needed.

The study plans were developed collaboratively by staff of the Pacific Northwest National Laboratory (PNNL); the Coeur d'Alene, Colville, and Spokane tribes, including representatives from the Upper Columbia United Tribes; and U.S. Geological Survey Western Fisheries Research Center. Through this collaborative effort, cost efficiencies were identified among the study plans. For example, the Juvenile Salmon Acoustic Telemetry (JSATS) receivers described in this study plan are the same receivers that would be purchased for the acoustic telemetry study of Chinook salmon smolt survival. Additional cost savings could be achieved if juvenile and adult studies that use JSATS receivers are conducted concurrently, which would save labor costs associated with receiver testing, deployment, servicing, and recovery as well as data management and analysis.

1. Objectives

1. Estimate juvenile Chinook and Sockeye salmon survival rates from release locations upstream of Chief Joseph, Grand Coulee and Spokane River dams to Rocky Reach and McNary dams.
2. Estimate adult Chinook and Sockeye salmon survival from Bonneville Dam to Wells Dam.
3. Estimate the release-to-Wells Dam smolt-to-adult return rates (SARs) of yearling Chinook salmon and subyearling Sockeye salmon.
4. Estimate the Wells Dam-to-Chief Joseph Hatchery ladder conversion rate of adult Chinook and Sockeye salmon.
5. Evaluate adult Sockeye salmon behavior in the tailraces of Chief Joseph and Grand Coulee dams, fallback at these dams, and their survival and behavior in respective impoundments.
6. Evaluate adult Chinook salmon behavior in the tailraces of Chief Joseph, Grand Coulee, Little Falls, Long Lake and Nine Mile dams, fallback at these dams, and their survival and behavior in respective impoundments.

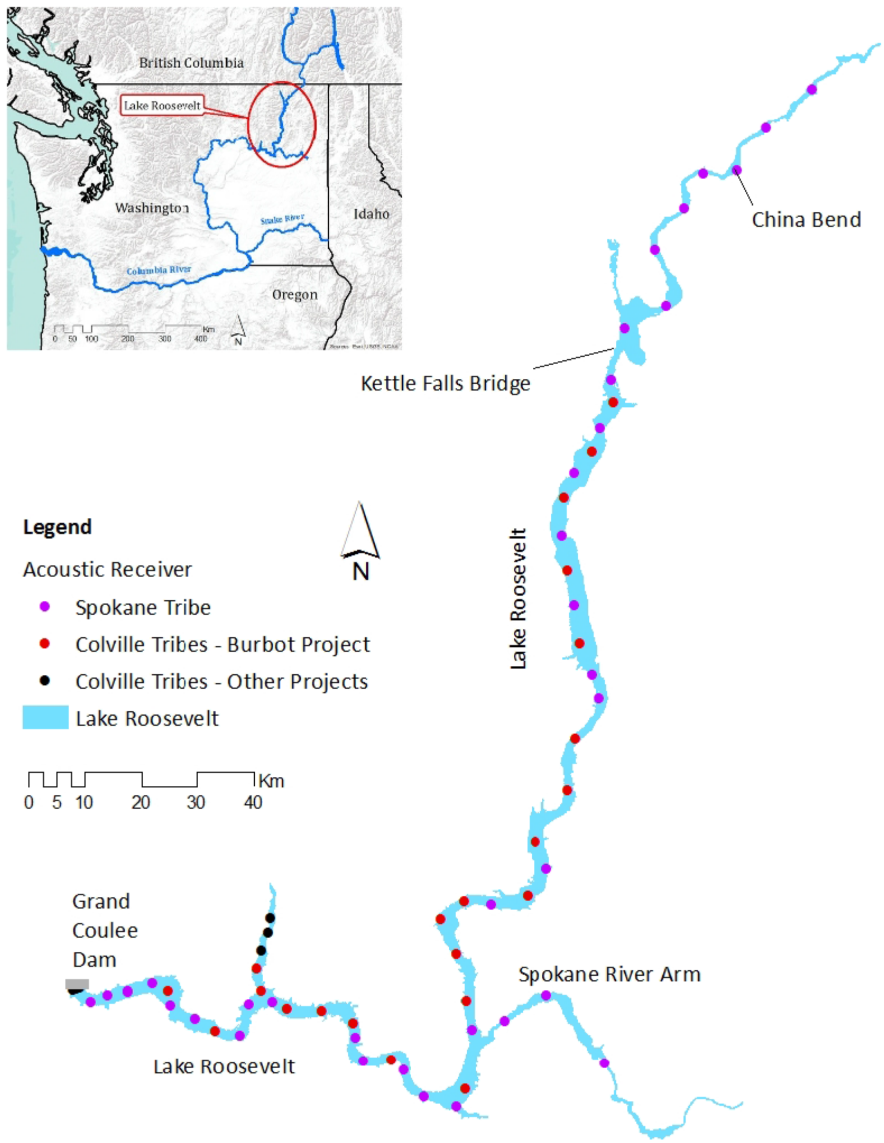
7. Estimate adult Chinook and Sockeye salmon behavior and survival upstream of Grand Coulee, Little Falls, Long Lake, and Nine Mile dams.

Objectives 1–3 are focused on evaluating the factors and life stages that influence the numbers of adults returning to the upper Columbia River. Combined with acoustic telemetry studies focused on smolt passage survival at Grand Coulee and Chief Joseph Dams (described in other appendices), these objectives provide information about factors that could be limiting adult production. Objective 4 is focused on determining the efficiency of the Chief Joseph Hatchery ladder (or other interim collection facilities) in collecting adults, which can then be passed upstream of Grand Coulee Dam for evaluations and other initial reintroduction goals. Efficiency evaluations of the Chief Joseph Hatchery ladder would also inform planning and development of interim or permanent adult passage facilities. Objectives 5 and 6 provide information about adult behavior in dam tailraces and fallback (i.e., adult salmon that pass upstream and are then swept back downstream of the dam through spillways or turbines), which can also be used to inform the placement and design of passage facilities at each dam in the project area. Finally, Objective 7 conducts tests to ensure that adults can successfully navigate through Columbia and Spokane River impoundments to their natal (natural-origin) or release (hatchery-origin) tributary.

Among the objectives outlined in this study plan, estimating the Wells Dam-to-Chief Joseph Hatchery ladder (or other interim collection facility) conversion rate and evaluating adult behavior in the tailrace of Chief Joseph Dam are the top priorities, because the ability to collect adults or develop interim passage at Chief Joseph Dam is imperative to the reintroduction effort. Evaluations of adult behavior, survival, homing, and fallback of fish released in the forebay of Grand Coulee Dam take second priority. If adults do not survive and swim back to the target areas, then an interim passage facility at Grand Coulee Dam will not be effective. The third priority, following confirmation of the successful return of adults to the target areas, would be to evaluate the behavior of adults in the Grand Coulee Dam tailrace to help scope a collection/passage facility at Grand Coulee Dam. The fourth priority among the objectives presented in this study plan would be to evaluate the behavior, survival, homing, and fallback of adults released throughout the Spokane River, as well as behavior in the tailraces of Little Falls, Long Lake, and Nine Mile dams.

Objectives 1–4 would be accomplished using passive integrated transponder (PIT) technology and Objectives 5-7 would use acoustic telemetry. PIT-tagged salmon that emigrate from Lake Roosevelt have the potential to be detected in the juvenile fish bypasses at Rocky Reach, McNary, John Day, and Bonneville Dams, in the Bonneville Dam Powerhouse 2 corner collector, and by the PIT trawl operated downstream of Bonneville Dam. Other opportunities for juvenile detection exist downstream of Bonneville Dam, including PIT antennas installed on pile dikes and during PIT scanning of piscivorous bird nesting colonies. PIT-tagged fish that return as adults have the potential to be detected in the adult fishways of mainstem Columbia River dams, including Bonneville, The Dalles, John Day, McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells Dams. Chief Joseph Hatchery ladder and multiple tributaries are also equipped with PIT-tag detectors, which would allow for detection of test fish and calculation of stray rates.

Opportunities for detecting PIT-tagged fish upstream of Chief Joseph Dam are limited. Therefore, PIT-tagged fish from Objectives 1–4 that return as adults and are collected in the ladder at Chief Joseph Hatchery, Wells Dam, or Priest Rapids Dam will be implanted with acoustic transmitters for Objectives 5-7. Adults tagged to evaluate tailrace behavior (Objectives 5 and 6) will be implanted with 416.7 kHz JSATS transmitters, which perform well in noisy environments such as dam tailraces, and released downstream of each respective dam prioritized for evaluation. Adults tagged to evaluate behavior and survival upstream of Grand Coulee Dam (Objective 6) will be implanted with 69 kHz Vemco acoustic transmitters to use the existing receiver arrays deployed throughout Lake Roosevelt (Figure 1). Due to differences in acoustic telemetry technologies and release locations, Objectives 5-7 will not occur concurrently. Evaluating Objectives 5-7 in the same year would require that substantially larger numbers of PIT-tagged juveniles be released to ensure enough of them returned as adults to evaluate both objectives.



Lake Roosevelt acoustic receiver (Vemco 69 kHz) array. Notice the black just under Grand Coulee Dam, which represents three CCT receivers.

Figure 1. Map of Vemco 69 kHz receiver locations in Lake Roosevelt.

1.1 Objectives 1–4: Juvenile survival, adult survival, smolt-to-adult return rates, and Wells Dam-to-Chief Joseph Hatchery ladder conversion rate

1.1.1 Sockeye Salmon

Subyearling Sockeye salmon, obtained from the Okanogan National Alliance Penticton Hatchery,[1] will be implanted with a PIT tag and released into the Sanpoil River during the spring with the expectation that they will migrate to and rear in Lake Roosevelt for a year before emigrating as yearlings the following spring.

Sample size analyses were performed to determine the number of PIT-tagged subyearling Sockeye salmon that would need to be released to achieve survival estimates with adequate precision to guide management actions and inform continued research. These analyses required knowledge of Sockeye salmon survival through each life stage and river reach from release as subyearlings to return as adults. The best available information was used to inform the assumptions (Table 1) used to estimate appropriate sample sizes. As survival estimates improve over time (through continued acoustic telemetry studies and evaluation of previous years' PIT-tag results) the assumptions and release group sizes will be adjusted to ensure adequate numbers of adults return to satisfy research objectives and priorities.

The Cormack-Jolly-Seber (CJS) model (Cormack 1964; Jolly 1965; Seber 1965) will be used to estimate survival of PIT-tagged juvenile and adult Chinook and Sockeye salmon to address Objectives 1–3, and 7. In general, the CJS model estimates survival as

$$S = \frac{\left(\frac{n_{10} + n_{11}}{N}\right)}{\left(\frac{n_{11}}{n_{11} + n_{01}}\right)}.$$

For juvenile survival estimation, n_{10} is the number of fish detected at the dam for which survival is being estimated but not downstream, n_{11} is the number of fish detected at the dam for which survival is being estimated that are also detected downstream, N is the total number of fish released, and n_{01} is the number of fish detected downstream of the dam for which survival is being estimated but not at the dam itself. The equation is the same for adult survival, but the secondary detection event applies to upstream detection locations. As such, the CJS model is the proportion detected $(n_{10} + n_{11})/N$ divided by the detection probability $n_{11}/(n_{11} + n_{01})$.

The Wells Dam-to-Chief Joseph Hatchery ladder conversion rate (Objective 4) will be calculated as a proportion:

$$\text{WEL to CJH conversion rate} = \frac{CJH\ N}{WEL\ N - (Harvest\ \times WEL\ N) - (Stray\ \times WEL\ N)}$$

where $CJH\ N$ is the number of PIT-tagged adults collected in the Chief Joseph Hatchery ladder, $WEL\ N$ is the number of PIT-tagged adults detected at Wells Dam, $Harvest$ is the estimated harvest rate between Wells and Chief Joseph Dams provided by the Colville Confederated Tribes and Washington Department of Fish and Wildlife, and $Stray$ is the stray rate estimated as the proportion of $WEL\ N$ fish

[1] Initial discussions with Okanagan Nation Alliance have occurred, but formal agreements to collect and transport fish still need to be developed.

that are detected in the Methow or Okanogan River basins or downstream of Wells Dam (after being detected at Wells Dam) that do not convert to the Chief Joseph Hatchery ladder.

Table 1. Survival and detection probability assumptions used to estimate the appropriate number of subyearling Sockeye salmon to implant with PIT tags and release in the Sanpoil River for estimating juvenile and adult survival and smolt-to-adult return rates.

Estimate	Probability
Survival Estimates (*S*)	
Release-to-yearling migration *S*	0.300
Release-to-Rocky Reach Dam juvenile *S*	0.059
Release-to-McNary Dam juvenile *S*	0.044
Grand Coulee Dam smolt passage *S*	0.500
Rufus Woods Lake smolt *S*	0.920
Chief Joseph Dam smolt passage *S*	0.880
Chief Joseph Dam tailrace-to-Bonneville Dam smolt *S*	0.410
Bonneville Dam-to-Bonneville Dam smolt-to-adult *S*	0.050
Bonneville Dam-to-Wells Dam adult *S*	0.760
Grand Coulee Dam-to-Sanpoil River adult *S*	0.900
Harvest Estimates	
Bonneville Dam-to-Wells Dam adult harvest	0.124
Wells Dam-to-Chief Joseph Dam adult harvest	0.050
Above Grand Coulee Dam adult harvest	0.100
PIT and Acoustic Telemetry (AT) Detection Probability Estimates (*p*)	
Rocky Reach Dam juvenile PIT *p*	0.300
McNary Dam juvenile PIT *p*	0.100
Wells Dam adult PIT *p*	0.990
Sanpoil River AT *p*	0.990
Joint Probability of Survival and Detection (*λ*)	
Below Rocky Reach Dam juvenile PIT *λ*	0.200
Below McNary Dam juvenile PIT *λ*	0.150

Ensuring that an adequate number of PIT-tagged adults return to evaluate the Wells Dam-to-Chief Joseph Hatchery ladder conversion rate (Objective 4) and Grand Coulee Dam-to-Sanpoil River survival (Objective 6) was the primary goal of analyses conducted to determine the appropriate number of PIT-tagged subyearling Sockeye salmon to release. Given the assumptions listed in Table 1, PIT-tagged subyearling Sockeye salmon sample sizes were estimated for two Wells Dam-to-Chief Joseph Dam conversion rates (Table 2). Given these sample sizes, precision was also estimated for release-to-Rocky Reach and release-to-McNary Dam juvenile survival (Table 3) and Bonneville Dam-to-Wells Dam adult survival (Table 4).

Table 2. Estimated precision (SE and 95% CI) of release-to-Wells Dam smolt-to-adult return rates (SARs), Wells Dam-to-Chief Joseph Hatchery ladder (WEL-to-CJH) conversion rates, and Grand Coulee Dam-to-Sanpoil River (GCD-to-Sanpoil) survival estimates by sample size for PIT-tagged subyearling Sockeye salmon released into the Sanpoil River and the estimated number of those fish that would return to Wells Dam and the Chief Joseph Hatchery and be available for studies of adult collection, survival, and behavior.

PIT N	SAR SE (%)	SAR 95% CI (%)	WEL-to-CJH N	WEL-to-CJH SE	WEL-to-CJH 95% CI	GCD-to-Sanpoil N	GCD-to-Sanpoil SE	GCD-to-Sanpoil 95% CI
WEL-to-CJH conversion rate = 0.49								
25,000	0.03	0.14-0.24	39	0.080	0.33-0.65	17	0.073	0.76-1.04
50,000	0.02	0.15-0.23	79	0.056	0.38-0.60	34	0.052	0.80-1.00
75,000	0.02	0.16-0.22	118	0.046	0.40-0.58	52	0.042	0.82-0.98
WEL-to-CJH conversion rate = 0.93								
25,000	0.03	0.14-0.24	39	0.040	0.85-1.01	33	0.052	0.80-1.00
50,000	0.02	0.15-0.23	79	0.029	0.88-0.99	66	0.037	0.83-0.97
75,000	0.02	0.16-0.22	118	0.023	0.89-0.98	99	0.030	0.84-0.96

PIT N = number of PIT-tagged subyearling Sockeye salmon released; SE = standard error; CI = confidence interval; WEL-to-CJH N = number of PIT-tagged fish that return to Wells Dam as adults for estimating the Wells Dam-to-Chief Joseph Hatchery ladder conversion rate; GCD-to-Sanpoil N = number of PIT-tagged fish that return to the Chief Joseph Hatchery ladder as adults for estimating Grand Coulee Dam-to-Sanpoil River survival.

Table 3. Estimated precision (SE and 95% CI) of release-to-Rocky Reach Dam (RRJ) and release-to-McNary Dam (MCJ) survival estimates for PIT-tagged subyearling Sockeye salmon released into the Sanpoil River.

PIT N	Release-to-RRJ SE	Release-to-RRJ 95% CI	Release-to-MCJ SE	Release-to-MCJ 95% CI
25,000	0.007	0.093-0.119	0.013	0.054-0.104
50,000	0.005	0.097-0.115	0.009	0.061-0.097
75,000	0.004	0.098-0.113	0.007	0.064-0.093

PIT N = number of PIT-tagged subyearling Sockeye salmon released; SE = standard error; CI = confidence interval.

Table 4. Estimated precision (SE and 95% CI) of Bonneville Dam (BON)-to-Wells Dam (WEL) adult survival estimates for Sockeye salmon PIT-tagged as subyearlings and released into the Sanpoil River that return as adults.

