PHASE 1 EXECUTIVE SUMMARY
PRELIMINARY FRAMEWORK FOR ECOLOGICAL RISK ASSESSMENT OF LARGE-SCALE HYDROPOWER ON BRAIDED RIVERS IN ALASKA

Prepared for
The Nature Conservancy

Prepared by
Anchor QEA, LLC

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Anchor QEA, LLC
23 South Wenatchee Avenue, Suite 220
Wenatchee, Washington 98801

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LIST OF ACRONYMS AND ABBREVIATIONS

AEA	Alaska Energy Authority
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
FERC	Federal Energy Regulatory Commission
Project	Susitna-Watana Hydropower Project
Report	*Preliminary Framework for Ecological Risk Assessment of Large-Scale Hydropower on Braided Rivers in Alaska: Phase 1*
RM	river mile
TNC	The Nature Conservancy

1 INTRODUCTION

This document summarizes the information contained in the comprehensive report *Preliminary Framework for Ecological Risk Assessment of Large-Scale Hydropower on Braided Rivers in Alaska: Phase 1* (Report; Anchor QEA 2015), conducted by Anchor QEA on behalf of The Nature Conservancy (TNC). The Report is a component of the larger ecological risk assessment (ERA) process that is being undertaken to consider risks posed by large-scale hydropower in Alaska to Pacific salmon (Chinook, chum, coho, pink, and sockeye salmon).

The ERA comprises two major efforts: Phase 1, which establishes the initial framework and informational foundation for the ERA; and Phase 2, which provides analyses and risk characterization for a case study, the Susitna-Watana Hydropower Project (Project) proposed by Alaska Energy Authority (AEA). This Executive Summary highlights the key results of Phase 1 and is written for an audience that is familiar with the basic scope of a large-scale hydroproject and the general life history patterns of Pacific salmon. Additional Project information is available at the AEA Project website (Susitna-Watana Hydro 2014).

1.1 Purpose

The information contained in the Report supports the overall purpose of the ERA, which is to evaluate risks to wild salmon that may result from hydropower development. When completed, the ERA can be used in the following ways: 1) develop salmon-friendly criteria for avoidance, minimization, and mitigation of risks to wild salmon resulting from large-scale hydropower; 2) comment on Project study plans and results; and 3) contribute to the public discussion and decisions about how to balance the benefits of large-scale hydropower and the risks to wild salmon.

1.2 Methodology

The Report and overall ERA methodology are based on the general ERA framework and approach used by the U.S. Environmental Protection Agency (EPA) and other recent ERAs conducted in the region. Using EPA's template (EPA 1998), the three primary ERA process steps are, sequentially: 1) problem formulation; 2) analysis; and 3) risk characterization. These steps will be conducted in a phased approach (Figure 1) and the reports generated at each phase will be subject to review by an external science panel. As noted in Section 1.1, the Report specifically addresses Phase 1. The ERA will use population endpoints (see Section 1.3) for considering risks to salmon.

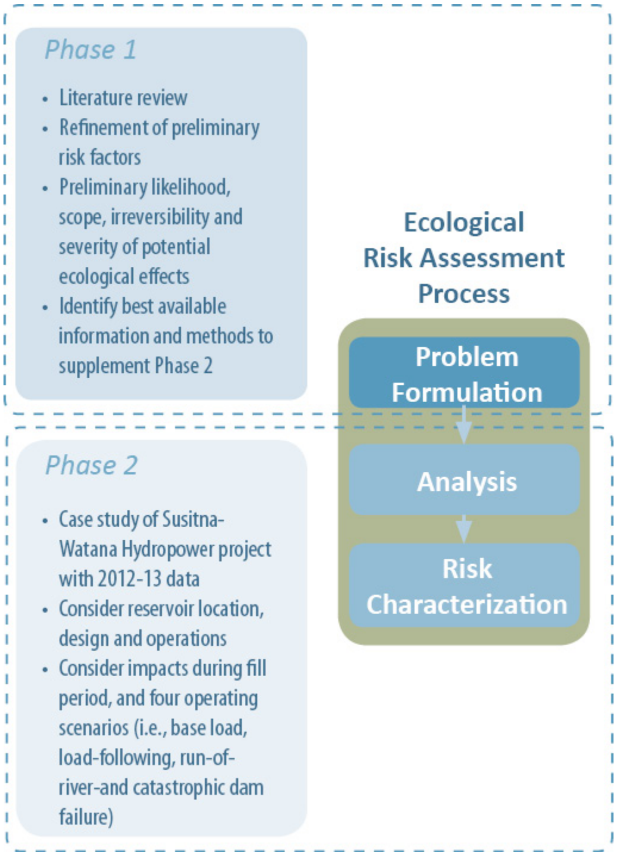


Figure 1
Phases 1 and 2 Contributions to the Conceptual ERA Model for the Proposed Project

1.3 Population Endpoints

In evaluating large-scale Project effects on salmon populations it is important to understand the population-level impact the Project may have. The definition of a population is an important starting point, and the ERA relies on information and concepts from McElhany et al. (2000). Specifically, a "population" is defined as "any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period is not substantially altered by exchanges of individuals with other populations." More generally, a population can be viewed as a group of salmon of the same species that spawns in a particular lake or stream at a particular season and that does not interbreed substantially with salmon from any other group spawning in a different place or in the same place at a different season (NMFS 2000). Independent populations are likely to inhabit geographic ranges on the scale of an entire river basin or major sub-basins (McElhany et al. 2000). Considering the spatial scale of the Susitna Basin, it is not unreasonable to expect that its multiple large tributary subbasins provide the requisite habitat variation to promote population structure and potentially support individual populations or subpopulations of multiple salmon species.