PIT N	BON-to-WEL SE	BON-to-WEL 95% CI
25,000	0.059	0.65-0.87
50,000	0.041	0.68-0.84
75,000	0.034	0.69-0.83

PIT N = number of PIT-tagged subyearling Sockeye salmon released; SE = standard error; CI = confidence interval.

1.1.2 Chinook Salmon

Hatchery yearling Chinook salmon will be implanted with a PIT tag and released at five locations upstream of Grand Coulee Dam during the spring. Releases will be timed with the intent to have the PIT-tagged smolts arrive downstream of Chief Joseph Dam on or about April 15, which coincides with the release timing of downstream hatcheries. Release locations include the Sanpoil River, the Transboundary Reach (near Northport, WA), and three locations in the Spokane River (below Little Falls Dam, below Nine Mile Dam/Little Spokane River, and below Spokane Falls/Hangman Creek).

Sample size analyses were performed to determine the number of PIT-tagged yearling Chinook salmon that would need to be released at each of the five release locations to achieve survival estimates with adequate precision to guide management actions and inform continued research. These analyses required knowledge of Chinook salmon survival through each life stage and river reach from release as yearlings to adult returns. The best available information was used to inform the assumptions (Table 1) used to estimate appropriate sample sizes. Again, these assumptions and release group sizes will be adjusted as more information becomes available to ensure adequate numbers of adults return to satisfy research objectives and priorities.

Table 1. Survival and detection probability assumptions used to estimate the appropriate number of yearling Chinook salmon to implant with PIT tags and release in the Sanpoil and Spokane rivers and the Transboundary Reach of the Columbia River for estimating juvenile and adult survival and smolt-to-adult return rates.

Estimate	Probability
Survival Estimates (*S*)	
Sanpoil River release-to-Grand Coulee Dam smolt *S*	0.910
Below Little Falls Dam release-to-Grand Coulee Dam smolt *S*	0.800
Little Spokane River release-to-Grand Coulee Dam smolt *S*	0.700
Below Spokane Falls release-to-Grand Coulee Dam smolt *S*	0.550
Transboundary Reach release-to-Grand Coulee Dam smolt *S*	0.640
Grand Coulee Dam smolt passage *S*	0.500
Rufus Woods Lake smolt *S*	0.920
Chief Joseph Dam smolt passage *S*	0.880
Chief Joseph Dam tailrace-to-Rocky Reach Dam smolt *S*	0.700
Chief Joseph Dam tailrace-to-McNary Dam smolt *S*	0.557
Chief Joseph Dam tailrace-to-Bonneville Dam smolt *S*	0.456
Bonneville Dam-to-Bonneville Dam smolt-to-adult *S*	0.025
Bonneville Dam-to-Wells Dam adult *S*	0.830
Grand Coulee Dam-to-Yearling release locations *S*	0.900
Harvest Estimates	
Bonneville Dam-to-Wells Dam adult harvest	0.269
Wells Dam-to-Chief Joseph Dam adult harvest	0.050
Above Grand Coulee Dam adult harvest	0.100

Estimate	Probability
PIT and Acoustic Telemetry (AT) Detection Probability Estimates (*p*)	
Rocky Reach Dam juvenile PIT *p*	0.300
McNary Dam juvenile PIT *p*	0.060
Wells Dam adult PIT *p*	0.990
Sanpoil River AT *p*	0.990
Transboundary Reach AT *p*	0.990
Spokane River AT *p*	0.990
Joint Probability of Survival and Detection (λ)	
Below Rocky Reach Dam juvenile PIT λ	0.140
Below McNary Dam juvenile PIT λ	0.150

Similar to the approach used for Sockeye salmon, the primary goal for determining the appropriate number of PIT-tagged yearling Chinook salmon to release was to ensure that an adequate number of PIT-tagged adults return to evaluate the Wells Dam-to-Chief Joseph Hatchery ladder conversion rate (Objective 4) and Grand Coulee Dam-to-release site survival rate (Objective 6). Given the assumptions listed in **Table 1**, PIT-tagged yearling Chinook salmon sample sizes were estimated for two Wells Dam-to-Chief Joseph Dam conversion rates (Table 2). Given these sample sizes, precision was also estimated for release-to-Rocky Reach and release-to-McNary Dam juvenile survival (Table 3) and Bonneville Dam-to-Wells Dam adult survival (Table 4).

Table 2. Estimated precision (SE and 95% CI) of Grand Coulee Dam-to-Wells Dam smolt-to-adult return rates (SARs), Wells Dam-to-Chief Joseph Hatchery ladder (WEL-to-CJH) conversion rates, and Grand Coulee Dam-to-yearling release location survival estimates (GCD-to-Release) by sample size for PIT-tagged yearling Chinook salmon released upstream of Grand Coulee Dam and the estimated number of those fish that would return and be available for studies of adult collection, survival, and behavior.

PIT N[a]	SAR SE (%)	SAR 95% CI (%)	WEL-to-CJH N	WEL-to-CJH SE	WEL-to-CJH 95% CI	GCD-to-Release N[b]	GCD-to-Release SE[c]	GCD-to-Release 95% CI[3]
WEL-to-CJH conversion rate = 0.49								
60,000	0.03	0.33-0.45	126	0.045	0.40-0.58	43	0.080	0.74-1.06
110,000	0.02	0.35-0.43	225	0.033	0.42-0.56	86	0.056	0.79-1.01
160,000	0.02	0.35-0.43	324	0.028	0.44-0.54	129	0.046	0.81-0.99
WEL-to-CJH conversion rate = 0.93								
60,000	0.03	0.33-0.45	126	0.023	0.89-0.97	81	0.058	0.79-1.01
110,000	0.02	0.35-0.43	225	0.017	0.90-0.96	163	0.054	0.82-0.98
160,000	0.02	0.35-0.43	324	0.014	0.90-0.96	244	0.044	0.83-0.97

PIT N = number of PIT-tagged yearling Chinook salmon released; SE = standard error; CI = confidence interval; WEL-to-CJH N = number of PIT-tagged fish that return to Wells Dam as adults for estimating the Wells Dam-to-Chief Joseph Hatchery ladder conversion rate; GCD-to-Release N = number of PIT-tagged fish released above Grand Coulee Dam as juveniles that return to the Chief Joseph Hatchery ladder as adults for estimating survival from Grand Coulee Dam to the yearling release location.

[a] PIT N is the total sample size of all release locations pooled.

[b] GCD-to-Release sample size is estimated for all above-Grand Coulee Dam release locations pooled.

PIT N[a]	SAR SE (%)	SAR 95% CI (%)	WEL-to-CJH N	WEL-to-CJH SE	WEL-to-CJH 95% CI	GCD-to-Release N[b]	GCD-to-Release SE[c]	GCD-to-Release 95% CI[3]

[c] GCD-to-Release precision is estimated for a single above-Grand Coulee Dam release location (i.e., Sanpoil River, Spokane River [all Spokane River releases combined], Transboundary Reach).

Table 3. Estimated precision (SE and 95% CI) of release-to-Rocky Reach Dam (RRJ) and release-to-McNary Dam (MCJ) survival estimates for PIT-tagged yearling Chinook salmon released into the Sanpoil River, Spokane River (below Little Falls, below Nine Mile Dam/Little Spokane River, and below Spokane Falls/Hangman Creek), and the Transboundary Reach of the Columbia River (near Northport, WA).

PIT N (Total)	PIT N by Release Location	Release-to-RRJ SE	Release-to-RRJ 95% CI	Release-to-MCJ SE	Release-to-MCJ 95% CI
Below Grand Coulee Dam / Rufus Woods Lake					
60,000	10,000	0.026	0.653-0.755	0.052	0.424-0.628
110,000	10,000	0.026	0.653-0.755	0.052	0.424-0.628
160,000	10,000	0.026	0.653-0.755	0.052	0.424-0.628
Sanpoil River					
60,000	13,150	0.019	0.285-0.360	0.041	0.161-0.320
110,000	26,300	0.014	0.296-0.349	0.029	0.185-0.297
160,000	39,450	0.011	0.301-0.344	0.023	0.195-0.287
Below Little Falls Dam (Spokane River)					
60,000	8,100	0.018	0.245-0.318	0.037	0.138-0.282
110,000	16,200	0.013	0.256-0.307	0.026	0.159-0.261
160,000	24,300	0.011	0.260-0.303	0.021	0.168-0.252
Below Nine Mile Dam / Little Spokane River					
60,000	5,050	0.022	0.203-0.290	0.044	0.099-0.269
110,000	10,100	0.016	0.216-0.277	0.031	0.124-0.244
160,000	15,150	0.013	0.221-0.272	0.025	0.135-0.233
Below Spokane Falls / Hangman Creek					
60,000	5,050	0.020	0.155-0.232	0.039	0.069-0.220
110,000	10,100	0.014	0.167-0.221	0.027	0.091-0.198
160,000	15,150	0.011	0.171-0.216	0.022	0.101-0.188
Transboundary Reach					
60,000	18,650	0.014	0.200-0.254	0.029	0.114-0.225
110,000	37,300	0.010	0.208-0.246	0.020	0.130-0.209
160,000	55,950	0.008	0.212-0.242	0.017	0.137-0.202

PIT N (Total) = total number of PIT-tagged yearling Chinook salmon released (all release locations combined); SE = standard error; CI = confidence interval.

*In certain years the proportion released at particular locations may be adjusted to provide more returning adults for behavioral studies at certain dams.

Table 4. Estimated precision (SE and 95% CI) of Bonneville Dam (BON)-to-Wells Dam (WEL) adult survival estimates for Chinook salmon PIT-tagged as yearlings and released upstream of Grand Coulee Dam in the Sanpoil and Spokane Rivers and in the Transboundary Reach of the Columbia River that return as adults.

Total PIT N	BON-to-WEL SE	BON-to-WEL 95% CI
60,000	0.026	0.780-0.880
110,000	0.019	0.792-0.868
160,000	0.016	0.799-0.861

Total PIT N = total number of PIT-tagged yearling Sockeye-Chinook salmon released; SE = standard error; CI = confidence interval.

Objectives 5 and 6: Adult Behavior in Dam Tailraces and Fallback

Adult behavior in dam tailraces and fallback will be evaluated to inform the placement and design of passage facilities at Chief Joseph, Grand Coulee, Little Falls, Long Lake, and Nine Mile dams. As mentioned previously, the behavior of adult Chinook and Sockeye salmon that encounter the dams will be evaluated using acoustic telemetry. Fish implanted with PIT tags as juveniles that are released upstream and downstream of Grand Coulee Dam will be collected as returning adults at a location downstream of Chief Joseph Dam (e.g., Chief Joseph Hatchery ladder, Wells Dam, Priest Rapids Dam) and implanted with a PNNL-designed JSATS transmitter specifically engineered to perform in noisy environments (Lu et al. 2016; Deng et al. 2018; Harnish et al. 2019). The tag will generate a 416.7 kHz coded acoustic signal every 2 s (i.e., 2 s pulse rate interval [PRI]) at a source level of 163 dB (re. 1 µPa at 1 m). This PRI and source level will increase the number of detections and achieve finer scale tracking in the noisy tailrace environment, while providing the tag life to monitor adult movements in the study area for a sufficient amount of time. Acoustic-tagged adults will be allowed to recover from tag implantation prior to being released either upstream or downstream of Chief Joseph Dam. Fish released to evaluate behavior in the Chief Joseph Dam tailrace will be released sufficiently downstream of the dam (~10 river kilometers) to allow adults to distribute vertically and horizontally as run-of-the-river fish prior to their approach to the tailrace. Adults released to evaluate tailrace behavior at Grand Coulee Dam will be released into the forebay of Chief Joseph Dam to allow for estimation of the fallback rate at Chief Joseph Dam and evaluation of adult survival in Rufus Woods Lake. A similar approach will be implemented at the Spokane River dams, provided there is adequate funding and fish availability. If funding or sample sizes of returning adults are too small to implement the studies simultaneously, then PIT tag release numbers in the Spokane River will be increased and adult behavior will be assessed there in subsequent years.

Acoustic-tagged adults will be detected by arrays of cabled and autonomous acoustic telemetry receivers deployed in the tailraces of Chief Joseph, Grand Coulee, Little Falls, Long Lake, and Nine Mile dams and on the upstream face of Chief Joseph Dam. Arrays of autonomous receivers will be deployed about 1 km downstream of the dams. Detections on these arrays will be used to monitor movements of tagged fish into and out of the tailraces and to evaluate their cross-channel approach locations. Using methods similar to those described by Harnish et al. (2019), a combination of cabled and autonomous receivers will be deployed in the immediate tailrace of the five dams to allow for two- or three-dimensional tracking of acoustic-tagged fish as they search for a route of upstream passage.

The proportion of tagged adults released upstream of Chief Joseph Dam that are detected in the Chief Joseph Dam tailrace will be used as an estimate of the Chief Joseph Dam fallback rate. An array of cabled receivers deployed on the upstream face of Chief Joseph Dam will allow for the approximate time and route (i.e., spillway, powerhouse) of fallback to be identified. Fallback at Grand Coulee Dam will not be evaluated as part of this effort. Instead, Grand Coulee Dam fallback will be evaluated using adults implanted with Vemco tags as part of Objective 7. If the fallback rate at GCD is relatively high and there are management concerns (e.g., behavior in the forebay, route specific fallback) that require a more detailed evaluation then an additional study with JSATS tags may need to be considered. The precision (SE) of the fallback rate estimate versus sample size is shown in Figure 1 for three fallback rates. Assuming a fallback rate of 0.10, 36 adults will need to be released above Chief Joseph Dam to achieve an SE of 0.05, which will produce a 95% confidence interval of 0.002–0.198.

A sample size of 36 adults will also achieve an SE of 0.05 for the estimate of adult survival through Rufus Woods Lake (assuming 90% survival and 99% detection probability) and provide a sufficient number of fish to evaluate Grand Coulee Dam tailrace behavior. Thus, a total of 70 to 80 adults are recommended to be released downstream and upstream of Chief Joseph Dam for evaluations of adult behavior in the tailraces of Chief Joseph and Grand Coulee Dams and fallback at Chief Joseph Dam. These sample sizes of returning PIT-tagged adults should be achievable given the proposed sample sizes of PIT-tagged juveniles presented in Table 2 and Table 3. However, depending on the number of PIT-tagged juveniles released, their survival to returning adult, and the Wells Dam-to-Chief Joseph Hatchery ladder conversion rate, at least some adults may need to be captured at Wells Dam and/or Priest Rapids Dam instead of at the Chief Joseph Hatchery ladder.

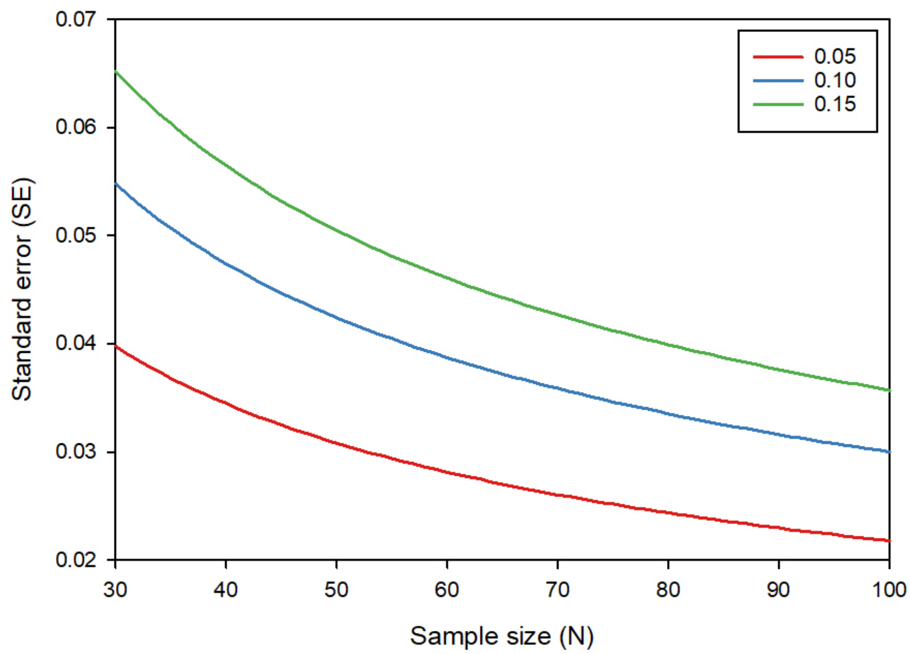


Figure 1. Relationship between standard error (SE) and sample size (N) for three Chief Joseph Dam fallback rates (0.05, 0.10, and 0.15).

Depending on the number of returning adults originating from the Spokane River release sites and ensuring that sufficient numbers of adults have been made available for evaluations at Chief Joseph and Grand Coulee Dams, similar adult behavior and fallback rate studies will be conducted at each of the three dams on the Spokane River. Due to the much smaller scope of each of these projects and the narrow width of the Spokane River, tailrace behavior will focus on adult approach to each dam in order to identify the most appropriate location for passage or collection facilities. Adults therefore will be released at least 10 km downstream of Little Falls Dam, and in the forebay upstream of Little Falls, Long Lake and Nine Mile Dams. Fall back rates will be calculated based on detections on receivers in the tailrace of each respective dam. Calculations will be estimated as a proportion with precision that is similar to that previously described for Chief Joseph Dam fallback under Objective 5.

Increasing juvenile release group sizes at sites in the Spokane River may be necessary to ensure a sufficient number of adults are available to evaluate migratory survival (Objective 7) and upstream approach for each of the three dams. A larger sample size of adults originating from the Spokane Falls/Hangman Creek juvenile release group may be necessary to gather accurate information on tailrace behavior at Nine Mile Dam as these fish will have an opportunity to stray into the Little Spokane River prior to reaching the tailrace of Nine Mile Dam. Juvenile release group sizes will be adjusted in subsequent years as survival assumptions are informed by results from previous releases.