The endpoint of a salmon-focused ERA should examine what impact, if any, a proposed action may have on the sustainability and resiliency of affected populations. The ERA takes into consideration the population-level effects of the Project on Pacific salmon through the use of the following four underlying population parameters, which can be evaluated at different levels of resolution: 1) abundance; 2) productivity; 3) spatial structure; and 4) diversity. These parameters also provide a logical endpoint for a risk analysis because they represent general attributes that are important to all populations and all species, they are measurable, and they represent familiar metrics within the salmon conservation world and have recognized, yet flexible, utility as 'endpoints' for the evaluation of project impacts (McElhany et al. 2000; Busch et al. 2008). The four parameters are described as follows:

1. **Abundance.** "Abundance" refers to the number of salmon returning annually and represents the general size of the population. A population should be large enough to survive expected environmental variation, maintain genetic diversity, and continue to provide ecological feedback (McElhany et al. 2000). A key metric of abundance is "escapement," which refers to the number of returning salmon that annually reach spawning habitats. Abundance varies annually and large decadal fluctuations may naturally occur in response to shifts in marine productivity. To account for this variation, abundance is usually calculated over several years.
2. **Productivity.** "Productivity" refers to the growth of a population. This can be viewed simply as a population's ability to replace itself under normal conditions and potentially grow if abundance declines (McElhany et al. 2000). In the field of salmon management, a common metric for population growth is "returns/spawner," which refers to the number of returning offspring divided by the number of their parental

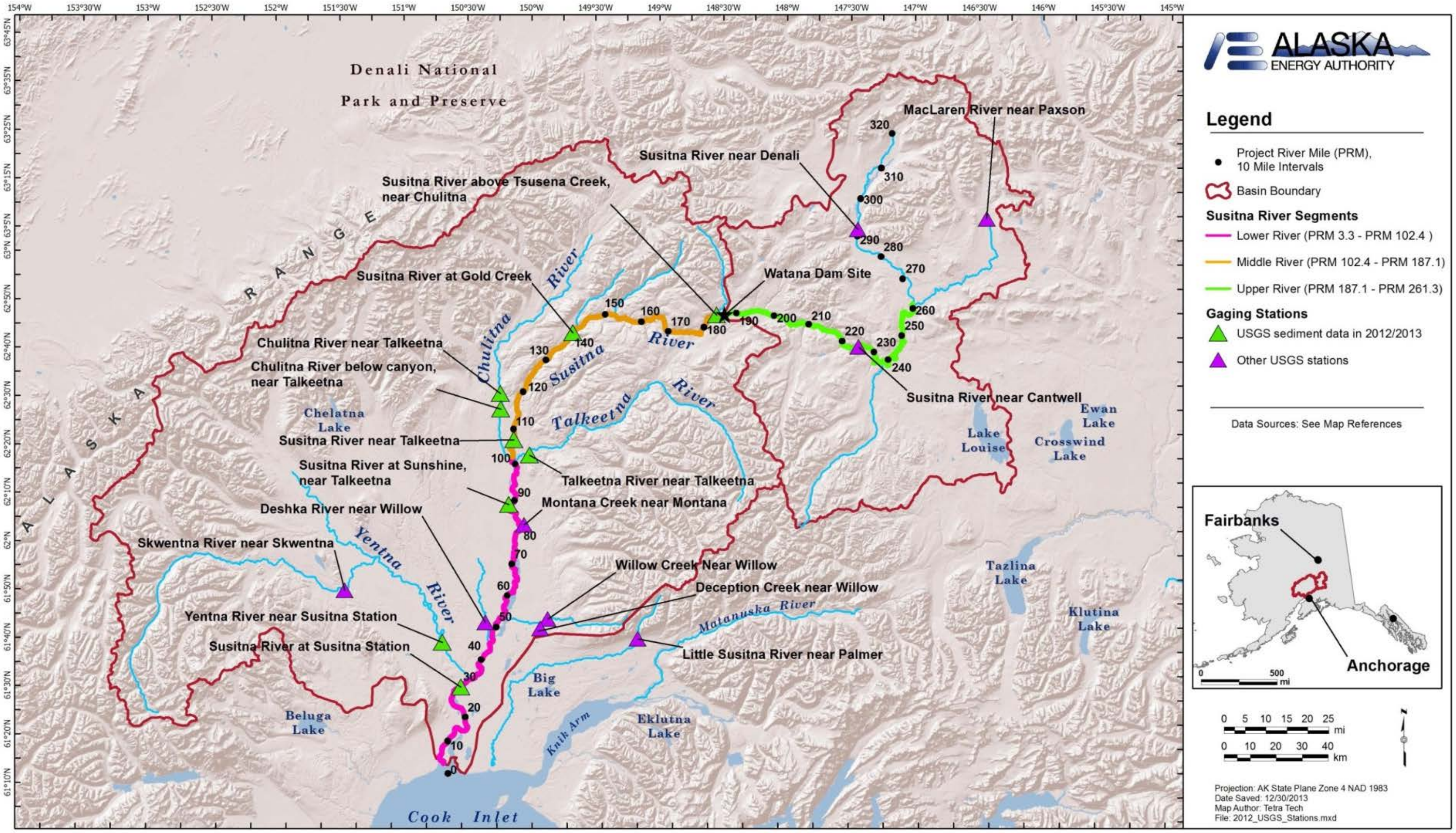
spawners. For example, if ten spawners produce ten returning offspring, then replacement has occurred (i.e., 10 returns/10 spawners = 1).

3. **Spatial Structure.** "Spatial structure" refers to the geographic distribution of a population and the factors that generate the distribution. Spatially structured populations are often generically referred to as "metapopulations." A population's spatial structure depends fundamentally on habitat quality, spatial configuration, and dynamics as well as the dispersal characteristics of individuals in the population (McElhany et al. 2000). Spatial structure is often measured in terms of stray rates within and among subpopulations (i.e., reproductive isolation) and the geographic distribution of spawners or spawning habitats that form discrete spawning areas.
4. **Diversity.** "Diversity" refers to the genetic, morphological, and life history traits that exist within a population. These traits may include variation in anadromy, morphology, fecundity, run timing, spawn timing, juvenile behavior, age at smolting, age at maturity, egg size, developmental rate, ocean distribution patterns, male and female spawning behavior, physiology, and molecular genetic characteristics (McElhany et al. 2000). Measuring population diversity requires documenting variability in morphological and life history traits and, ideally, examining the environmental or genetic basis for expression of the trait. The documentation of diversity is a key prerequisite for delineating populations.

2 IDENTIFICATION OF PROJECT RISKS

2.1 Project Description

The Project is a case study used to illustrate the approach to an ERA that can be applied to other proposed dams in Alaska. The Project consists of a 700- to 800-foot-high by about 2,700-foot-long dam at river mile (RM) 184 of the Susitna River. The dam would create a reservoir with a surface area of 20,000 acres. The Project would be operated in a load-following mode such that power generation is maximized during November through April, and daily power generation would average 6,000 megawatt hours during peak winter months. Environmental studies will guide the daily range of flow variation permitted (FERC 2012). The total schedule from pre-application studies to completion of the Project would be 12 years. The Pre-application studies are expected to take 3.5 years (AEA 2011) and would support the license application to the Federal Energy Regulatory Commission (FERC). More comprehensive descriptions of the Project and schedule are available from AEA directly (Susitna-Watana Hydro 2014).



Source: Tetra Tech and Watershed GeoDynamics 2014

Figure 2

Project Vicinity Map Depicting the Watana Dam Site at River Mile 184 of the Susitna River

2.2 Project Assumptions and Uncertainties

At the time the Report was written, there were a number of key Project attributes that were not fully described but would be likely to influence Pacific salmon directly or through habitat modifications. If the Project is pursued, AEA would conduct a number of studies that are anticipated to generate data and results that will reduce this uncertainty and improve the resolution of the final analysis and risk characterization for Phase 2 of the ERA. The Project attributes discussed in Sections 2.2.1 through 2.2.8 remain unclear or require significant assumptions in order to consider risks to salmon species.

2.2.1 Anticipated Project Operations

The entire suite of fluvial processes and potential risks to salmon downstream of the Project will be dependent on how the Project is expected to be operated. Operational descriptions contained in available FERC documents and AEA reports are portrayed as load-following, but the expected intensity of flow regulation is not specific enough to evaluate any scenario other than Maximum Load Following OS-1. It is understood that the OS-1 scenario represents the maximum intensity of flow regulation, but it is not clear what the most likely level of flow regulation will be. It is assumed that AEA will model a number of operational scenarios that contemplate flow requirements for fish.

2.2.2 Upstream Passage

A passage feasibility study is underway but there is no existing proposal to provide upstream passage, so it is assumed that adult passage above the Project will not occur.

2.2.3 Downstream Passage

A study evaluating the future reservoir fish community and risk of entrainment is underway, but there are no proposed plans or measures that would provide downstream passage. It is assumed that juvenile passage or survival standards for out-migrating juveniles will not be provided at the Project location.

2.2.4 Lower River Effects

Project studies note that some habitat impacts associated with Project operations will attenuate across a downstream gradient and the most significant effects will occur in the middle river reach (Figure 2). Focusing on the most intense areas of habitat alteration is logical, but should not displace attention on the lower river. Changes to flow regimes and sediment supplies will cause a cascade of habitat effects that may take decades to reach a state of dynamic equilibrium following construction. It will be important to develop long-term predictions across the river continuum, including the lower river, to develop rigorous, comprehensive estimates of Project impacts to salmon.

2.2.5 Duration and Intensity of Construction and Initial Inundation

Similar to Project operations, the level of detail provided for interpreting effects of construction and initial inundation is low. A high resolution description addressing the stepwise progression of each activity is required to fully interpret the effects on salmon and interpret the risks posed. It has been assumed that the construction timeline will be followed. As such, effects of construction and initial inundation have been categorized as "temporary" because their duration would be less than 10 years, and the effect of these activities are considered independent of the existence of the Project (which is permanent). The assumption will be revisited when additional Project details are available.

2.2.6 Mitigation

There is currently no mitigation plan proposed for the Project. It is expected that as Project operations become more clear, so will the potential effects to habitat and the relevancy of, or necessity for, mitigation. In the absence of a mitigation proposal, the ERA assumes no beneficial effects from compensation for losses of fish or habitat availability, quality, or function.

2.2.7 The Determination of Population Level Impacts to Affected Salmon Species

The Project-related fisheries studies do not specifically address population-level impacts to affected salmon species. Given the large size of the watershed, abundance and diversity of salmon habitats, and the considerable modification of habitats that may result from the Project, multiple salmon population units will be affected for some or all species.

The current Project-related studies provide connections between habitat effects on individual species and different geographic study reaches but these are not nested for consideration within an explicit population-level framework for any salmon species. It remains unclear how the studies examining specific Project effects will be used to quantify impacts to salmon populations or if the ongoing analyses are being conducted at the correct resolution to predict effects to specific population units. This type of analysis would first require the delineation of existing population structure data and then consideration of how the Project affects each component. The designation of a population unit is typically performed by fisheries managers after consideration of genetic and other biological and ecological data. In other locations where salmon conservation drives analyses of project impacts (including hydroelectric dams), the affected population unit or "conservation unit" is defined, and specific population parameters are used as the endpoint of effect analyses (e.g., abundance, productivity, spatial structure, and diversity) and to provide a framework for interpreting effects and risks.