Objective 7: Adult Survival Upstream of Grand Coulee and Spokane River Dams

PIT-tagged fish that are released upstream of Grand Coulee Dam as juveniles and return as adults will be used for evaluations of behavior and survival upstream of Grand Coulee Dam. Returning adults will be captured downstream of Chief Joseph Dam (e.g., Chief Joseph Hatchery ladder, Wells Dam, Priest Rapids Dam), implanted with a 69 kHz Vemco tag, and transported to and released in the forebay of Grand Coulee Dam. Survival will be estimated from the Grand Coulee Dam forebay to detection arrays located near the juvenile release sites using the CJS model, as described previously. For fish released in the Spokane River, survival will be estimated to a location downstream of Little Falls Dam, which is not equipped with upstream passage. Depending on the total number of returning adults and their respective juvenile release locations, local-origin adults may also be released above hydro-electric projects in the Spokane River. Behavior and straying rates in the Spokane River will be assessed using the PNNL -designed JSAT transmitters described above. Receivers will be located at the tailrace of each dam, the mouth of the Little Spokane River located between Long Lake and Nine Mile Dams, at the mouth of Hangman Creek upstream of Nine Mile Dam and upstream of Hangman Creek below Spokane Falls.

In addition to evaluations of behavior and survival in Lake Roosevelt, acoustic-tagged adults released in the Grand Coulee Dam forebay will also be used to evaluate fallback at Grand Coulee Dam (Objective 5 and 6). At least one 69 kHz Vemco receiver will be deployed near the tailrace of Grand Coulee Dam to monitor for tagged adults that fallback over Grand Coulee Dam. The fallback rate will be estimated as a proportion with precision that is similar to that previously described for Chief Joseph Dam fallback under Objective 5 and 6.

Coordination with Canada

This study plan does not address research needs for Chinook or Sockeye in Canada. We assume that evaluations of Chinook and Sockeye coming from Canada will be initiated by entities in Canada and that there will be opportunities and mutual benefits to collaborate to answer similar questions for those populations. However, it is pre-mature to develop transboundary study plan at this time and we recommend adding that to the overall implementation plan through an adaptive management process at a later date.

Rough cost estimates

The initial ballpark cost estimate is $2.3 million, with the following assumptions and nuances:

- Table 2 PIT=50,000 and 0.49 conversion rate (sockeye salmon)
- Table 6 PIT=110,000 and 0.93 conversion rate (Chinook salmon)
- PNNL serving as advisor role on each task w/ significant support from UCUT
- Includes estimate for renting and operating Whooshh adult scanner/sorter at one Wells Dam adult ladder for 4 months
- Includes estimate to subcontract BioMark to PIT-tag 160,000 fish, including cost of PIT tags
- Cost assumes '1 year' of study for each element (i.e., tagging/releasing 160,000 PIT-tagged fish, 4 months of Whooshh-adult sorting and transport [assume 200 adults to sort/tag/transport], 4 months of JSATS gear installation/upkeep at autonomous receivers in the tailrace of GCD and CJD and dam-face JSATS array on CJD)
- Purchasing JSATS and Vemco acoustic tags for adults
- PIT-tagging to occur at the rearing hatchery w/ Biomark tagging trailer
- Travel costs are assumed to primarily fall on tribal staff so it does not include PNNL burdening
- Purchases do not include PNNL burdening as it is assumed UCUT would buy supplies directly to avoid overhead
- The main cost elements/tasks are: 1. Sockeye tagging & release, 2. Chinook tagging and release, 3. Installation and maintenance of JSATS autonomous nodes in dam tailraces, 4. Installation and maintenance of dam-face JSATS array to CJD, 5. Data analysis for entire project, 6. Sorting adults at Wells using Whooshh separator, 7. Tagging and transporting adult sockeye and chinook, 8. Management, and 9. Reporting

1.2 References

Cormack RM. 1964. Estimates of survival from the sighting of marked animals. *Biometrika*. 51(3-4):429–438.

Deng ZD, H Li, J Lu, MJ Myjak, JJ Martinez, J Xiao, RS Brown, and SS Cartmell, Battelle Memorial Institute, Inc. 2018. *Acoustic transmission device and process for tracking selected hosts.* U.S. Patent 10,101,429.

Harnish R, J Martinez, ZD Deng, T Fu, B Pflugrath, R Mueller, C Grant, X Li, S Titzler, K Ham, X Lin, and H Li. 2019. *Adult spring Chinook salmon passage at Little Goose Dam, 2018*. PNNL-29172. Prepared for the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA, by Pacific Northwest National Laboratory, Richland, WA.

Jolly GM. 1965. Explicit estimates from capture-recapture data with both death and immigration-stochastic model. *Biometrika.* 52(1-2):225–248.

Lu J, ZD Deng, H Li, MJ Myjak, JJ Martinez, J Xiao, RS Brown, and SS Cartmell. 2016. A small long-life acoustic transmitter for studying the behavior of aquatic animals. *Review of Scientific Instruments* 87(11):114902.

Seber GAF. 1965. A note on the multiple-recapture census. *Biometrika*. 52(1-2):249–260.

Appendix E: An Adult Upstream Fish Passage Concept for Chief Joseph and Grand Coulee Dams

Whooshh Innovations
Port of Seattle, Pier 91, Bldg. 156
Seattle WA 98119

Adult Upstream Interim Fish Passage Concept for Chief Joseph and Grand Coulee Dams

Prepared by: Whooshh Innovations, Inc.

For: Casey Baldwin, Senior Research Scientist, Colville Confederated Tribes

Final Document for CCT Contract # C21-118

Contents

1. Introduction

The overall objective of this task was to evaluate the use of the fish transport tube technology as an interim solution to providing upstream adult passage at both Chief Joseph and Grand Coulee Dams for programs considering reintroduction of a number of previously blocked anadromous species. The purpose of this document is to provide a results summary of the background review of publicly available site information and present initial passage concepts with preliminary cost estimates. The fish passage solution described herein is conceptual in nature and is to be used to support the ongoing development of an effective and cost-efficient fish passage program at the dams. The solution presented will provide safe and efficient adult salmon transport during Phase 2 of the reintroduction effort. Additional considerations and costs would be incurred to make these installations permanent. Review, modification, permitting and approval by dam owners and operators will also be necessary before plans can be fully developed and implemented.

2. Scope of Document

The following tasks were performed during preparation of this document.

- Reviewed salient publicly available background information relating to fish passage at similar dams, and previous projects involving installation of the Whooshh Passage Portal (WPP). [1.]
- Noted any differences in the target facilities as described, and requirements for a WPP solution capable of operating intermittently for several years during Phase 2 of the reintroduction effort.
- Summarized site fish passage requirements as understood; and
- Developed a fish passage concept incorporating the use of the fish transport tube (Whooshh) technology.

These activities and resulting conclusions inform the contents of this document. This technical memorandum offers a description of project considerations and criteria and includes a concept for upstream fish passage and anticipated costs and performances associated with the design elements of these concepts at both dams. It is understood that the system may need to be installed and tested at CJD before proceeding with GCD, and the GCD system may then be modified based on what is learned at CJD.

The document is organized into several sections. First is a general description of the key physical and topographic characteristics at each dam and biological considerations for passage are then briefly addressed. The next section deals with the features involved in a passage installation using the Whooshh Passage Portal technology, noting different approaches required to deal with particular geographic, and site-specific features. Elements of the solution proposed are then discussed, and the application of the solution elements to each of the 4 locations being considered at the two dams is presented. Finally, some initial budgetary projections of project cost are included.

3. Background

3.1 Key Project Characteristics

The two fish passage projects are located at major Federally owned dams on the Columbia River. Chief Joseph dam is operated by the US Army Corps of Engineers, and Grand Coulee is operated by the US Bureau of Reclamation. See Table 1.

Table 1. Summary of Key Project Characteristics

Characteristic	Description
1. Chief Joseph Dam	
Dam crest road elevation at spillway	972 feet
Forebay elevation (10 yr mean)	953 feet
Forebay operating range	948-955 feet
Tailrace elevation (10 yr mean)	782 feet
Tailrace operating range	773-792 feet
Nominal hydraulic height	171 feet
Tailrace to crest nominal height	190 feet
2. Grand Coulee Dam	
Dam crest elevation	1311 feet
Crest road elevation	1418 feet
Forebay elevation (10 yr mean)	1275 feet
Forebay operating range	1208-1290 feet
Tailrace elevation (10 yr mean)	962 feet
Tailrace operating range	954-978 feet
Nominal hydraulic height	313 feet
Tailrace to crest road nominal height	456 feet

3.2 Site Map

The dams are located on the Columbia River. Chief Joseph is at river mile 545, and Grand Coulee is at river mile 596.6. Map 1 shows the locations in Eastern Washington State.

Map 1. Location within Washington State. (courtesy Google Maps)

4. Site specific topographic challenges to passage

4.1 Chief Joseph

General

The forebay operating range will accommodate a fixed exit installation for the transport system. The tailrace operating range requires a design that accommodate the approximate 20 feet variation in stage height.

River right:

The main river channel at the spillway on the right bank runs downstream perpendicular to the dam face. When the spillway is operating, flows will be high on this right bank close to the dam. The structure will need to be designed to be resilient to these flows.

At the dam crest there is a maintenance/spillway gate access road. Any over the road passage structure needs to accommodate existing provision for access using this road by over-height vehicles. Precise height requirements are outside the scope of this document but should be incorporated into more detailed design activity.

River left:

A choice exists for placement of the system on the left bank. Fish may aggregate at the mouth of Foster Creek, or potentially at the leftmost powerhouse end, depending on flows. A determination will need to be made as to which location is optimum for a passage entrance, or whether a combination of both is required. Both entrance locations and subsequent tube routing will need to accommodate existing provision for access to the powerhouse by over-height vehicles. It may be possible to route the transport tubes under the road at the bridge over Foster Creek, but this level of detail is outside the scope of this current document.

In addition, there is an access road to the top of the dam that requires similar provisions to maintain existing vehicular access.

4.2 Grand Coulee

General

The forebay operating range is considerable at this facility. If the system is operated during drawdown and refill (~February-May), the exit from the passage system will need to accommodate variation in elevation of as much as 80 feet based on historical records. However, given that the Phase 2 work is currently planning to study Sockeye and Summer Chinook, it may only be operated from July to October, which would reduce the forebay operating range to approximately 20 feet. The tailrace operating range requires a design that will be able to absorb the approximate 24 feet variation in stage height, provided the exit structure is removed during non-operational periods.

River right:

At the base of the dam there is a large parking lot/staging area and access to the Third Powerhouse. Routing will need to accommodate maintained vehicular access. Similarly, the dam crest road access requires appropriate consideration.

River left:

On the left side of the dam there is a small frontage road which appears to provide waterfront access via steps. Passage structure siting will determine if design provisions are required to maintain access to these steps and the frontage road. Routing will need to cross the larger parking lot and access road to the First Powerhouse. At the crest, there is another parking area on top of the Pumping Station, and access to the spillway road. Routing will have to accommodate the potential for oversize vehicular access in these areas.

5. Biological Considerations for Upstream Passage

Target Species

The initial target species for this project are Chinook and Sockeye. Other salmonid species that may enter the system include Coho, steelhead/Rainbow Trout, and Bull Trout. Non-target species will need to be returned to the river utilizing the imaging and sorting capabilities. Although initially only Chinook and Sockeye are being considered, this proposal envisages solutions that can accommodate the range of species encountered.

Period of Migration

The primary target species are typically present from July to October. The operating schedule of the system may need to be adjusted to accommodate ESA or other permitting requirements.

Population Abundance and System Capacity

There is uncertainty regarding the numbers of fish expected, however it is reasonable to assume that the number of fish that need transported will increase as the program grows.

At Wells Dam, the next dam downstream of Chief Joseph the daily counts for summer Chinook typically max out at about 2,000 per day, whereas Sockeye can sometimes approach 30,000 per day (data available in DART[2]). Theoretical maximum capacities are presented in this document for the solution being contemplated and are provided for illustration only. We anticipate that it would be many years into a successful reintroduction before larger capacities would be needed for these systems. If larger capacity is required, accommodations are possible, however future amendment to this document with capacity specification defined is recommended. Because the Whooshh system is both relatively inexpensive and modular, additional capacity is relatively easy to bring on-line at an existing installation as needed.

6. Formulation and Description of Passage Concepts

Whooshh Innovations has developed technologies and products over the past decade that have been adapted from prior innovations in agriculture and fish processing to provide transport solutions for live fish over distances of as much as 1700 feet and over barriers exceeding 650 feet. The technology and products have undergone extensive testing throughout the Pacific Northwest and Northeast of the United States on live fish species ranging from salmon and steelhead to shad and sturgeon. Results show no significant injury or mortality as a result of transport through the Whooshh system, and performance equivalent to, or better than, trap and haul. Example projects and testing results can be found at www.whooshh.com/studies.html .

Recently the Company's Passage Portal system was deployed by Fisheries and Oceans Canada on the Fraser River at the Big Bar rockslide, where several thousand Sockeye and Chinook were safely and volitionally transported past the slide. Data resulting from numerous studies and deployments show that fish passage through the Whooshh systems can be done safely[3,4] and can accommodate a more rapid deployment timeline than other traditional fish passage technologies. It can also be scaled to large volumes more easily than equipment intensive operations like trap and haul. The core technology is also being used successfully to move live fish at hatcheries and aquaculture facilities around the world.

In general, the Whooshh Passage Portal system consists of a flexible Migrator tube that is connected to an air pump. In the tube, a pressure differential of about 1-2 PSI is induced between the front and the back of the fish, thereby gently pushing the fish through the tube. Once in the tube, fish travel at a speed of approximately 25 feet per second and exit the tube directly into the desired body of water upstream of the passage barrier. Misters located within the tube keep the inside surface of the tube wet and relatively frictionless. As fish are transported, they are travelling with a bolus of water that is created by the water emitted by the misters in front of the fish; the result is a simple glide through the tube with no measurable loss of slime or scale or any other physical damage to the fish. In addition, studies have shown no significant stress impact on the fish.[3]

The system is designed to handle a number of different species. Whooshh has considerable experience transporting a variety of fish species. Each Migrator tube is designed to handle a range of fish sizes. For the initial target fish, Chinook, a minimum of three tube sizes are recommended. This will ensure passage of the vast majority of adult and jack Chinook. A smaller tube may be required for Sockeye fish passage. Therefore, a WPP three tube minimum system is being recommended, however precise configuration requirements will need to be assessed based on customer provided size data.

As the scope of the project increases over time to accommodate other species, additional tubes and supporting equipment can be added as modules to the existing baseline installation to accommodate other sizes of fish and/or significant increases in the number of fish requiring passage. Precise size ranges anticipated should be confirmed before installation as tubes are sized by girth of target species, not by weight.

It is assumed that the outflow from the base of the dam is sufficient to attract migrating fish to the approximate vicinity of the passage structures. A short fish ladder will need to be constructed to connect the tailrace water at differing stage heights to the location above the high-water line where the Whooshh fish transport system is to be installed. Water from the ladder plus possible auxiliary supply will serve to provide attraction flow for the fish in the vicinity.

At the top of the ladder, there should be a gallery or pool. From there the fish will enter a short perhaps (20’-30’ in length) steeppass (provided by Whooshh) at the top of which is a flow box and false weir. The false weir serves to partially dewater, and isolate each fish for transport. The partially dewatered fish then slide down a wetted surface through a scanner (Whooshh FishL™ Recognition) that will be used to count, size, and image each fish and direct them through sorting gates to a transport lane sized for that fish. Each lane comprises an accelerator which acts as an airlock that introduces the fish to an appropriate diameter transport tube which safely conveys the fish to its destination.

A high volume, low pressure blower will be used to provide temperature controlled air at the accelerator entrance to facilitate loading of the fish into the transport tube(s). The tubes are lubricated by a water spray introduced approximately every 6 feet along the tubes providing a wet, smooth, relatively friction free envelope along which the fish glide via the air stream. Temperature inside the Migrator™ tube is regulated through the system to minimize thermal stress on the fish. Temperatures of the motive air and lubrication water are maintained at approximate tailrace water values to minimize any thermal effects on the fish.

Instrumentation tracks the velocity of each fish being transported, and controls are used to decelerate the fish to an appropriate speed for entry into the lake. At the distal end of the tube the fish are directed through an appropriate re-entry device that delivers them safely and correctly angled for reentry into the water at speeds typically below 20-25 feet per second. At the exit end, the fish travel through the water to approximately 2 fish lengths within which they regain full control and start swimming post transport. It is recommended that the fish exit into water that is a minimum of 3 feet in depth, and that there are no obstacles in the water within 6-8 feet of the re-entry point. It is anticipated that these requirements will be readily achieved at the sites being considered.

Ancillary components include several control cabinets, the air temperature control and blower components, and communications for remote monitoring. The transport tubes are typically routed using tensioned cables, hangers/carriers and towers.

Power and pumped or gravity fed water supply of 25-50cfs for the ladder will need to be provided externally by the other project implementors (i.e., Tribe, dam owner/operator). An assumption is being made that the 25-50cfs ladder flows will provide sufficient attraction to the passage structures as contemplated because this is consistent with the Chief Joseph Hatchery ladder which is very successful at attracting Chinook. More detailed design and calculation may be needed in this area for whatever passage technology is ultimately installed, and is outside the scope of this document. Note that this pumped water requirement is somewhat independent of a Whooshh implementation – if the fish are to be traditionally trapped and transported past the dams, a similar configuration will likely be needed.