If different populations or contributing subpopulations are present within the basin, the diversity among these groups may be important to preserve in order to maintain sustainable productivity within the Susitna River. While the population structure data may exist (e.g., management studies conducted by state or federal agencies), or will be collected in the course of Project studies, they have not been discussed in relation to Project effects. In areas where salmon are abundant and resilient to large-scale declines (e.g., Bristol Bay sockeye salmon), their stability is supported by multiple population units, which provide the necessary diversity to maintain overall abundance and productivity when environmental changes or other perturbations decrease the contribution of any individual population component (e.g., Schindler et al. 2010). The understanding of a species population structure is a key component to the maintenance of its existence as well as understanding the significance of specific Project impacts.

2.2.8 Level of Precision

The Project-related fisheries studies do not articulate a standard for the level of precision expected or required for “valid” estimates of habitat effects or direct Project effects on fish populations. If there is no standard, it will be important to understand the observed precision of the studies that were conducted and develop appropriate confidence intervals for the results. In general, when a specific parameter is estimated using a very small sample size (e.g., using a small number of sample years to characterize the mean annual abundance of salmon), the estimate may be accompanied by a high standard error and low precision, which translates into an unreliable estimate. Predicting future effects using low precision estimates will not meaningfully reduce the uncertainty surrounding potential risks to Pacific salmon.

2.3 Categorization of Project Activities

Four different categories of Project activities were considered: 1) construction, which includes staging for and building the Project as well as filling the reservoir, but is independent of operations or the presence of the Project; 2) operations, which includes flow control for generation and reservoir operations; 3) the presence of the Project itself, which considers the ongoing existence of the dam independent of operations; and 4) a hypothetical catastrophic failure scenario (e.g., resulting from a seismic event).

Each activity was also sorted into subcategories based on the expected duration of the activity (i.e., short-term or long-term) and the persistence of its effects (transient, dynamic, and permanent). Short-term activities include those that will be completed in less than ten years (e.g., one to three salmon generations) and long-term refers to those taking ten years or longer to complete (multiple salmon generations). For persistence of impact, categories are defined as follows: 1) transient impacts attenuate after conclusion of activity; 2) dynamic impacts continue for the duration of an activity but fluctuate in intensity; and 3) permanent impacts are temporally stable.

The duration of a Project activity or persistence of an effect is one of the most important considerations when evaluating risks to salmon populations because the propagation of a risk from an activity to a salmon population is dependent upon the number of generations that are affected. In general, short-term activities with transient impacts (i.e., affecting one or two generations) represent less risk than long-term activities with dynamic or permanent impacts (i.e., affecting multiple generations).

Healthy populations are resilient to short-term habitat disturbances (i.e., few generations affected) for a number of reasons. First, healthy populations typically have multiple contributing sources of production to buffer the decline of a single population component. Second, the returns of multiple age classes from a single spawning cohort reduce the risk of an isolated catastrophic event because the loss of a single age class does not represent the loss of the entire cohort (or population). Third, by definition, a short-term disturbance does not cause the long-term or permanent loss of habitat. Long-term or permanent disturbances reduce the resiliency of populations because the temporal scale of the disturbance exceeds the risk hedge conferred by multiple age classes of progeny, and the loss of available habitat may preclude rebounds in abundance, productivity, diversity, and spatial structure of the remaining population.

2.4 Review of Identified Project Effects and Determination of Habitat Controls and Response Categories

The AEA licensing documents and associated studies were reviewed to identify the range of anticipated direct and indirect effects to salmon and their habitats. This review was intended to help structure individual risks and connect linkages between Project activities, habitat processes, and salmon populations.

Different ways were examined for organizing the impacts into categories that could efficiently explain the propagation of risk within the criteria identified by TNC. Not all impacts were considered because the scope of the ERA is limited by finite funding resources. As such, some Project effects, including increased risk of forest fires or changes in estuarine dynamics, were not evaluated. Additionally, the effects of harvest were not considered because the emphasis of the ERA is related to habitat changes associated with the Project.

Different frameworks represented in peer-reviewed literature were also considered to provide a structural foundation for depicting relationships between impact categories. The general approach selected was based on Burke et al. (2009), which effectively distilled complex habitat interactions within a hydropower context. Based on the categorization and framework review effort, hierarchical groupings of activity-related impacts and an initial risk framework were generated. The individual components of the framework are described in the following paragraphs and summarized in Figure 3.

First Order Impacts: This category encompasses the direct impacts to physical drivers of fluvial systems that would result from the Project. First order impacts are detectable in the immediate vicinity of the Project and are highly predictable in both scope and magnitude. Most importantly, they generate secondary ecological responses occurring at subordinate impact levels, and therefore represent the "hub" of influence from which other impacts will radiate. The probability of first order impacts occurring is assumed to be 100% (upon construction and completion of the Project). First order impacts affect the following: 1) flow regime; 2) water quality; 3) sediment supply; and 4) instream barrier.

Second Order Impacts: This category encompasses the habitat processes that result from first order impacts or feedback from third or fourth order impacts. Second order impacts are indirect (as opposed to first order impacts) and their intensity and propagation varies over spatial and temporal scales. Consequently, they are less predictable and understanding their probability of occurrence and magnitude requires significant analysis. Secondary impacts are highly interdependent and may not be apparent or reach a stable/dynamic equilibrium for years or decades after the Project is constructed. Second order impacts affect 1) riparian and community succession; 2) ice formation and breakup; 3) floodplain and channel morphology; 4) surface and groundwater flow; 5) sediment erosion and deposition; and 6) nutrient and trophic cycles.

Third Order Impacts: This category encompasses the habitat attributes that are required by salmon and can be thought of as "what salmon need" while they are in freshwater. Third order impacts may be affected by first or second order impacts, as well as feedback from fourth order impacts. Each habitat attribute is potentially interdependent and each salmon species has specific requirements. Habitat attributes can be measured instantaneously and reflect "real time" habitat conditions. Over multiple generations the variability in habitat attributes is the foundation of local adaptation and governance of parameters that sustain salmon populations. Third order impacts affect 1) water quality; 2) water quantity; 3) habitat connectivity; and 4) habitat structure.