A smaller quantity of water is required for lubrication of the transport tubes (50gpm, approx. 6.5 cfm or 0.1cfs) and will also need to be provided by the other project implementers (Tribe, dam owner/operators).. This water will need to conform to sediment load specifications and must be pre-filtered to 5 micron maximum particle size.

Error! Reference source not found. summarizes the anticipated functional elements of the preliminary proposed major design features for this concept.

Table 2. Summary of anticipated fish passage system functional elements

Project Element	Function and Intent
Water pumps or gravity fed water supply	Provides water to ladder (approx. 25-50 cfs) and steep pass and false weir (approx. 10 cfs), also serves to provide lubrication water for tubes (approx 0.1 cfs)
Entry ladder, vertical slot or similar	Serves to absorb tailrace fluctuations and flows, providing fish access to Whooshh Passage Portal
Entrance designed for adult salmonids	Steeppass fishway from top ladder gallery to flowbox and false weir entry to Whooshh Passage Portal (WPP)
Flow box	Integrates additional flow required for steeppass with smaller volume of water coming over false weir.
False weir	Provides means to isolate and partially dewater fish prior to transport
Scanning system	“FishL Recognition System” used to image each fish and provide size, species and other information to WPP. A pictoral record along with timestamp, sizing data and disposition (transport or return to tailrace) is logged for every individual fish and can be used for reporting purposes.

Project Element	Function and Intent
PIT tag reader	A third party PIT tag reader (Biomark) will need to be integrated into the system and positioned either immediately prior to or after the scanning system. Positioning will depend on optimal location to provide reliable tag reads with a minimum of electrical interference from other parts of the system.
Sorting system	Directs fish to appropriate transport lane or back to river depending on scanner data, PIT tag data and installation settings. Any fish that is of inappropriate size to safely transport through the tube sizes as installed will be returned to the tailrace. In addition, those fish not of the target species, or with out of range/incorrect PIT tag values will also be returned to the tailrace.
Auxiliary bypass	An additional sorting lane will be provided to a holding tank located adjacent to the sorting system. Based on daily settings, this will permit programmable selection of fish for additional trap and haul operations.
Accelerator system	Function as an “airlock” to introduce fish to be transported into the transport tube. Accelerators are arranged in modular increments supporting up to 3 lanes per subassembly. Up to six can be supported in a single installation. Sensors ensure doors operate ahead of the fish allowing for an uninterrupted slide through the accelerator system.
Whooshh fish transport tubes	Migrator tubes which convey fish to distal exit. Supported on stands or overhead cabling and covered with environmental shroud
Support and control skids	Modular equipment frames for blowers, chillers/heaters (as required), support equipment and control systems.
Booster subsystem	For distances over 300m, a continuous flow (no stopping) device to allow for supplemental air to be introduced into the tube to compensate for distance - associated losses travelling through the system and to maintain/control fish velocity.
Over road structure	Elevate section of tube(s) to maintain vehicular access to powerhouses, spillway roads etcetera
Floating exit to accommodate forebay fluctuation and allow for safe transition from Migrator tube to the forebay	Ensures fish exit the transport tube safely to the forebay surface at a desired location, angle and depth. Accommodates forebay fluctuation anticipated to occur during the period of migration.
Support cables, optional booms	Depending on precise configuration, bathymetry and anchoring locations, the over water tube routing to floating exits will need to be designed. This may use any combination of floating booms, cable anchors and tensioning mechanisms.

Project Element	Function and Intent
Optional supplemental buildings and structures.	1. At the base of the system the steeppass could be routed through the wall of an appropriately sized building or shed built on or around the equipment pad to provide weather protection and security for the equipment. 2. Smaller housing structure for Booster subsystem if required (20ft by 10 ft typical) for up to 6 lanes. Note. A minimum amount of environmental protection will be needed. In absence of more permanent buildings, shade from direct sunlight is required. Similarly some provision may be needed for snow protection.
Optional considerations for winter operations (if needed)	For operation during months when outside temperatures could be below freezing, additional heating will need to be provided for the building(s) to keep the interiors and equipment above freezing, and the transport tube should be manufactured with optional heat tape addition that will be used to prevent localized freezing of the misters. Note that when the system is not actively transporting fish, water drains by gravity from the tube subsystem, so there is not a significant accumulation when quiescent, reducing likelihood of frost damage.

7. Key Installation requirements and structures

Main Equipment pad

The equipment for each system weighs approximately 2000lbs, is housed on 5 modular skids that occupy a total 20ft by 30ft footprint. Each skid needs to be craned into position onto a suitable pad. The false weir and “flow box” skid serves to connect and channel water to the steeppass. The false weir is typically located approximately 5 feet above the pad surface. The height of the equipment pad relative to the ladder top pool or gallery water surface will dictate the length of steeppass required. The “accelerator skid” contains sorting chutes and the accelerators, and the remaining skids house the scanner, propulsion system, controls and ancillary equipment. Equipment skid examples are shown in Fig.1.

Fig.1. Control skid and blower skid

Booster equipment pad

The booster equipment consists of a single skid that will fit on a 10x20ft pad and weighs approximately 1000lbs. Water, power and communications connections to the booster equipment will be made from the main equipment skids.

Tube hanging on land

The fish transport tube subassemblies will be attached to tensioned support cables which in turn are attached to support anchors. These anchors will be positioned along the land route chosen consistent with slope and clearance constraints. A temporary support stand is shown in Fig.2. Environmental housings can be provided for tubes as illustrated in Fig.3

Fig 2. Simple temporary support stand for over land tube section

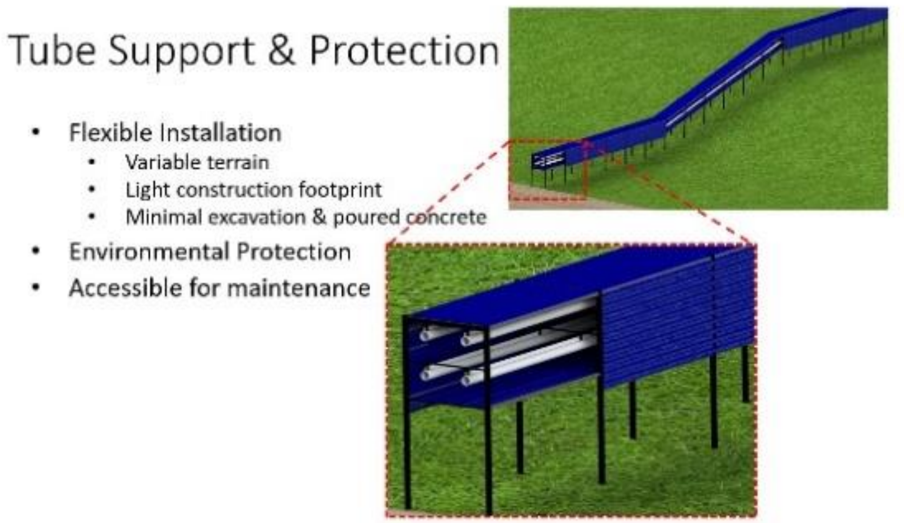


Fig 3. Environmental housing concept

Tube hanging over road

At road crossings, a simple fish transport tube support gantry bridge can be constructed to maintain existing vehicular access to power houses and spillways. Precise height and width will be tailored to suit site requirements. Longer spans can be implemented with towers and tensioned cables. An illustration of a temporary road crossing structure is provided in Fig.4..

Fig.4. Simple over road tube hanging structure.

Tube hanging over water

The tube(s) will be suspended over water by a free span of tensioned support cable(s) as shown in Fig.5. Fig 6. shows the same installation at low water. Depending on the length of the overwater section, the deployment may benefit from integration of additional floating booms. These can be used to distribute anchor loads, assist with tube profile at different water stages, and reduce total cable tension required. Precise installation recommendations will be provided at a later stage once the bathymetry, geology and other constraints of the sites are understood. That is outside the scope of this current document.

Fig 5. Over water tube routing, high water

Fig.6. Over water tube routing, low water.

Fish exit.

Due to the variable stage height of the Grand Coulee forebay during the operating months, the fish exit will need to be on a floating structure. To allow for safe fish re-entry into forebay, the transport tube ends are redirected to ensure that fish enter the water at a 30 degree angle as close to the water surface as practicable on the upstream side of the floating structure. Fish typically are travelling at less than 25 feet/sec when they reenter the water. An example of such a floating structure is provided in Fig.7.

Fig 7. Fish exit barge configured for single lane.

Communications

A 10MBit/10MBit internet linkage is required to facilitate remote monitoring and daily fish passage reporting.

Power requirements

Power is required to operate the blowers, control cabinets, air chiller and compressor subassemblies. Power may also be required for the steeppass if the water is pumped rather than gravity fed. Pumps for the ladder may consume up to 350kW. The steeppass consumes 75 kW. Depending on water supply source these numbers should be added as appropriate to the numbers below. It is highly advantageous from a power consumption perspective to gravity feed the ladder and steeppass if at all possible.

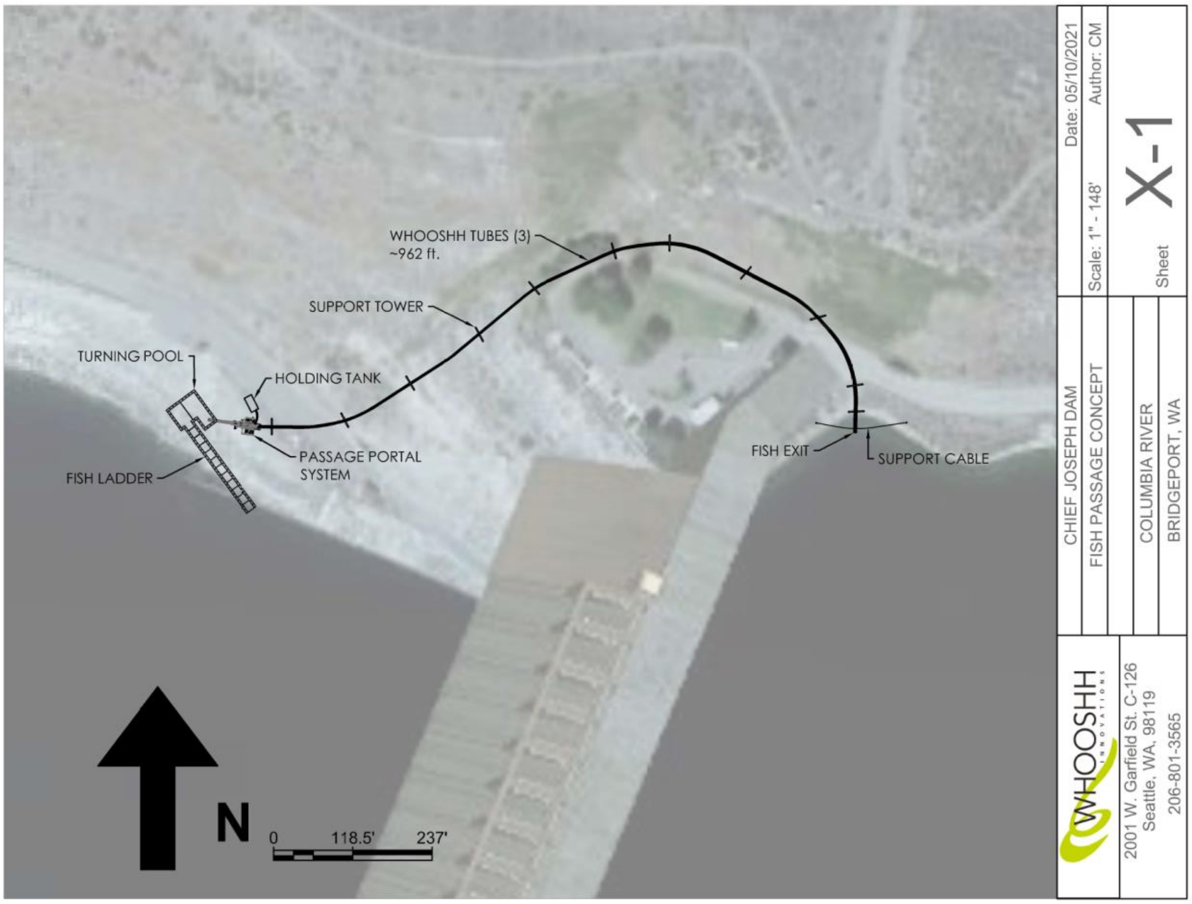
- Voltage 480V 3 phase
- Maximum power draw: 50kW excluding steeppass and ladder. This occurs under conditions of hot temperatures and maximum fish throughput of ~15 fish per minute.
- Quiescent (idle, no fish being transported) consumption: 15kW during inclement weather (air chiller or heaters in operation), 1kW otherwise. Steeppass and ladder not included.

Note: Particularly for smaller runs and seasonal migration, the quiescent values are the typical values for power consumption, as a power draw increases only during the brief periods that fish are being actively transported.

8. Installation specific considerations

The following show conceptual routing at each of the locations suggested by the Fish Passage and Reintroduction Phase 1 report submitted by the UCUT to the NWPCC in May of 2019. Following the routing diagram is a list of the functional elements required for the passage system contemplated. *Note that position and orientation of entrance ladders in this section 8., are provided for illustration purposes only and are subject to refinement/modification after more detailed flow and fish behavioral analysis.*

8.1. Chief Joseph, River Right



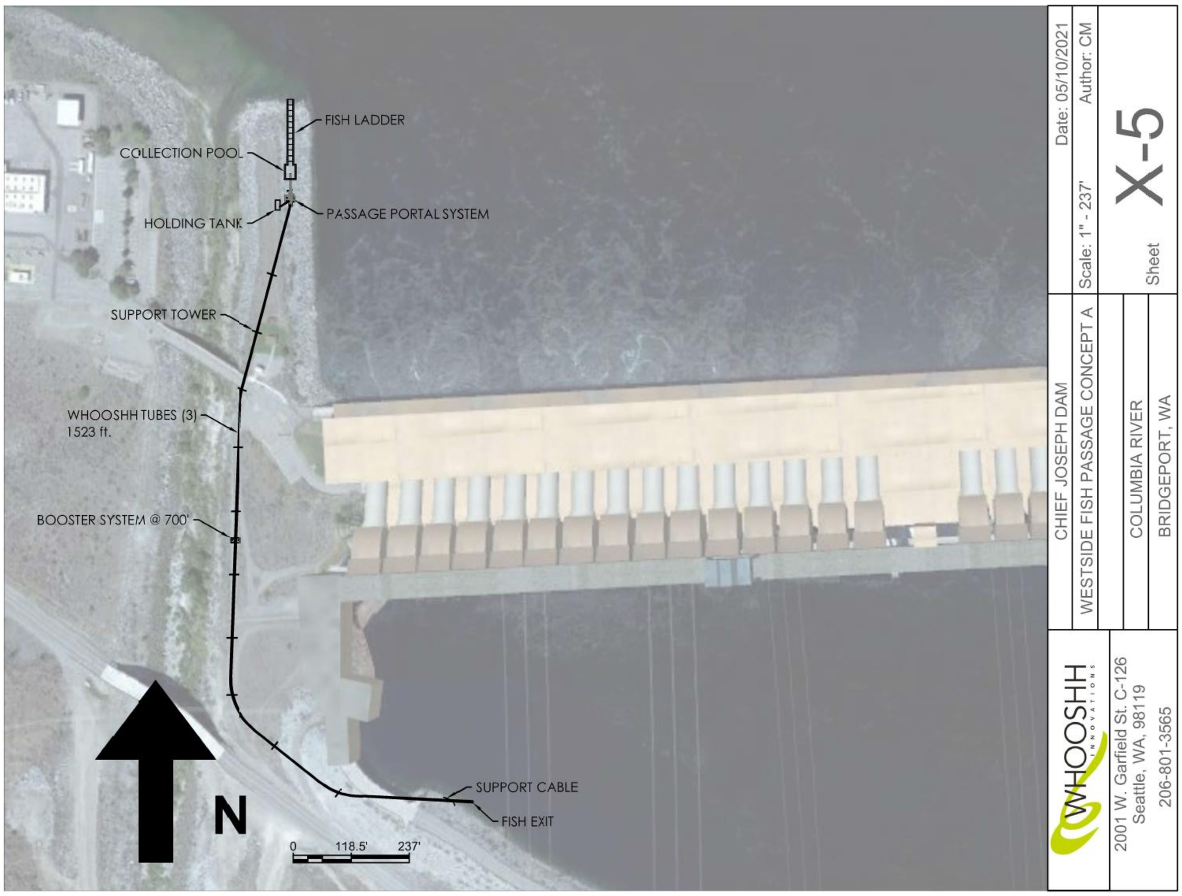
Required elements:

- Entrance ladder to absorb tailrace fluctuations.
- Passage Portal consisting of steeppass, flowbox/false weir, scan, sort and accelerator components and support skids on pad.
- Optional side collection/holding tank for fish auto-selected for trap and haul or other operations.
- Environmental protection (building or tent – not shown)
- Tube (3) routing over road, up hillside, around parking structure, and over spillway crest access road. Total length required 962ft approx.
- Towers to support over road sections and additional stands or hangers to route tube up hill and around parking lot.
- Shore based anchoring for tube exits, suspended nominally at 957’ with a small amount of adjustment to provide for a maximum exit to water surface of 6’ at low pool.