Fourth Order Impacts: This category encompasses impacts to parameters that sustain salmon populations resulting from changes to habitat attributes. Whereas habitat attributes reflect the instantaneous condition of the available habitat, the population parameters are typically lagged response metrics that reflect changes in long-term sustainability. More specifically, if a habitat attribute is not functioning or has been degraded, the detection of a response by a population may not be instantaneous. As an example, the establishment of a barrier to passage that limits access to spawning grounds may reduce the abundance of a population, but detecting this reduction requires the evaluation of returns from the years of spawning that were affected by the barrier. In the case of Chinook salmon, this response may take more than 5 years to fully evaluate if spawner-to-spawner comparisons are used because the returns from any spawning year-class may be distributed over multiple years. For this reason, and to account for natural population variability, some population parameters are evaluated as they move along a decadal or longer scale (i.e., abundance and productivity). In other cases, the impact to a population parameter may be more immediately clear. Using the same example of a barrier to passage, the permanent truncation of available spawning habitat or elimination of a specific spawning area would immediately change the spatial structure of affected populations and could reduce life history diversity as well. Fourth order impacts affect: 1) abundance; 2) productivity; 3) spatial structure; and 4) diversity.

Biological Feedback: This pathway describes potential routes in which salmon populations affect the habitat processes and attributes that create sustainable populations (i.e., influence second and third order impacts).

External Modulators: This category represents external processes or changes (i.e., not associated with the Project) that have the effect of increasing or decreasing the amplitude of impacts associated with the Project or directly affect salmon populations independent of the Project. In the ERA, climate change and marine productivity cycles (e.g., Pacific decadal oscillation) are primary external modulators. Other external modulators that are not considered in the ERA include harvest and other sources of anthropogenic development.

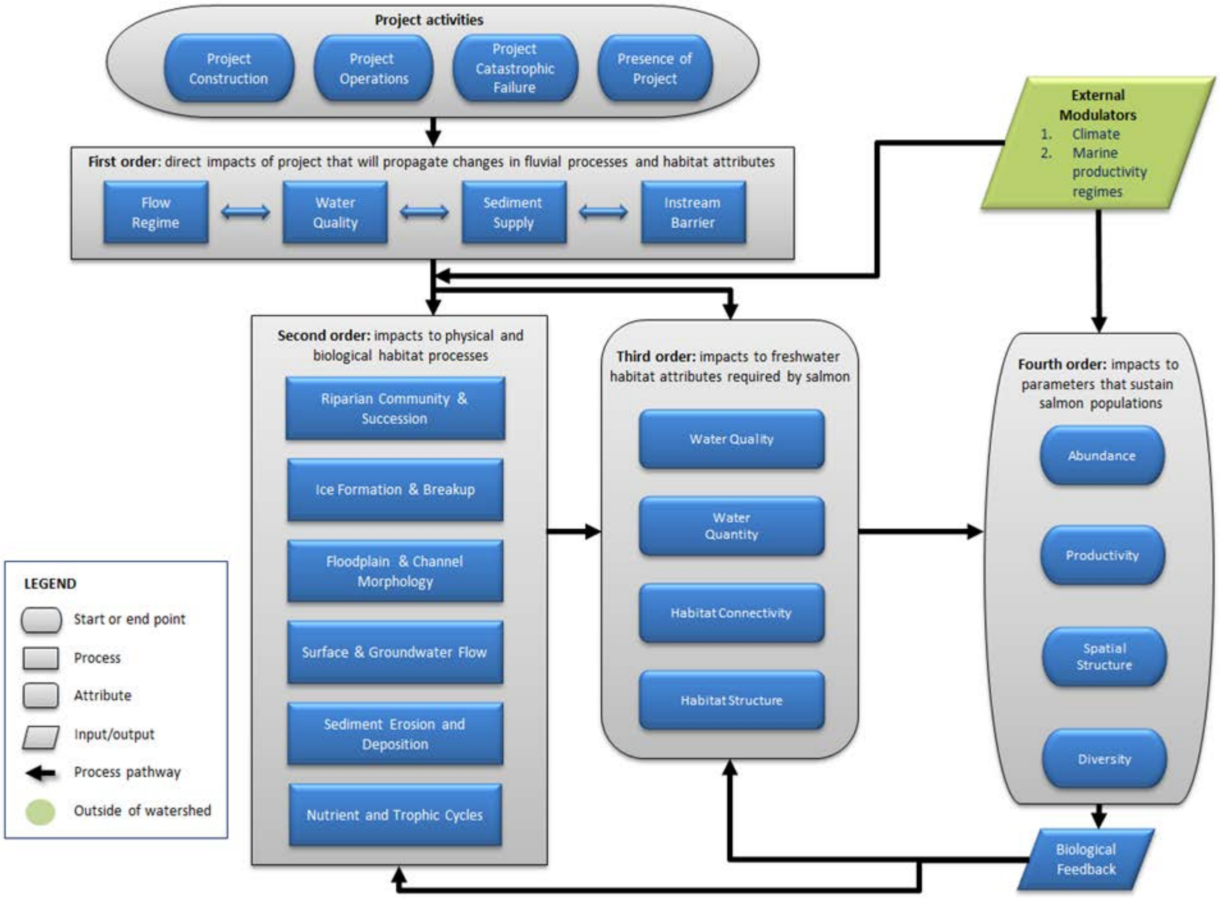


Figure 3

Risk Profile Depicting the Relationships among Project Activities and Impact Categories

2.5 Identified Risks

In the Report, risks posed by the Project to salmon populations were examined by first identifying those specific proposed activities and processes that could affect salmon and their habitat. This initial step considered criteria provided by TNC as well as information contained in AEA Project descriptions, studies associated with the Project, the FERC licensing process, and external literature. The Report also includes detailed profiles and figures depicting each risk.

2.6 Risk Hypotheses and Profiles

Specific risk hypotheses were developed using Project descriptions and available scientific literature. The relationships among hypothesized risks and impacts are depicted in risk profiles (e.g., Figure 3). The formulation of explicit hypotheses for each risk clarifies the relationships that are being examined between specific actions, habitat processes, and attributes. All of the hypotheses should be considered as precursors to the analysis portion of the ERA. More specifically, each hypothesis has yet to be rigorously evaluated within the context of the proposed Project and does not reflect the full body of information that is expected to be available when the Project-related studies are completed.

1. **Presence of an Instream Barrier**
   Hypothesis: The presence of the proposed Project will create an instream barrier that will permanently affect habitat processes and attributes necessary to sustain wild salmon populations.
2. **Changes to Flow Regime**
   Hypothesis: Long-term Project operations will dynamically alter the flow regime of the Susitna River and affect habitat processes and attributes necessary to sustain wild salmon populations.
3. **Changes to Water Quality**
   Hypothesis: Long-term Project operations will dynamically alter the water quality of the Susitna River and affect habitat processes and attributes necessary to sustain wild salmon populations.
4. **Changes to Sediment Supply**
   Hypothesis: Long-term Project operations will reduce the sediment supply of the Susitna River and affect habitat processes and attributes necessary to sustain wild salmon populations.
5. **Changes to Biological Feedback between Salmon Populations and Habitat Processes**
   Hypothesis: Impacts to salmon populations resulting from first, second, and third order impacts will affect biological feedback to habitat processes and attributes necessary to sustain wild salmon populations.
6. **Modulation of Direct and Indirect Impacts Caused by External Factors**
   Hypothesis: External factors will modulate the direct and indirect impacts associated

with the operation and presence of the Project and affect habitat processes and attributes necessary to sustain wild salmon populations.

7. **Construction Activities and Catastrophic Failure**
   Hypothesis: Construction activities or catastrophic failure of the Project will temporarily (i.e., less than 10 years) affect habitat processes and attributes necessary to sustain wild salmon populations.

3 DRAFT SUPPORTING INFORMATION

To develop a comprehensive information base for the ERA and future case studies, we compiled relevant information from external and Project related sources. A second objective was to develop a list of the best available information (i.e., regional datasets, models, gray and peer-reviewed literature, regional experts, and FERC studies) for reference in subsequent analyses and evaluations.

3.1.1 Search Criteria and Sources of Information Considered

There were two primary methods of obtaining literature for the Report and its associated literature review: 1) use of an online search engine (Google Scholar 2014) to search external literature; and 2) use of the AEA Project website (Susitna-Watana Hydro 2014) and Alaska Resources Library and Information Services (ARLIS 2014) to search current and historic Project-related literature. In total, more than 320 documents were included and the results are summarized in Appendix A of the Report. It is expected that during the FERC licensing process, additional reports and studies will be forthcoming and will contribute to the final analysis of risks.

3.1.2 Best Available Information

As mentioned above, best available information will include literature, regional datasets, models, and regional experience. In order to prioritize application of existing information to this risk assessment, each source in the Draft Annotated Bibliography (Appendix A of the Report) was scored according to relevance criteria (Table 1). Using these criteria, those sources with high scientific quality and value (i.e., peer-reviewed), geographic relevance (i.e., in the Susitna watershed), species relevance (i.e., salmon focused), and temporal relevance (i.e., more recent) constitute the best available information. In Phase 2, information sources will continue to be catalogued and scored based on these relevance criteria and the risk factor hypotheses.

Overall, a large proportion of the highest scoring studies originate from previous or current pre-licensing efforts within the Susitna Basin. There are no other hydroprojects of the same scale that are highly congruent with the geographic, species, or temporal ranking criteria selected for the Report. The majority of studies that document the impacts of constructed hydroprojects on Pacific salmon are from areas with different climates and different habitat processes (e.g., Columbia River, Washington). For habitat impacts associated with Alaska's high northern latitude (e.g., risks posed by changes to patterns in ice formation and break up), the most relevant studies are from projects constructed at locations outside of Alaska, or focus on non-Pacific salmon species, or were completed decades prior to the current pre-licensing process. These studies may receive relatively low scores according to the best available information criteria but remain the most informative in the absence of comparable projects. The lack of similar case studies highlights how important it is that the data and studies conducted by AEA are designed and carried out to effectively evaluate impacts to Pacific salmon.

Table 1
Relevance Criteria

Category	Points
Scientific Quality and Value	
Peer-reviewed journal	3
Agency approved document	2
Other form of scientific review	1
Unknown	0
Geographic Relevance	
Within Susitna Watershed	3
Within Pacific Rim	2
Within North America	1
Elsewhere	0
Species Relevance	
Addresses Pacific salmon (*Oncorhynchus* spp.)	3
Addresses other salmonids	2
Addresses non-salmonids	1
Not related to fish	0
Temporal Relevance	
Published between 2000 and present	3
Published between 1990 and prior to 2000	2
Published between 1980 and prior to 1990	1
Published prior to 1980	0

4 KEY ECOLOGICAL ATTRIBUTES

4.1 Narrative Description of Key Ecological Attributes

All Pacific salmon require the same four essential habitat attributes during their freshwater life history: water quality, water quantity, habitat structure, and habitat connectivity (Figure 4). However, each species has unique requirements within each attribute that are related to its life history characteristics and associated spatial and temporal use of habitat within a watershed. Additionally, there may be variation within the same species across different watersheds. The final Report from the ERA will consider the specific requirements for each species.