8.2. Chief Joseph River Left

Two options are presented for the river left tailrace collector. Prioritization of chosen option should be based on potential ladder attraction flow and observed fish behavior at these locations and is beyond the scope of this current document.

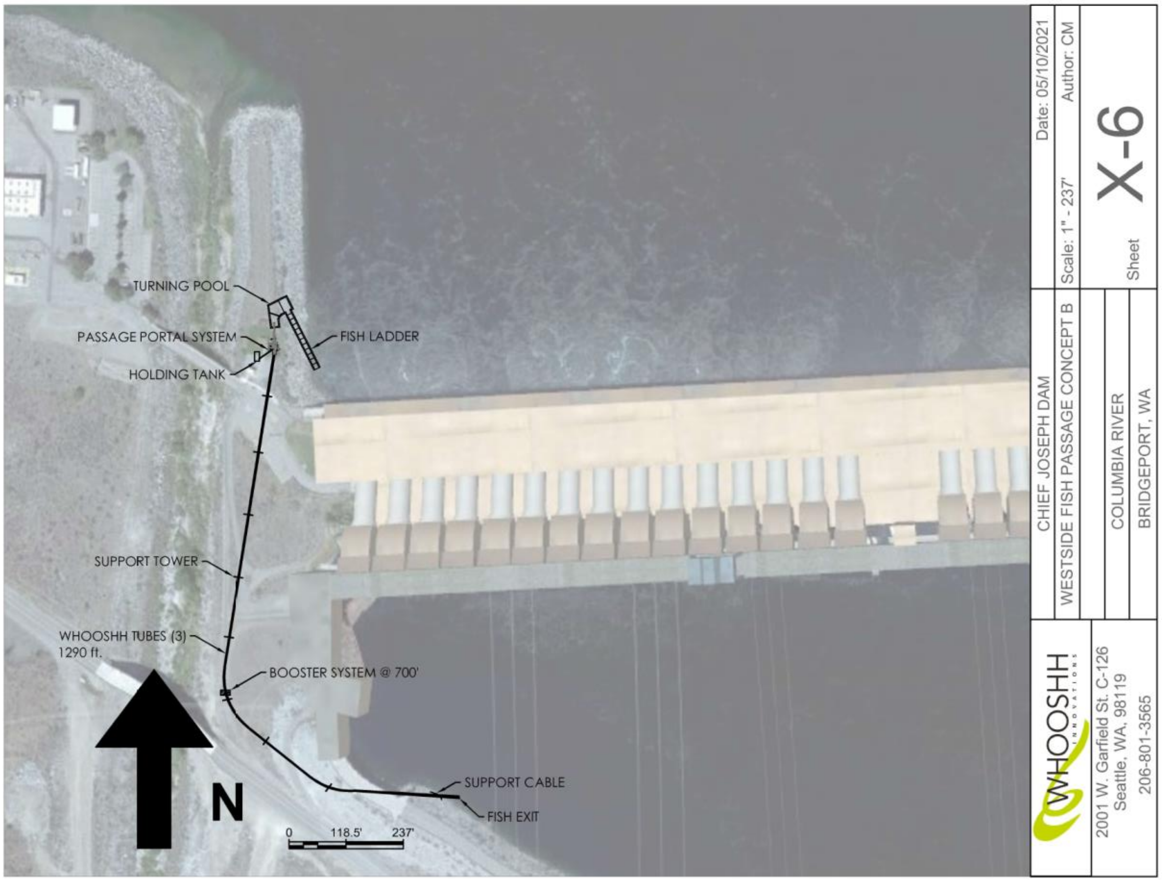
Option A. Mouth of Foster Creek.



Required elements:

- Entrance ladder to absorb tailrace fluctuations.
- Passage Portal consisting of steeppass, flowbox/false weir, scan, sort and accelerator components and support skids on pad.
- Optional side collection/holding tank for fish auto-selected for trap and haul or other operations.
- Environmental protection (building or tent – not shown)
- Tube (3) routing over road (may be possible to go under Foster Creek bridge), up hillside, over power house crest access road. Total length required 1523ft 18pprox..
- Booster components to compensate for losses on longer tubes.
- Towers to support over road sections and additional stands or hangers to route tube up hill.
- Shore based anchoring for tube exits, suspended nominally at 957’ with a small amount of adjustment to provide for a maximum exit to water surface of 6’ at low pool.

Option B. Close to leftmost powerhouse exit

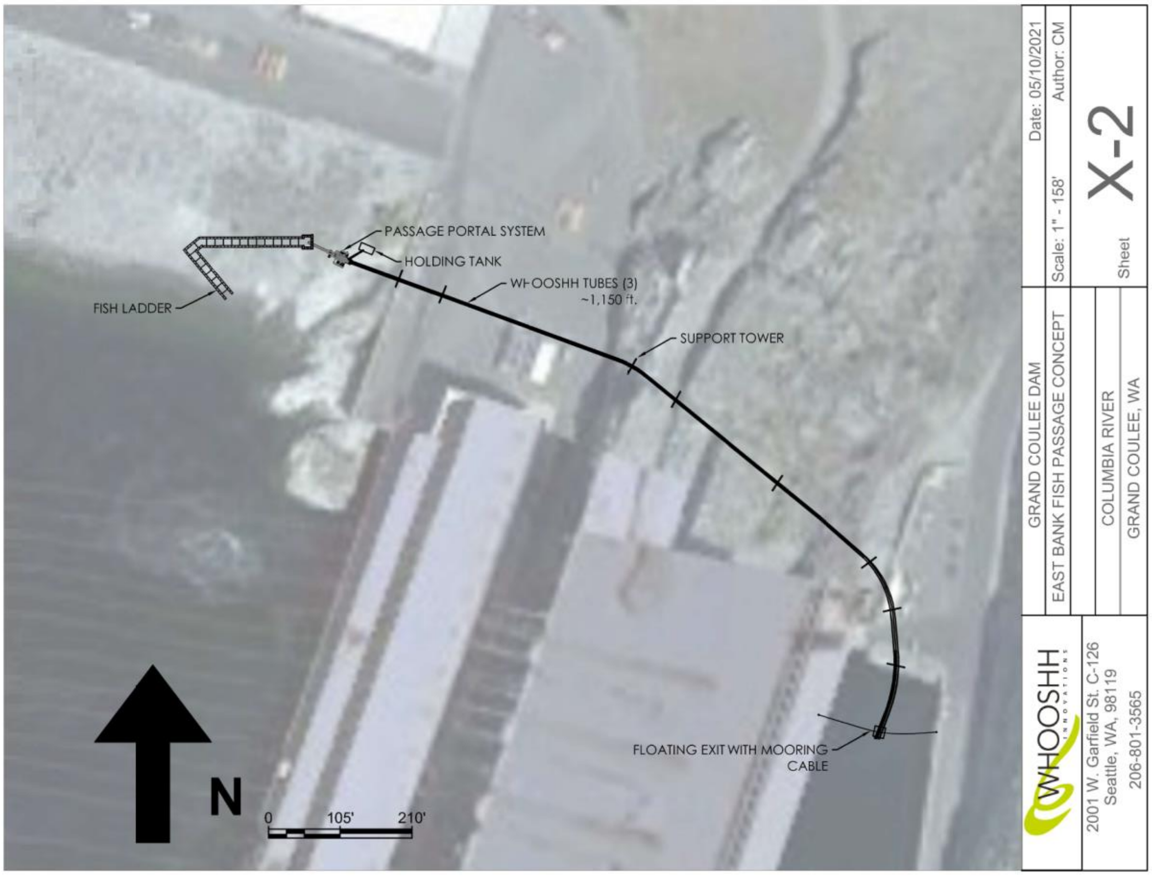


Required elements:

- Entrance ladder to absorb tailrace fluctuations.
- Passage Portal consisting of steeppass, flowbox/false weir, scan, sort and accelerator components and support skids on pad.
- Optional side collection/holding tank for fish auto-selected for trap and haul or other operations.
- Environmental protection (building or tent – not shown)
- Tube (3) routing over road (may be possible to go under Foster Creek bridge), up hillside, over power house crest access road. Total length required 1290ft approx..
- Possible booster components to compensate for losses on longer tubes.
- Towers to support over road sections and additional stands or hangers to route tube up hill.
- Shore based anchoring for tube exits, suspended nominally at 957' with a small amount of adjustment to provide for a maximum exit to water surface of 6' at low pool.

Note. Both illustrations 8.2a and 8.2b provided here for Chief Joseph River Left have not taken into consideration possible presence of a Floating Surface Collector (FSC) and associated juvenile guidance netting in the forebay. In the event that the design needs to accommodate these additional structures, the exit would need to extend upstream of the guidance netting. Booster components would be required for 8.2b. An FSC may also provide an ideal structure for attachment and routing the exit of the transport tubes.

8.3. Grand Coulee River Right

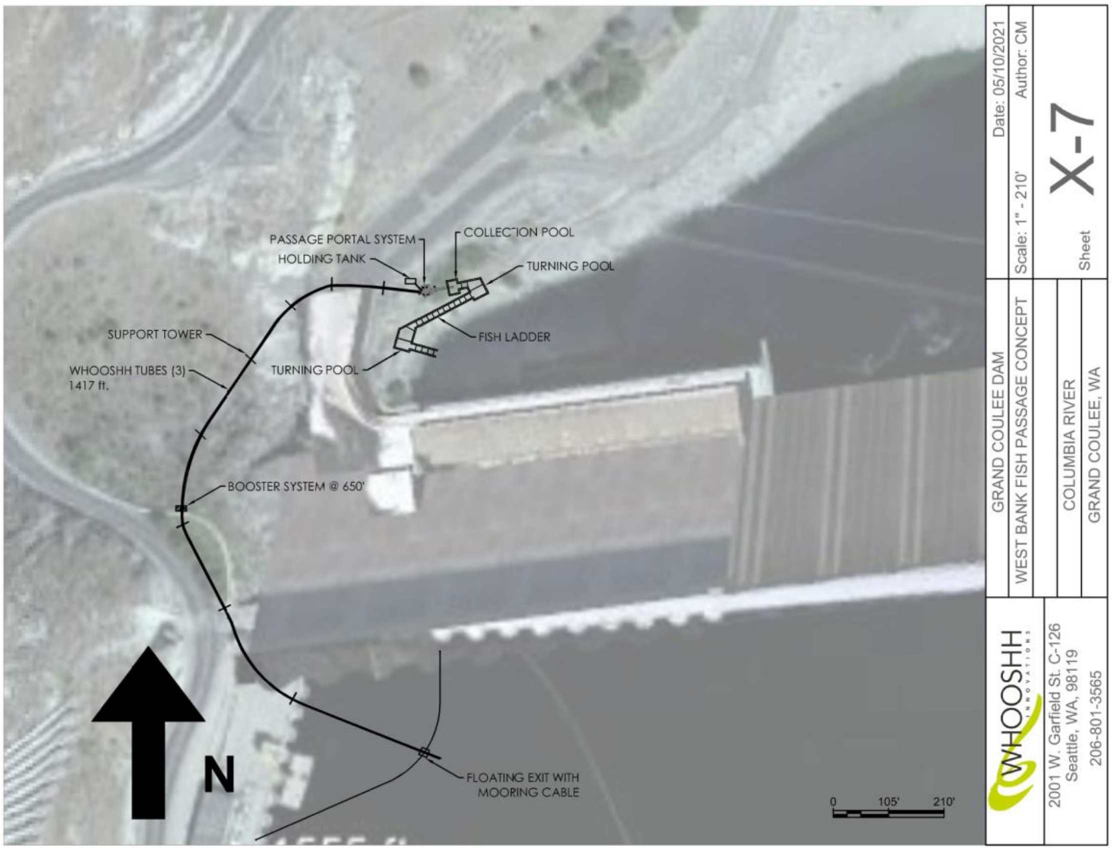


Required elements:

- Entrance ladder to absorb tailrace fluctuations.
- Passage Portal consisting of steeppass, flowbox/false weir, scan, sort and accelerator components and support skids on pad.
- Optional side collection/holding tank for fish auto-selected for trap and haul or other operations.
- Environmental protection (building or tent – not shown)
- Tube (3) routing over powerhouse access road/staging area, up hillside, over power house crest access road. Total length required 1150ft approx.
- Possible booster components to compensate for losses on longer tubes.
- Towers to support over road sections and additional stands or hangers to route tube up hill.
- Floating structure to accommodate tube exits. This will provide exit to water surface of approximately 2-3' at all forebay water levels.
- Shore based anchoring for tube exit structure with appropriate (powered?) winches to facilitate pool fluctuations.

Note. Illustration 8.3 here has not taken into consideration possible presence of a Floating Surface Collector (FSC) and associated juvenile guidance netting in the forebay. In the event that the design needs to accommodate these additional structures, the exit would need to extend upstream of the guidance netting. If the FSC could be used as an attachment structure for the tube exits, it would remove the need for additional infrastructure to support a separate floating tube exit.

8.4. Grand Coulee River Left



Required elements:

- Entrance ladder to absorb tailrace fluctuations.
- Passage Portal consisting of steeppass, flowbox/false weir, scan, sort and accelerator components and support skids on pad.
- Optional side collection/holding tank for fish auto-selected for trap and haul or other operations.
- Environmental protection (building or tent – not shown)
- Tube (3) routing over powerhouse access road/staging area, up hillside, over corner of pumphouse parking area and crest access road. Total length required 1417ft approx.
- Booster components to compensate for losses on longer tubes.
- Towers to support over road sections and additional stands or hangers to route tube up hill.
- Floating structure to accommodate tube exits. This will provide exit to water surface of approximately 2-3' at all forebay water levels.
- Shore based anchoring for tube exit structure with appropriate winches to facilitate pool fluctuations.

9. Operational Theory

During normal operation, water will continuously be flowing down the steeppass to the ladder top gallery pool. Water will also be coming over the false weir.

Fish, having ascended the ladder to above flood stage, attracted to the flow from the steeppass, will climb the steeppass and transition through the flowbox. Fish have a natural tendency to singulate, and will clear the false weir individually. After dewatering at the top of the false weir, they go through the scanner on a wetted gravity slide. As they enter the scanner, the control system activates the accelerator and tube misting and the propulsion blowers. Fig.8. Shows multiple sockeye in the flowbox singulating over the false weir.

Fig.8. Sockeye singulating over false weir.

The scanner images and sizes each fish, and provides data to the control system. Fish images and scanned data are automatically recorded with assigned sequential file names and time/date of imaging captured. An example of scan processing is provided in Fig.9, and of a scanned sockeye in Fig10.

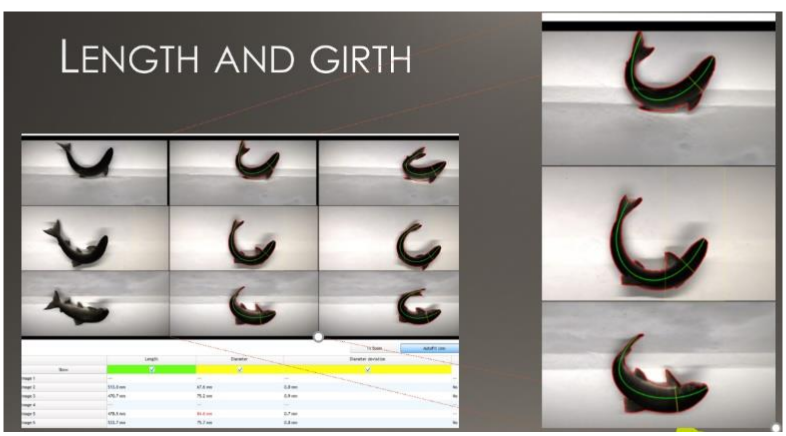


Fig.9 Scanning system measurement

Fig.10 Wild chinook imaged by scanner

The control system confirms all systems are on and working correctly, and then using the scan information directs the fish via sorting gates to the appropriate accelerator, or to the bypass which returns the fish to the tailrace (or ladder depending on specific configuration). The main bypass route is the default route, so fish are only nominated for transport when the scanning system is able to provide valid scanned size, species and hatchery/wild data. Any fish not scanned will therefore also be bypassed and returned downstream of the Passage Portal entrance. This failsafe arrangement guards against the rare circumstance that more than one fish enters over the false weir at the same time.

The control system is also capable of integrating other external input into the decision making, including PIT tag values read in real time that fall within a predefined range, provided a suitable reader is integrated into the decision array.

An optional side sampling chute is also available, that can be locally programmed to deliver specific numbers and/or selected species to a suitably located holding tank next to the scanning and sorting system (see site specific illustrations). Fish directed to these tanks can be used for additional workup or auxiliary trap and haul operations.

Having entered the accelerator, the fish selected for transport in that lane continues its gravity slide to the mouth of the transport tube. The accelerator acts as an air lock and facilitates the introduction of the blower stream behind the fish providing the motive force for transport.

The entire sequence from false weir to tube entry takes typically 2-3 seconds.

10. Anticipated Performance

Based on the data provided, it is anticipated that each tube will be able to accommodate a fish every 4-5 seconds. Throughput will be regulated by the control system to a maximum of 5 fish per tube section simultaneously. Transit time for each individual fish will be of the order of 45-60 seconds for the longer tube runs at Grand Coulee and as little as 25 seconds on the shorter lengths required at Chief Joseph. Note that the fish is always travelling with a bolus of water, so this is not equivalent physiologically to that period in free air.

Additional capacity can be provided by the system infrastructure as designed by augmenting blower and sorting capacity to support additional accelerator/tube subsystems up to a total of six lanes. At this time the maximum theoretical capacity of each system with multiple tubes installed is approximately 30 fish per minute. This translates to a maximum of 1800 fish per hour, or in the region of 20,000 fish per day during average daylight hours per system.

Peak daily numbers at Rocky Reach in the last 10 years are about 30,000 fish for both ladders during peak sockeye migration. So for the foreseeable future as the reintroduction program proceeds, 30 fish per minute per system (so 60 at each dam) should provide ample passage capacity for the expected populations.

11. Deployment Construction Sequence and Duration

Deployment construction should be completed in four stages. Note these estimates are purely for the deployment construction activity and do not include any time for fabrication, manufacturing or procurement of long lead items, or transit from Seattle to the site in question. In addition, there is a detailed design activity and permitting that will be required prior to any deployment.

1. First would be site preparation, staging, performing any needed excavation/fill work for main structures.

   Estimate: 3-4 weeks

2. Next the supporting infrastructure should be installed. This would include equipment pads, over road structures, support stands/towers, floating exits, any booms required and over water anchoring. Also completed at this stage should be any power provisioning or gravity fed water piping required. It may be advantageous to schedule this months in advance of step 3, to leverage optimal site construction and flow conditions.

   Estimate:3-4 weeks

3. Whooshh equipment and tube hanging takes place after site preparation is complete.

   Estimate 1-2 weeks

4. Commissioning and testing. Should be conducted in suitable time before anticipated fish arrival

   Estimate 1-2 weeks

If housing structures are required for the Whooshh equipment, these could be assembled after Phase 2. or potentially after Phase 4. A tradeoff exists between construction complexity and installation efficiency; the former makes craning components into position easy, the latter requires larger access doors and additional equipment such as forklifts to install the subsystems.

12. Summary of Costs

Order of magnitude construction, and operations & maintenance costs were evaluated for implementation of the proposed technology at the theoretical sites as described herein. The costs developed for this document are based upon limited information generated as part of concept alternative development and should be considered to be for comparative purposes only.

In general, costs presented below are rounded and are designed to be conservative (i.e. high). Should this alternative be selected for further consideration, more accurate cost information can be updated as the design development of the alternative progresses. All costs are presented in 2021 USD.

Since this project is contemplated as only interim, it is assumed that Whooshh will remove the equipment at the end of the project for return to Seattle. In the event that a more permanent installation is required at any or all of the four locations contemplated, it should be possible to redeploy many of these components to reduce the costs of a more permanent design.

Lifecycle costs amortized over the expected life of the project were not calculated as part of this document.

Opinion of Probable Construction Cost

An order of magnitude Opinion of Probable Construction Cost (OPCC) was developed for purposes of comparing the potential cost for this concept against other alternatives. Cost data generated as part this OPCC is based upon bids and actual costs for other projects similar in nature, available vendor cost data, and professional judgment.
The anticipated base line cost value for this project is estimated as follows.

	One time Equipment and construction costs			**Annual O&M**	
Location	Whooshh Passage Portal equipment (+/-5%). Assumes 5 yr lease.	Site construction (+/- 25%)	Total	Diesel power for ladder pumps (annual)*	Whooshh Services
1. Chief Joseph Right bank	$4,000,000	$2,600,000	$5.75-7.45M	$320,000	$62,500
2. A) Chief Joseph Left Bank, Foster Creek	$4,500,000	$2,700,000	$6.3-8.1M	$320,000	$62,500
2. B) Chief Joseph Left Bank, tailrace	4,400,000	$2,700,000	$6.21-$7.99M	$320,000	$62,500
3. Grand Coulee right bank	4,800,000	$2,900,000	$6.74-$8.67M	$320,000	$62,500
4. Grand Coulee left bank	5,100,000	$3,000,000	$7.1-9.2M	$320,000	$62,500
Total			$25.8M-$33.3M	$1.6M per season	$250,000 per season

* assumes four months of continuous ladder operation per year

Passage Portal numbers include Whooshh supplied equipment and structures for tube routing assuming a 5 year active project span.

Site construction numbers are based on preliminary estimates from partners for similar projects, and includes design, installation of ladder, an allowance for tube support hardware installation, provision of pumps and site restoration post deployment.

For the purposes of this cost assessment, it is assumed that construction would begin in 2023 and would occur over a one year construction period with construction and installation work conducted on-site during the approved in-water work windows.
Implementation of the Whooshh concept at the project will also require permitting, construction management, and commissioning of various civil, structural, piping, hydraulic, and electrical improvements. These are outside the scope of this document.

Taxes imposed by local agencies or governments are not included as part of the OPCC and should be added onto the total OPCC provided.

Operation and Maintenance Costs

Operation and maintenance costs include those reoccurring or one-time costs that are incurred over the life of the project.

Operational costs are costs associated with items such as staffing required to keep the facilities functioning, power costs, any required debris cleaning, and periodic inspection.

Maintenance costs are the costs associated with keeping system components functioning and actions that allow system components to achieve their optimal useful life, such as painting, lubrication of moving parts, repair of damage, replacement of broken or non-functional parts, updating electronic components, and improving PLC programming. Expendables as well as equipment and electrical power costs are incorporated to the extent possible given the level of detail formulated as part of preliminary alternative development. An allowance has also been made for evaluation and data analysis of passage data and reporting.

Estimates of annual operating and maintenance costs are anticipated to be on the order of an additional $250,000 per year total for the four sites, inclusive of all labor, materials, expendables, and electrical costs assuming a local supply source at currently prevailing rates (not including costs to pump water for the ladder).

No attempt has been made to estimate additional expertise required such as fisheries biologists to adaptively manage the re-introduction effort, which would be identical for any passage solution.

Pumped water for ladder costs.

Estimated costs are presented here for diesel generation of power for the submerged screened pumps that supply the ladders. Note each site would require its own power supply, and so these costs could therefore be potentially X4. It should also be noted that these ladder operational costs will be similar for other fish transport solutions at these sites.

Auxilliary power (includes rental of diesel generator with backup, and fuel supply).
$80,000 per month per location.

13. Discussion of Tradeoffs

This alternative exhibits the following advantages:

- Results from prior deployments indicate that injury and stress to fish is equal to or less than that of other conventional, upstream passage technologies including trap and haul;
- Provides more timely passage than traditional trap and transport methods as fish are passed as they enter the system (no passage delay);
- Reduces effort and time for fish to ascend a ladder. Some studies have shown ladders contribute significant delays to passage.
- Can more easily accommodate the full range of tailwater and reservoir fluctuations than other technologies; long downhill gravity slides from dam crest to forebay with other technologies like ladders can be stressful for migrating fish
- Eliminates fish transport by truck and reduces the anticipated level of effort and expense of driving fish to or around the reservoir and maintaining vehicular access at low pool
- Requires equivalent or less construction than a trap and transport facility for equivalent volumes of fish.
- Subsequent system expansion for species and capacity does not change operating costs significantly unlike trap and haul
- Considerably reduces water pumping required for a purely ladder-based solution and is roughly equivalent to that would be required for a trap and transport facility.
- Anticipated to have a lower capital cost than fish ladders and similar capital cost to a trap and transport facility;
- Entrance and exit could be modified as needed to operate under a number of future conditions and different release locations and operating stage heights;
- Requires significantly less earthwork and potential dam modification than that of other alternatives such as a fish ladder;
- Operation and maintenance effort is anticipated to be less than other alternatives
- A permanent electronic record of passage and characteristics for each individual fish is captured, unlike trap and haul or ladder solutions.

This alternative exhibits the following disadvantages:

- Potential for mechanical failure or power loss could interrupt fish passage until repaired;[same as trap and transport, and any ladder solution that requires pumps]
- In case of mechanical failure, trap and haul options will need to be developed as temporary backup, although these backup operations will still need to attract and remove fish from the river.
- Anchorage for floating platforms can increase construction complexity for this solution only

References:

1. T.J.Koch, S.C.Evans, A.C.Hansen et al. (2017). Evaluation of Sockeye Salmon after Passage through an Innovative Upstream Fish-Passage System at Cle Elum Dam. USGS Open File Report, 2017-1116

2. Columbia River Research DART tool. http://www.cbr.washington.edu/dart

3. D.R. Geist, A.H. Colotelo, T.J. Linley, K.A. Wagner, A.L. (2016). Effects of a Novel Fish Transport System on the Health of Adult Fall Chinook Salmon. *Journal of Fish and Wildlife Management* (2016) 7 (2): 347–358.**https://doi.org/10.3996/102015-JFWM-108**

4. L. Garavelli, T. J. Linley, B. J. Bellgraph, B. M. Rhode, J. M. Janak, A. H. Colotelo (2018) Evaluation of passage and sorting of adult Pacific salmonids through a novel fish passage technology. Fisheries Research 212 (2019) 40-47. https://doi.org/10.1016/j.fishres.2018.12.010

Appendix F: Total Dissolved Gas Levels in the Blocked Area

Assessment of Total Dissolved Gas in response to the ISAB review of the Phase 1 Report on the reintroduction of salmon upstream of Chief Joseph and Grand Coulee dams.

The Independent Scientific Advisory Board (ISAB) reviewed the Phase 1 report and suggested that additional analyses should occur on water quality parameters in the blocked area. They referred to some cursory data regarding Total Dissolved Gas (TDG) levels near the border of Canada, at Grand Coulee Dam (GCD) and in Lake Rufus Woods and questioned whether or not TDG might be a limiting factor for rearing or outmigrating salmon. To address this issue, we accessed data readily available on the Data Access in Real Time (DART) website (http://www.cbr.washington.edu/dart) and conducted some preliminary analyses to summarize the issue. There are several factors that make the assessment of TDG and its potential effects on fish problematic. First, every fish will experience a different TDG exposure profile (combination of maximum and average TDG levels over time) because of differences in hatchery release points, natural production areas, outmigration timing and outmigration depth. Second, the effects of TDG are dependent upon intensity and duration of exposure, so chronic exposure to moderately high TDG may be as bad as short-term exposure to high TDG. Finally, we only have measurements of TDG in a few locations and it is unclear how those measurements relate to what the fish actually experience.

Regardless of the uncertainties around all those caveats, we took a closer look at what we do know about the TDG levels within the blocked area and compared those to a couple of locations downstream.

We know that Lake Roosevelt and Lake Rufus Woods have healthy populations of resident fish, so in general the TDG levels in those reservoirs must not be catastrophic. But that does not mean that TDG will not affect salmon survival in some years or in some locations during certain years. TDG tends to be highest in high flow years (Figure 1), so we wanted to assess what is known about TDG under an average flow year and a high flow year. To select the right years for assessment, we looked at inflow at GCD. 2018 had the highest peak inflow at GCD (331 kcfs) since 1997 and was the second highest since 1972. We selected 2013 for the average flow year, based on its similarity to the 10-year average hydrograph (Figure 2).

Due to the uncertainties mentioned above, we looked at both maximum TDG and the duration of exposure to high (>125%) TDG. The DART website was queried for maximum daily TDG in each respective year and results summarized across the months. Next, we summed the number of days each month when the maximum TDG level exceeded 125%. We did this for four locations in the blocked area (Boundary, GCD forebay, GCD tailrace, Chief Joseph Dam (CJD) forebay) and four locations in the extant anadromous zone (CJD tailrace, Wanapum Dam tailrace, Priest Rapids Dam tailrace, and the Dalles Dam tailrace).

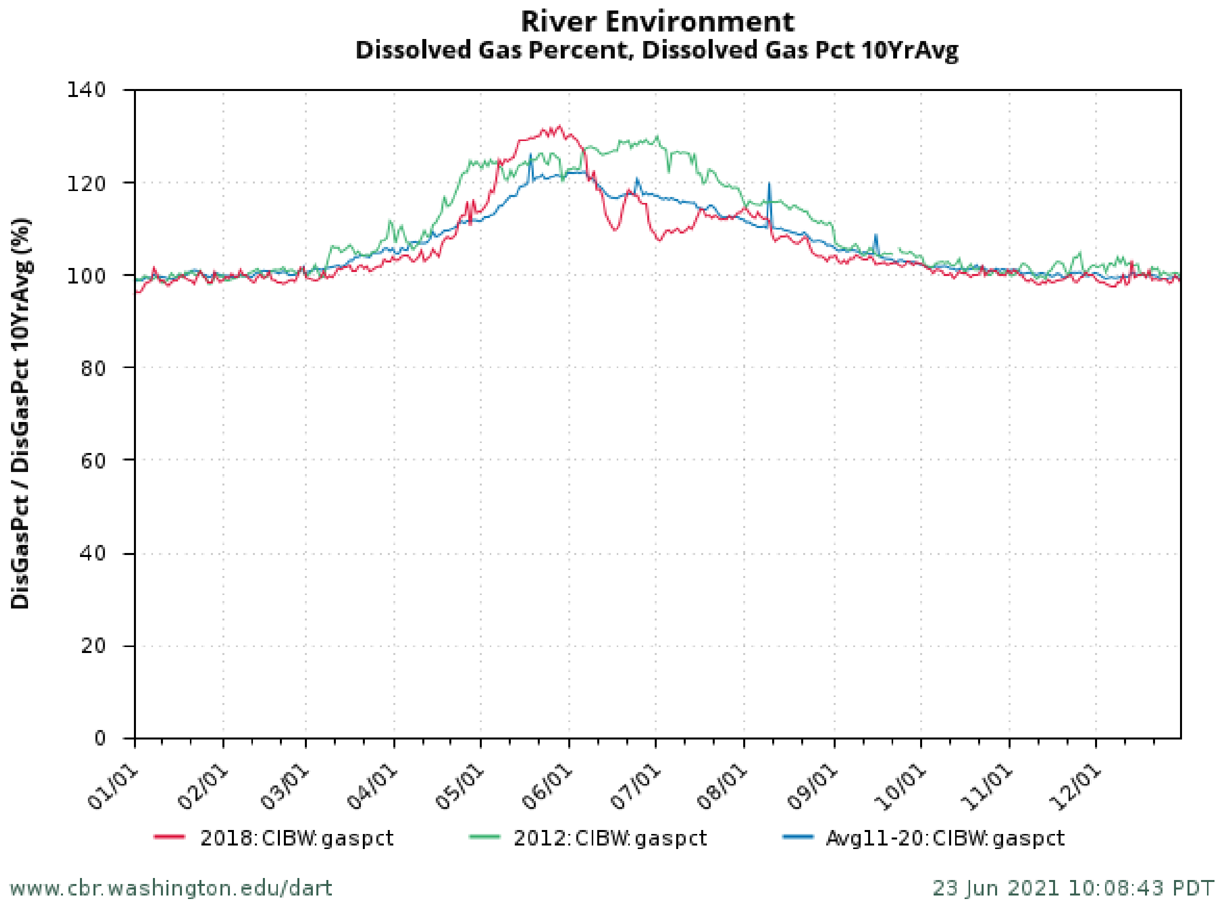
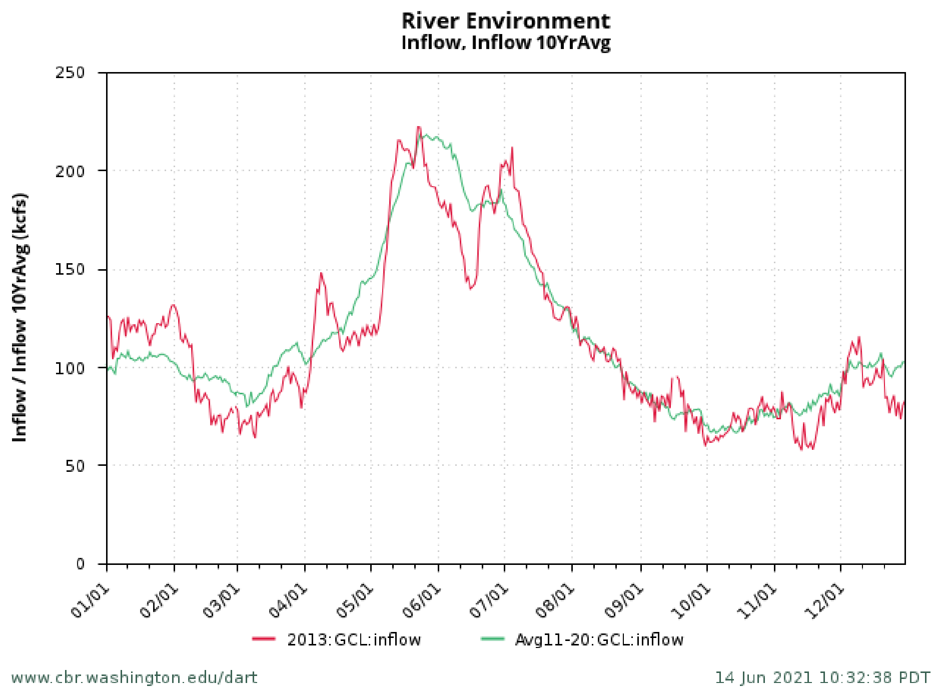


Figure 1. Total dissolved gas at the Boundary monitoring station (CIBW), at the upstream end of Lake Roosevelt near the border with Canada in the two highest flow years (2012, 2018) since 1997, compared to the 10-year average from 2011-2020.

a)



b)

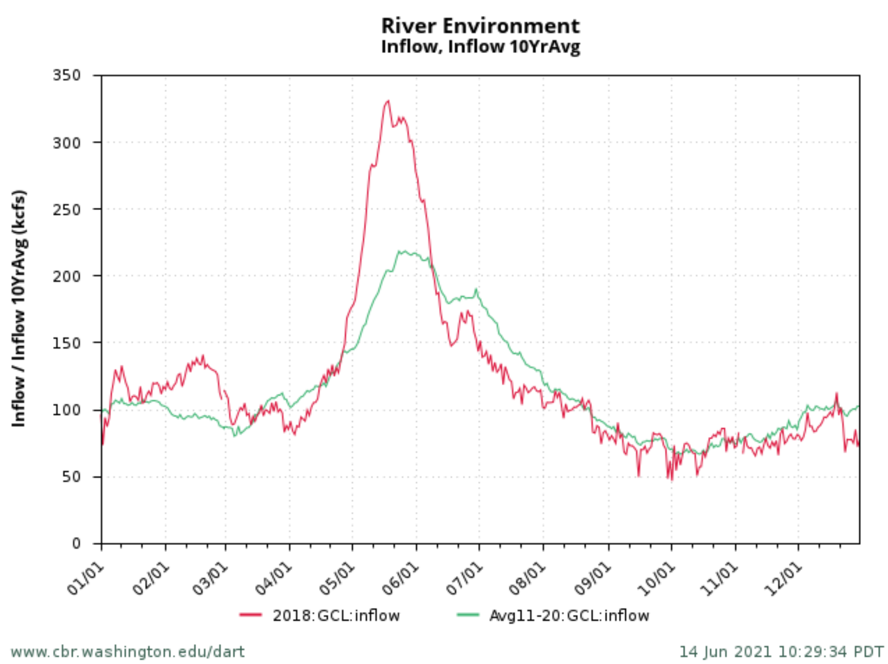


Figure 2. Inflow at Grand Coulee Dam as an indicator of average flow (2013, panel a) and high flow (2018, panel b) years, compared to the 10-year average (2011-2020).