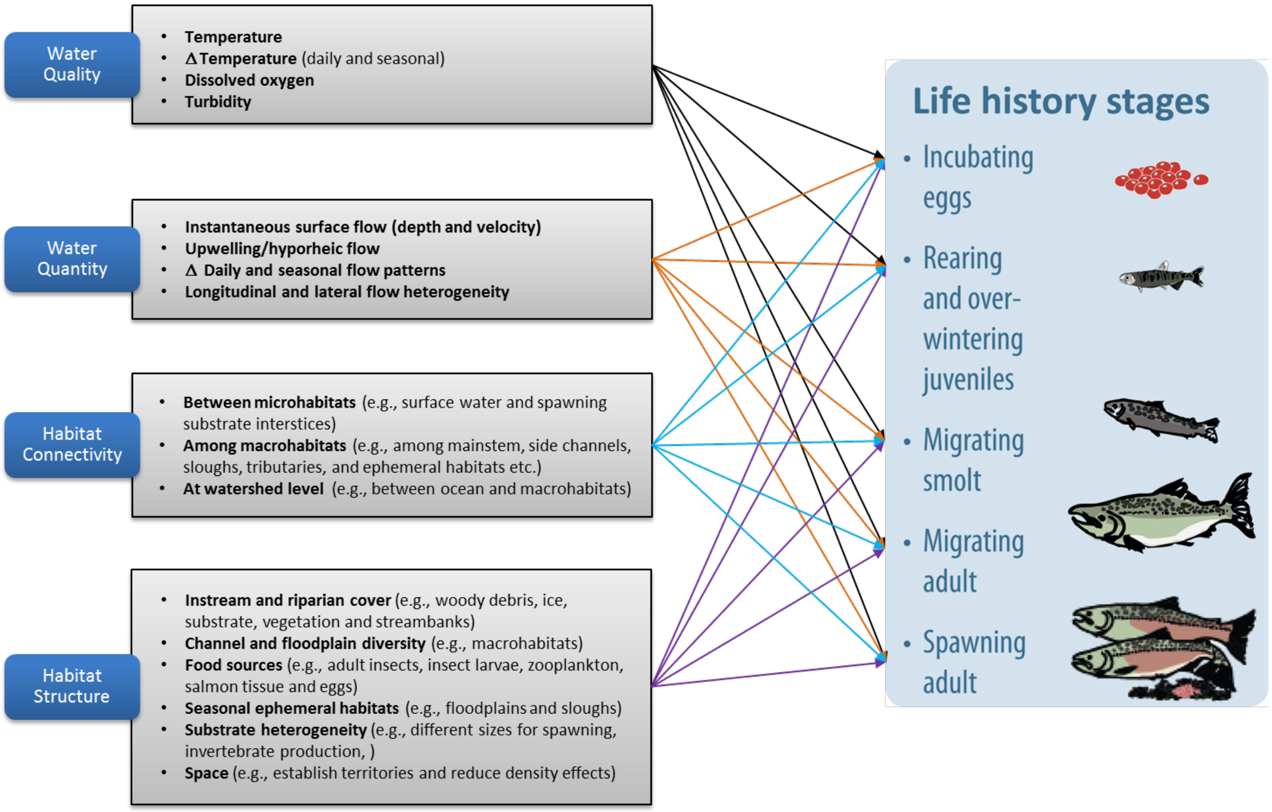


Figure 4

Ecological Relationship between Salmon Habitat Attributes and Different Life History Stages

5 PRELIMINARY CONSIDERATION OF ECOLOGICAL RISK

5.1 Interactions between the Risk Factors and Ecological Attributes

This section provides an initial consideration of ecological risk for the Project activities considered in the ERA based upon available literature and Project descriptions. The evolution of the risk framework must acknowledge the complexity of interactions between habitat processes and must evaluate how changes to habitat attributes intersect with spatial and temporal characteristics of each species life history. When major alterations to habitat overlap with a species' life history usage of that habitat, there is potential for impacts to occur at the population level. The direction and magnitude of a population impact is only detectable if measured against a baseline condition.

Project operations represent the most complicated, long-term activities with dynamic, persistent effects that pose risk to salmon population. The presence of the project is the most clear and permanent risk to salmon represented by the dam itself. Project construction or catastrophic failure describe temporary but intense short-term risks to salmon and their habitats. These risks are summarized in Figure 5.

5.2 Initial Consideration of Ecological Risk

The most complicated effects of the Project are expected to result from operations that are long-term in nature and have dynamic effects on fluvial processes drivers, including flow regime, water quality, and sediment supply. Review of the external and Project related literature strongly indicates that subordinate habitat processes (resulting from operations and the presence of the Project) and salmon habitat will be directly or indirectly altered through numerous pathways. Some of the impacts may not be significant, but the veracity of any assessment requires comparison against a baseline that, in this case, is still forming. More specifically, there is a high degree of uncertainty about the magnitude or probability of these risks impacting salmon because the most likely operational scenario has yet to be described.

That said, the most significant habitat impacts appear to be located in the middle river, immediately downstream of the Project (see middle river reach delineated in Figure 2), and pose risks to salmon through the following:

1. Changes in water temperature that could affect the growth and development of eggs and rearing salmon
2. Loss of connectivity between macrohabitats (i.e., side channels and sloughs) that represent key sources of habitat complexity for juvenile and adult salmon
3. Disruption in timing and cues for juvenile and adult migrations
4. Poorly understood ice processes that appear to interact with virtually all habitat attributes/processes and will undergo substantial change
5. Loss of habitat above the Project (assuming a no-passage scenario)
6. Flow regulation that has the potential to directly dewater redds or strand juveniles and indirectly cause habitat changes that alter the suitability of habitat for all life history stages

Because so many fluvial variables are affected, the potential for Project operations to affect the long-term abundance, productivity, spatial structure and diversity of all species is high. As noted in Section 2.2.1, the magnitude of risk is uncertain because the intensity of flow regulation and reservoir operations are unknown.