Average Flow Year Results

In 2013, with average flows the Boundary monitoring station exceeded 125% TDG during May (10 days) and September (1 day) (Tables 1 and 2). None of the other monitoring stations exceeded 125% TDG (Table 1). Total Dissolved Gas did not exceed 120% at any of the Grand Coulee or Chief Joseph monitoring sites, whereas it did exceed 120% at both Wanapum and Priest Rapids dams (Table 1). In general, daily maximums over 115% from April to August were more common in the extant area downstream of CJD than they were in the blocked area.

Table 1. Maximum daily TDG value each month in 2013, an average flow year. Data taken from DART website. Yellow highlights indicate values between 115-119%, orange highlights = 120-125% and red highlights > 125%.

Month of 2013	Boundary	GCD Forebay	GCD tailrace	CJD forebay	CJD tailrace	WAN tailrace	PRD tailrace	The Dalles tailrace
1	105	99	98			100	104	100
2	101	101	100			101	102	102
3	100		103	103	104	105	104	105
4	110	106	104	106	110	115	117	118
5	126	114	110	111	111	118	119	119
6	123	117	114	115	114	120	121	118
7	122	115	114	114	113	120	121	118
8	109	114	110	111	112	115	115	115
9	147	105	104	106	106	106	107	107
10	104	100	99	99		100	102	101
11	104	99	98			99	102	101
12	101	97	96			97	98	99

Table 2. Number of days each month in 2013, an average flow year, when TDG is greater than 125%, data taken from DART website.

Month of 2013	Boundary	GCD Forebay	GCD tailrace	CJD forebay	CJD tailrace	WAN tailrace	PRD tailrace	The Dalles tailrace
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	10	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	1	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0

High Flow Year Results

In 2018, with high flows in the spring, all monitoring station exceeded 125% TDG during 1-2 months except GCD forebay (Table 3). May was the most common month with TDG levels exceeding 125%, Wanapum Dam had the highest maximum TDG (143%), followed by CJD tailrace (138%) and forebay (137%) (Table 3). As for duration, Wanapum had the most days in May that exceeded 125% (23 days), followed by Boundary (20 days) and CJD forebay (17 days) (Table 4). Similar to the average flow years, the stations in the blocked area had fewer months with TDG levels exceeded 115% and 120% than areas downstream of CJD (Table 3).

Table 3. Maximum daily TDG value each month in 2018, a high flow year. Data taken from DART website. Yellow highlights indicate values between 115-119%, orange highlights = 120-125% and red highlights > 125%.

Month of 2018	Boundary	GCD Forebay	GCD tailrace	CJD forebay	CJD tailrace	WAN tailrace	PRD tailrace	The Dalles tailrace
1	102	99	98			99	104	101
2	102	102	101	101	109	112	118	119
3	103	103	102	103	102	105	105	110
4	116	109	113	112	111	122	119	120
5	132	124	138	137	129	143	132	127
6	130	123	121	121	121	128	124	120
7	114	114	114	114	126	116	114	116
8	114	108	107	108	108	114	114	121
9	104	105	105	105	104	103	104	104
10	103	102	100	102	101	107	102	101
11	101	98	98	98		101	105	101
12	103	97	97			105	100	98

Table 4. Number of days each month in 2018, a high flow year, when TDG is greater than 125%, data taken from DART website.

Month of 2018	Boundary	GCD Forebay	GCD tailrace	CJD forebay	CJD tailrace	WAN tailrace	PRD tailrace	The Dalles tailrace
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	20	0	16	17	11	23	16	10
6	7	0	0	0	0	3	0	0
7	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0

Discussion and Conclusions

This evaluation of TDG was meant to provide additional insight regarding the TDG levels in the blocked area and how those compared to areas in the extant anadromous zone during average and high flow years. Rather than just looking at average TDG levels, we thought it was important to look at a high flow year because TDG is higher in a high flow year. Of course, additional analysis on other high flow years, or averaging the high flow years together would provide a more comprehensive evaluation of how bad things might be during the worst years. Those kinds of analyses could easily be conducted in the future if managers determine that a more in depth look at TDG is warranted.

This assessment suggests that TDG levels are generally not a problem during an average (and therefore below average) flow year, except perhaps in the transboundary reach where we should expect TDG levels to exceed 125% for a week or two in May of most years. Unfortunately, without additional monitoring stations we cannot determine how far downstream into Lake Roosevelt the high TDG levels reach. Also, it appears that moderate-to-high TDG levels from April to August are a larger problem in the extant area downstream of CJD than they are in the blocked area.

Based on this information, managers should consider releasing hatchery smolts in March and April to avoid exposure to >125% TDG that is regularly observed at the Boundary station in May. If changes to hydro-operations in Canada occur in the future, then TDG levels should be reassessed.

Appendix G: UCUT Responses to Comments Received for the August 9, 2021 Version of the Phase 2 Implementation Plan

Organization	Comment #	Comment	Response
US Dept of Interior	1	We encourage you, in coordination with the UC BAAF working group, to engage with stakeholders in the Upper Columbia, including irrigation districts and power customers. This communication will foster a common understanding of the plan and provide opportunities to align various interests in a way that promotes the plan's chances of successful implementation	The UCUT has already begun the coordination process with the entities that may be interested or could be affected by reintroduction activities. We agree with the Department that such a coordination effort will increase the program's chance of success. We will work with Federal partners through the UCBAAFWG process to identify appropriate groups for outreach. The UCUT organization and member tribes remain committed to timely and transparent information sharing throughout the duration of Phase 2.
US Dept of Interior	2	We appreciate the plan's effort to design Phase 2 such that its implementation would not affect current or future system operations. There is uncertainty associated with future dam and reservoir operations in the Upper Columbia, however, due to other regional processes, litigation on the Columbia River System, and climate change. Such operational changes could necessitate altering the approach of some steps in the P2IP. Therefore, it would be helpful to consider whether the plan can function only under current operations, or if it can practicably be adapted to a range of possible future operations.	The plan has developed a robust adaptive management plan to address and incorporate new information (e.g., change in dam operations) as it becomes available. However, the plan has a stated goal of not significantly affecting flood control, irrigation, power production and other major dam operations now or into the future. Thus, if these operations are altered the plan, by design, will adapt and continue to function.
US Dept of Interior	3	The level of involvement by our agencies will depend on specific activities affecting federal lands or facilities and their associated purposes. Federal involvement could also include regulatory compliance requirements that may affect timelines, scope, and budget for some	We would greatly appreciate your participation in implementing the plan. We will need the Department's expertise in dam operations and fish passage development to implement the activities identified in the P2IP and achieve our goals.

Organization	Comment #	Comment	Response
		Phase 2 actions. Our agencies will work through the UC BAAF working group to determine whether and how our involvement is needed as the details of implementation develop.	
US Dept of Interior	4	In addition to the technical, biological, and logistical components of the P2IP, a plan for securing regional and national support would help this effort move forward successfully. Our agencies would hope to be engaged in policy discussions concerning the implications of any proposals on our respective missions as part of such conversations.	The UCUT value your participation in the plan and will coordinate with you on all pertinent topics and especially those related to your missions.
NOAA	5	During Phase 2 step 1 (years 1–6) NOAA supports the use of unlisted Chinook salmon and sockeye salmon for reservoir behavior and dam passage studies. However, we welcome further discussion and evaluation of spring-run Chinook salmon and/or steelhead in the blocked area. Expanding these stocks into the blocked areas could improve spatial diversity and abundance metrics and improve the resilience of these species in the Upper Columbia.	We are not looking to use ESA-listed fish for reintroduction efforts, particularly in the studies for Phase 2 so that we can avoid the regulatory burden of ESA, to be responsive to concerns of stakeholders in the blocked area, and to focus our work on healthy and productive stocks that are most likely to be successful. The overall goal of reintroduction is to have healthy and harvestable salmon populations above Grand Coulee Dam and we think the best way to achieve that is by using non-ESA listed stocks. However, UCUT tribes also have a strong conservation ethic and recovering weak stocks to healthy and harvestable levels is consistent with our long-term goals. We look forward to discussing this further with you. In the current plan, we conclude that ESA policy constraints must be resolved prior to using listed spring Chinook or steelhead for reintroduction and testing. Because we have yet to quantify fish

Organization	Comment #	Comment	Response
			passage feasibility and fish survival through dams and reservoirs, we are of the opinion that unlisted stocks should be used to gather needed information. The use of Upper Columbia River steelhead was explored in the Phase 2 Report (pg. 38). Because of disease and genetic concerns, steelhead from extant stocks were not selected for reintroduction. However, one notable exception was proposed. The Phase 2 Report states: *Redband trout (*O. mykiss gairdneri*) from the blocked area have been documented in the anadromous zone and evidence exists that a portion of the resident populations are expressing anadromous life history (McLellan et al. 2021).* The plan calls for identifying, using genetic or marks, any steelhead/Redband trout juveniles captured at interim collection facilities and then transporting them downstream to below Chief Joseph Dam (with approval of regulatory agencies). Returning adults would then be transported and released upstream of the dam(s). Therefore, the plan does call for a limited effort to return blocked area origin *O. mykiss* to the blocked area, if it can be achieved while addressing ESA constraints in the blocked area.
NOAA	6	Juvenile studies in the Phase 2 document primarily use yearlings, but we suggest you	The Plan does call for using subyearling hatchery Sockeye.

Organization	Comment #	Comment	Response
		consider including releases of subyearlings.	Subyearling Chinook present a unique challenge because it is not possible to collect and tag an unbiased sample of the population due to their small size and protracted emigration and many of the emigrants then rear in the reservoir, rather than actively migrating. Likewise, hatchery subyearlings are much larger than natural origin migrants and may not provide a valid surrogate for natural-origin migrants. Despite these challenges, we have added some studies of subyearling Chinook to this version of the P2IP because we agree that it would be helpful to understand survival and behavior of subyearling Chinook, as this is the major juvenile life history of summer Chinook in extant areas. However, because of the difficulty in separating subyearling rearing mortality from migration mortality (Gingerich and Kahler 2020), the primary purpose of the subyearling releases will be to evaluate fish behavior and survival at the dams. Details can now be found in Section 2.5.1.1.
NOAA	7	Similarly, understanding the growth, development, and outmigration timing of juvenile Chinook salmon in the tributaries would provide more information on subyearling growth and migratory behavior. Juvenile sampling could be accomplished using screw trapping or other methods downstream of adult spawning areas or remote site incubators.	We do not believe this information is required for determining the possible success of the reintroduction effort if we are able to get adult to adult recruitment per our proposal for using PBT to estimate adult R/S. Also, much of the summer Chinook production may come from areas that are not conducive to capturing juvenile outmigrants (large river / reservoir production)

Organization	Comment #	Comment	Response
			and was therefore not prioritized for collection in the first edition of the P2IP. While juvenile migration timing from tributaries is interesting and will be informative at the local tributary level, it is the migration timing at the juvenile passage systems that is of most interest for this program. We expect that some Chinook will rear in the reservoirs and migrate as yearlings. However, there are existing juvenile salmonid trapping (rotary screw traps) efforts underway in two of the important tributaries (Sanpoil R. and Tshimikain Ck). The STI and CCT expect these efforts to continue throughout Phase 2 and we will use the information from these efforts to document information about anadromous species. We failed to mention this in the first draft of the P2IP and will add it to the next version. As part of the adaptive management approach, we will consider adding additional juvenile trapping projects in more tributaries (or beach seining in recruitment areas of the reservoirs) if it is determined that the information is needed to support the feasibility evaluation.
NOAA	8	…consideration of the use of Upper Columbia River *Oncorhynchus mykiss* should be explored.	See response to NOAA comment #5
NOAA	9	…genetic comparisons between anadromous steelhead populations below Chief Joseph dam and *O. mykiss* above natural and manmade	We agree with this comment. The P2IP states:

Organization	Comment #	Comment	Response
		barriers could identify any residualized steelhead populations that have persisted above the mainstem dams. These populations can contribute to anadromous populations when passage occurs.	*Redband trout (*O. mykiss gairdneri*) from the blocked area have been documented in the anadromous zone and evidence exists that a portion of the resident populations are expressing an anadromous life history (McLellan et al. 2021).* The plan calls for identifying (using genetics or marks) any steelhead (or Redband) juveniles captured at interim collection facilities and then transporting them downstream to below Chief Joseph Dam (Section 2.9). Returning adults would then be transported and released upstream of the dam(s). As noted in the comment, returning adults may potentially contribute to anadromous populations. Additionally, UCUT is interested in working with NOAA on further investigations on how blocked area origin *O. mykiss* are contributing or could contribute to extant populations of steelhead.
NOAA	10	Routine project operations often route flows through penstocks or regulating outlets. These passage routes are deeper in the water column and can be more difficult to find by juvenile salmon than surface passage routes. It would be useful to have more detailed descriptions of the current structures and operations of dams in the mainstem and tributaries. These descriptions should include the elevations of penstocks, regulating outlets, and spill bays, and routine project operations and special operations, including flood risk management	The information identified in the comment will be collected and organized as part of the three phased fish passage design study outlined in the plan (Section 3, pg 49). The report will be edited to make it clear that such data will be collected. Additionally, the Phase 1 Plan (Fish Passage and Reintroduction Phase 1 Report: Investigations Upstream of Chief Joseph and Grand Coulee Dams) provided substantial information on dam operations, flows, penstock depth, etc. for each project. This information was used to conclude

Organization	Comment #	Comment	Response
		rule curves. The range of expected reservoir elevations during different water years will inform the types of collection systems or operational passage plans that could be employed.	that it was possible to develop safe, timely and effective fish passage at Chief Joseph, Grand Coulee and Spokane River dams.
NOAA	11	NOAA is currently participating in the Upper Columbia Blocked Area Anadromous Fish working group where the UCUT are coordinating this and other issues with the Federal agencies. As specific issues regarding regulatory authorizations and expanding existing hatchery production and facilities emerge, we stand ready to assist the UCUT in engaging with other hatchery programs and fishery co-managers in the basin to address these important issues.	We appreciate your support and will continue coordinating activities and needs as the P2IP is implemented.
NOAA	12	The type, distribution, and amount of habitat above the dams will be integral to the success of reintroduced salmon. One important set of environmental factors to consider is the hydrologic and stream temperature regime of tributaries above the dams. The timing and magnitude of peak and low flows, as well as the suitability of stream temperatures to the various life stages of Chinook salmon, are important to consider in relation to the success of reintroduced fish. Quantifying the proportion of time each of the tributaries is suitable for Chinook salmon migration, spawning, incubation, emergence, optimal growth, and outmigration would help us better understand how tributary habitats will support summer, fall,	The plan currently relies on habitat analyses in many of the tributary habitats using the Ecosystem Diagnosis and Treatment Model (EDT). The methods, input data etc. for the EDT analysis is described in the following reports: ICF 2017. Anadromous Reintroduction Potential for The Sanpoil River and Select Upper Columbia Tributaries on The Colville Reservation Using the Ecosystem Diagnosis and Treatment Model. ICF 2018. Anadromous Reintroduction Potential for the Spokane Basin and Select Tributaries to Lake Roosevelt Using the Ecosystem Diagnosis and Treatment Model. Project # 2016-003-00.

Organization	Comment #	Comment	Response
		or spring Chinook salmon. This effort could be accomplished initially through a literature review, but we recommend eventually completing quantitative studies, with existing information or through field-based studies.	Habitat inputs for the Sanpoil River and other Lake Roosevelt tributaries were based on empirical habitat surveys conducted by the tribes. Data on stream flow (min, average, peak), stream temperature etc. were also incorporated where data exists. The habitat data set for the Spokane River is less robust than the Sanpoil River and may need to be improved with additional data collection if initial fish passage studies show relatively high survival. High survival would indicate that monies spent on habitat improvement may increase the likelihood of program success. The proportion of the time the habitat provides suitable conditions for fish is expressed by the percent of the life history trajectories modeled in EDT that were successful. Based on current knowledge, the data indicate that initial efforts and research needs to address the critical uncertainty of fish passage survival. The need for additional habitat analyses will be considered later in the process.
NOAA	13	Based on our experiences with reintroduction in other river basins, we have found it important to assess habitat threats and limiting factors that may decrease survival rates for rearing and emigrating juveniles in blocked area tributary habitats. We would be interested in learning more about how these factors have been considered, e.g., the number and potential	Although the results were not presented in the Phase 2 Implementation Plan, we have habitat surveys and associated EDT results that describe the limiting habitat factors by life stage for Chinook and steelhead. The tribes do have habitat restoration programs in the blocked area to benefit resident fish. Actions taken to benefit resident fish will also benefit salmon during the

Organization	Comment #	Comment	Response
		effects of unscreened diversions and intakes in reintroduction areas.	reintroduction testing in Phase 2. If a decision is made to move forward with reintroduction in Phase 3, the habitat data will be updated for use in selecting habitat improvement actions that would be most beneficial for salmon.
NOAA	14	We acknowledge the importance of communicating and coordinating reintroduction efforts with existing forums that address issues such as broodstock selection and harvest (U.S. v Oregon, Pacific Salmon Treaty), Columbia River System management (Technical Management Team, Fish Passage Operations and Maintenance), blocked areas goals (Columbia Basin Partnership), Columbia River Treaty project operations, and reintroduction efforts within Canada. NOAA stands by to assist in such coordination efforts as identified by the UCUT.	We appreciate NOAA's commitment to assist in the implementation of the plan.
USFWS	15	The P2IP outlines nine Implementation Strategy Principles. While we defer to the UCUT on what principles are contained in the P2IP, the Service does highlight two concerns that—even if not listed as principles—should be considered as you finalize and implement the P2IP: o Coordination should occur to avoid negative impacts to existing hatchery production or goals outlined in other basin-wide or local agreements (e.g., *US v Oregon*). o Studies and actions to meet program goals should be implemented in a manner that minimizes impacts to ESA listed species and	The possible sources of hatchery fish for the program and possible effects to other hatchery programs are described starting in section 5.1.1 of the plan. The program will consider four possible sources of hatchery fish: 1. Use of fish from existing hatchery programs 2. Within the +10% of existing program production 3. Surplus fish from existing programs 4. New production The use of any of the four sources will require consultation with the regulatory agencies before

Organization	Comment #	Comment	Response
		critical habitat.	implementation. Possible effects the four options may have on processes such as *US v Oregon* would be evaluated at that time.
USFWS	16	When assessing passage options and design of upstream fish passage at any of the dams within the range of bull trout (i.e., Chief Joseph, Grand Coulee and to some extent, Spokane River Dams), we urge consideration of passage and recovery needs for bull trout by all the relevant parties. We also ask that the Service be included in development of design and implementation of any upstream passage facilities or solutions.	The Service will be invited to participate as a member of the fish passage team. It is in this forum that the needs of bull trout will be considered in the design, construction, operation and evaluation of each passage facility. We welcome the USFWS expertise on Bull Trout recovery and management and are willing to incorporate your recommendations on Bull Trout passage at the temporary facilities.
USFWS	17	Non-Native and invasive species are a significant concern. The Service views several non-native and invasive aquatic species as relevant to the studies and actions proposed in the P2IP, including but not limited to: Northern Pike, Smallmouth Bass, Walleye, Zebra and Quagga mussels, New Zealand mudsnails, and Rusty crayfish. Preventing the spread of non-native and invasive species as a component of evaluating potential fish passage solutions, as well as mitigating the risk of introducing non-target species during salmon reintroduction efforts (e.g., Trap and Haul) should be considered. The Service recognizes, supports, and helps fund ongoing early detection monitoring for aquatic invasive species in the region. The Service supports efforts to monitor and control Northern Pike in the blocked areas, as well as downstream of Chief Joseph Dam. We	UCUT tribes view downstream collection systems having the ancillary benefit of being an opportunity to intercept non-native and invasive fish species to prevent expansion of their range and to further manage populations. Non-native and invasive invertebrates and plants are currently being monitored for and managed by UCUT tribes as well as other agencies and organizations. Early detection systems and rapid response protocols have been developed and will be implemented by multi-agency coordination groups such as the Washington Invasive Species Council. The Tribes view the control and management of non-native and invasive species as tremendously important and have programs dedicated to this issue.

Organization	Comment #	Comment	Response
		urge all of the concerned parties to continue to support these important efforts. Early detection monitoring for non-native and invasive aquatic species at facilities (both interim and permanent sites) should be considered as a component of the P2IP, along with implementing best management practices and risk mitigation like Hazard Analysis Critical Control Point (HACCP) planning to prevent the unintentional introduction of non-target species.	
USFWS	18	Access to hatchery produced juvenile fish is a key underpinning of the entirety of the P2IP, however the document lacks a detailed description of existing hatchery facilities that may be available to help serve this purpose. Given the importance of this aspect of the plan to facilitating the initial studies evaluating juvenile survival and migratory behavior, a fuller discussion of this topic is needed either within the P2IP or as part of a separate evaluation that can be directly referenced in the document. We support a detailed and thorough investigation of the availability of existing hatchery resources (within existing Federal, State or Tribal facilities) as well as future plans to develop dedicated hatchery space and facilities to support this effort. In the near term any inability to rear Chinook Salmon and Sockeye juveniles needed for the initial studies will likely lead to a delay to the implementation of the P2IP as a whole	We are of the opinion that the approach outlined in the plan cover the concerns of the Service (see section 2.11.2). We intentionally avoided naming specific hatcheries and programs because that would require extensive planning and outreach that would have been out of context without the rest of the information in the P2IP defining the need. Now that we have the P2IP, we are working with the USFWS and others on the specifics of how to access and raise the juveniles to meet the needs of the P2IP. As you suggested, the details will be captured in a separate document/process. Over the near term, the approach for artificial production in Phase 2 is to rely on local existing land-based facilities, increased net pen infrastructure and develop acclimation facilities to culture Chinook and Sockeye needed for the reintroduction effort. The use of existing facilities is the lowest cost approach for achieving hatchery production needs. We have already implemented the steps required to raise needed fish this year.

Organization	Comment #	Comment	Response
			More information on hatchery facilities operated by federal, state or tribes could be required in late Phase 2 or early Phase 3 but believe most of this information is already summarized in existing Hatchery Genetic Management Plans or other operational documents.
USFWS	19	The Chief Joseph Hatchery Adult ladder is proposed within the P2IP as a possible means to support collection of returning adult Chinook salmon for Trap and Haul Programs below Chief Joseph Dam. Improvements to this facility may be needed to improve fish handling and holding conditions if this location were to be utilized. The document references this concern (pg 40 sec 2.11.1) however a detailed evaluation of the Chief Joseph Hatchery adult trapping, holding and spawning facilities as whole may be warranted and could be proposed as a component of the implementation plan. Such a study could benefit both the proposed P2IP efforts and the existing and ongoing Chief Joseph Hatchery production programs.	We agree with this comment. Because the Chief Joseph Hatchery ladder may be used to achieve fish passage objectives, any alterations and/or improvements will be addressed by the fish passage Team as part of their work in Phase 2.
WDFW	20	Timeframe adaptability. The P2IP sets forth a logical, multi-step approach to iteratively move towards establishing the infrastructure and information needed to support reintroduction goals. The entire approach is identified as a 21-year process. We understand the data collected in earlier steps of Phase 2 will be used to inform later steps, and that an adaptive management process will be utilized to maintain flexibility in your program. We suggest that as you	The UCUT will be continuously looking for funding opportunities to accelerate studies and the implementation of interim fish passage structures and hatchery facilities, when appropriate. We are also participants in many regional forums and our policy staff track, and help shape, federal and state fisheries legislation. However, to some degree, the time required to implement the plan is restricted by the life history

Organization	Comment #	Comment	Response
		adaptively manage this process, you also consider whether emerging strategic political or funding opportunities might decrease the amount of time needed to complete Phase 2. Perhaps aim for a faster timeline with check-ins to slow down if necessary.	of the species being tested. For example, Chinook express a 5-year life history. This means that sufficient data for decision-making will take at least 10-years to compile and analyze. To observe a range of typical ocean conditions, and their effect on program success, could take 20-years.
WDFW	21	Climate change. In its review of Phase One, the Independent Scientific Advisory Board (ISAB) noted that climate change would require additional treatment in the P2IP document. While reintroduction of anadromous fish above the blocked area is likely to be a critical climate resilience action for Columbia Basin salmon, we also agree with the ISAB that the P2IP document should account for uncertainties and challenges relative to climate change, as well as documenting how reintroduction can provide climate resilience through providing access to higher elevation, colder water habitat.	The ISAB suggested that both positive and negative effects climate change may have on reintroduction efforts upstream of Chief Joseph and Grand Coulee dams be addressed. They suggested the topic be covered in more detail in future planning and implementation efforts. We agree with the ISAB and will consider climate change impacts and adapt with them. As climate change effects in the blocked upper Columbia are better known, we will incorporate that information into our life cycle model and adjust management plans, as needed. More detailed discussion of climate change uncertainties will likely occur when Phase 2 analyses are synthesized and used for Phase 3 decision making. We envision covering climate change in the evaluation factors listed in section 2.12. Specifically, climate change will be covered under the following factor: • {Reintroduction} Effects on extant salmonid populations, including ESA-listed salmonid populations downstream of Chief Joseph Dam. The next version of the plan will make this

Organization	Comment #	Comment	Response
			assumption explicit. We appreciate WDFW's recognition of our habitats being a critical climate resiliency tool for Columbia Basin Salmon. Adding these blocked area habitats to the State's databases (e.g., SaSI) would be beneficial to our reintroduction efforts by further acknowledging the contributions our region can make to salmon recovery and provide more equitable eligibility to receive funding supporting this work.
WDFW	22	Regulatory uncertainties. Section 2.3.2 describes a "stepwise" approach to Phase 2 and vaguely references the federal, state, and tribal regulatory challenges that may be present within the steps. It would be helpful to better understand where regulatory challenges are anticipated (i.e., utilization of federal facilities for acoustic telemetry equipment, interim collection, etc.) and what processes and action alternatives will be considered to resolve these challenges. Several near-term policy and legal venues concerning future Columbia Basin fish and wildlife management could be avenues to reduce regulatory, policy, and political uncertainties – this is another reason to accelerate the process for addressing policy and technical needs to the extent possible.	Section 2.3.2 was not intended to adequately address the regulatory considerations and we edited 2.3.2 to direct readers to more details in section 5. Section 5 provides further considerations of regulatory and policy considerations. We did not go so far as to propose pathways to resolve the challenges but outlined many of the considerations and a policy team framework for addressing them. In some cases, the pathway is clear and simple (apply for a transport permit from WDFW), in other cases (NEPA, ESA consultation) the pathway is not clear and the authors of the P2IP are not currently in a position to outline exactly what happens next. Our current challenge is to understand what processes need addressed and then consult with the appropriate entity to define the path forward, which will happen as we move through Phase 2.
WDFW	23	Pathogen testing. There is limited mention in	We agree the previous version did not adequately

Organization	Comment #	Comment	Response
		the P2IP of pathogen testing for juvenile or adult fish passed above Chief Joseph and Grand Coulee Dams. The same pathogen risks that exist with transferring fish for cultural releases remains for these potentially larger transfers of fish. Given that the P2IP is the second of a three-phase process and is still largely feasibility and testing, it would seem too early and inappropriate to knowingly move unwanted pathogens into the blocked area without testing for potential pathogens and making sound judgement on whether the risk of moving those pathogens into the blocked area during Phase Two implementation is appropriate. As we have previously discussed with our UCUT partners, it will be very important to manage and reduce risk to the existing resident fish community and their exposure to pathogens to which they are naïve. The risk associated with having a major population scale impact on native redband trout is a concern to WDFW and we believe to the comanagers on Lake Roosevelt as well. WDFW encourages UCUT to engage in a pathogen testing and risk assessment work group to develop a plan moving forward to get ahead of this issue and ensure it does not become a barrier to reintroduction or successful collaboration.	discuss the pathogen risk and pathogen testing topic. Although we do not believe the risks of transmission and the range of population responses in the wild are well understood, we agree that a cautious approach is warranted, particularly in the early years of Phase 2 when it's reasonable to implement with the relatively small number of fish that are being moved. However, as numbers increase through time the benefits of the reintroduction will increase and so will the cost and feasibility constraints of the pathogen testing protocol. We added a section (2.11.2) to explicitly recognize the pathogen sampling protocol that UCUT and WDFW developed and have been implementing since 2019. The UCUT will be happy to engage in the pathogen testing and risk assessment workgroup to develop a more detailed plan.
WDFW	24	Harvest. Per the *United States v. Oregon* Management Agreement, the harvest sharing framework is abundance-based and intended to meet the escapement goal of 20,000 fish past	We recognize that a successful reintroduction program may lead to increased harvest rates on Chinook and sockeye populations below Chief Joseph Dam. However, we see that as a benefit of

Organization	Comment #	Comment	Response
		Priest Rapids Dam. As production and returns increase from reintroduction or other means, the increased run size may trigger the utilization of a treaty/non-treaty harvest rate under the management agreement that could result in a higher proportion of the run being caught; however, the expected harvest is shared approximately 50/50 under most run size scenarios. Non-treaty fisheries have a mixture of mark-selective and non-MSF, while the other 50% is non-MSF.	the program. Higher harvest rates downstream could affect the success of the reintroduction effort. However, substantial number of adult returns from the reintroduction effort will not occur for many years. The habitat assessments and life-cycle modeling suggest that the translocation of surplus hatchery fish into the blocked area will result in the production of natural-origin offspring, which will partially offset the effects of higher harvest rates. It will be up to the fisheries managers to determine how fisheries and harvest rates may be impacted by increased production from the blocked area.
WDFW	25	Page 4 P2IP Depending on the source of the Chinook, it will have an impact on run timing, ocean migratory habits, and which fisheries they are subject to (i.e., upper Col summer vs URB).	Agreed.
WDFW	26	Page 8-9 This depends on if we are talking about upper Columbia summer or URB for harvest rates. I am assuming the reference to greater than 55% is based on summer Chinook, and We cannot confirm that given there had been errors in the estimate of impacts being accounted for in FRAM. But based on the updated FRAM runs for 2008-2018, there appears to be a similar exploitation rate for summers (57%) and the current and corrected FRAM model estimates that the total (ocean, in-river treaty, in-river non-treaty) exploitation rate is ~57% for upper	Correct. The harvest rate was based on summer/fall Chinook.

Organization	Comment #	Comment	Response
		Col summer and ~51% for URB.	
WDFW	27	Page 13 It would be helpful to have a marking and tagging section inserted prior to Phase 2 Studies (2.5) detailing the marking/tagging strategies for the different studies. Additionally, for proposed larger juvenile releases (in particular Chinook) external mass marking (mark or not mark) needs to be addressed. This info does appear through the various sections of the document, but it would be helpful to summarize it one section.	A final marking strategy will be developed as part of Phase 2 activities. The strategy will need to be agreed to by the management agencies. Possible marking techniques that could be used in the plan are discussed in section 5.1.5. However, the number of hatchery fish released to meet the feasibility tests of Phase 2 will be very small compared to the downstream programs. We are of the opinion that current document structure regarding marking is sufficient, and that further refinement of the tag/mark plan should be handled separately as part of Phase 2 implementation.
WDFW	28	Page 75 This document does not address adequately communicating/coordinating with the HC/HSC and receiving approval and/or engaging in appropriate process to receive surplus juvenile/adult salmon (in particular, Chinook, and even production from the ONA Sockeye Hatchery). UCUT should coordinate with a WDFW representative for all requests and those requests should be identified at the beginning of the year. There is a lot of demand for UCR summer Chinook by other parties that must be balanced with reintroduction efforts.	We are aware that access to surplus hatchery fish is an ongoing annual process for both Mid-C and federal facilities and each entity has an associated process for sharing amongst the various tribes. We do not believe that the P2IP is the right place to capture all the details of accessing available surplus fish, however, we have reviewed and modified the language on page 75 to partially address WDFW's concerns via this comment. It has been unclear what the appropriate mechanism is to interact with downstream groups such as the HC/HSC because only 1 of the UCUT tribes are a formal party to those processes. Being included in those discussions or invited to present would help improve communications between all managers involved.

Organization	Comment #	Comment	Response
WDFW	29	Page 75 For the larger juvenile releases into the blocked area (and probably all), UCUT should address drafting HGMPs for NOAA approval.	Once the sources of Chinook and sockeye for testing/reintroduction have been determined, the UCUT will work with NOAA to determine their requirements for new or amended HGMPs.
WDFW	30	Page 79 Other approvals that should be addressed (whether needed or not needed) are SCPs (collection of NO adults/juveniles from State waters), Fish Transport Permits on non-reservation lands, and whatever permits are required for potentially transporting fish to and from Canada.	A summary list of needed permits and processes to interact with is now included in Section 5. We request that WDFW assist tribal staff by seeking solutions to alleviate administrative burdens as much as possible. For example, consider issuing multi-year permits and contracts for related work.
WDFW	31	MSF fisheries are not present in the ocean fisheries, where a large proportion of the harvest occurs. Most of the harvest in-river occurs by treaty fisheries, and they are not MSF. The most meaningful MSF fishery would be the upper Columbia summer fishery; however, they are largely focused around terminal areas (yet could catch some of these fish in the Brewster Pool if they decide to 'stage'). Not ad-clipping in order to increase returns would not likely have a significant impact on returns expected to occur (so this marking strategy to distinguish fish can occur if it is the easiest option to utilize by staff identifying fish).	Agreed. We will work with the regulatory agencies to determine the best marking strategy for each species.