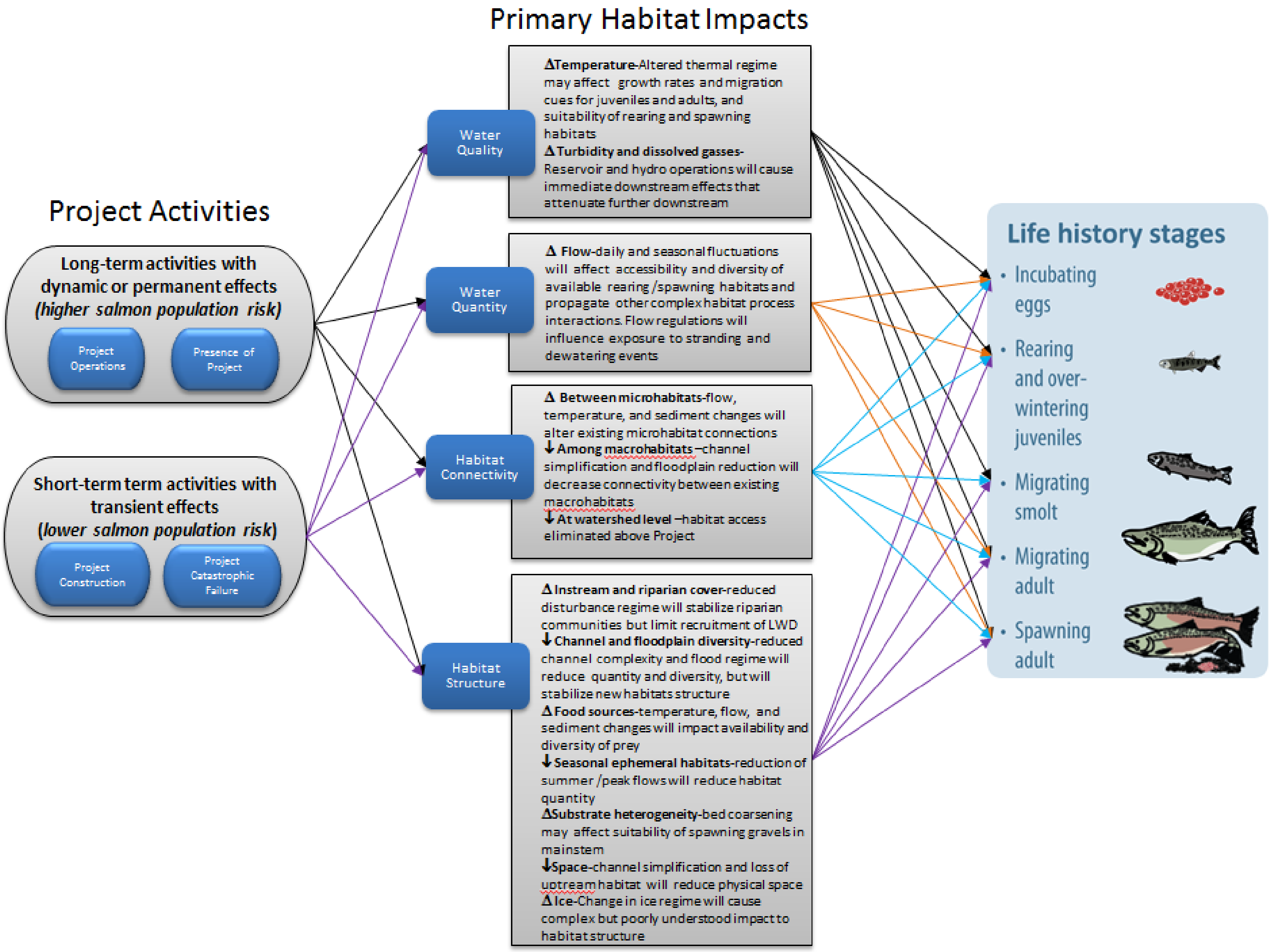
Overlaid on long-term Project risks is the prospect of a rapidly changing climate that could modulate the Project impacts within the watershed and marine production outside of the watershed. Based on observations in Alaska and elsewhere, it appears that the effect of climate change will be significant and cause both the reduction of habitat through water quality and quantity pathways, as well as increasing the suitability of other habitats that were formerly inaccessible or intolerable to salmon. In the absence of the Project, there would likely be major impacts to some or all of the salmon species in the Susitna River based on the magnitude of climate change that is expected in Alaska and the glacial dynamics of the Susitna River system.

In summary, based on a preliminary qualitative review of external and Project-related literature, it appears that Project operations would affect all species, life history stages, and habitat attributes. That is, all species will be affected by the proposed operational activities throughout their freshwater life histories after the Project is constructed. Additionally, because the operations will continue for decades into the foreseeable future, the effects will be persistent. The existence of overlap does not mean that all risks will translate to major declines in the populations, but it does suggest that the requisite components for population level effects are in place. What remains largely unknown is the magnitude, and in some cases the direction, of the effect. Climate change and climate variability (i.e., marine productivity) are likely to amplify the effects for some species.

The most straightforward Project risk that was evaluated is related to presence of the dam itself. As proposed, the existence of the Project at RM 184 will create a permanent barrier to passage and eliminate salmon production above the dam. The extent to which salmon, particularly Chinook salmon, use these habitats is currently a focal issue for AEA fisheries investigations. While a natural series of barriers below the Project site typically restricts or precludes passage for most species, it does appear that Chinook salmon successfully reproduce within the upper river (see delineation of upper river in Figure 2) above the Project site. The risk to salmon from the presence of the Project is, therefore, the truncation of potential available or ephemeral habitats and the loss of any population spatial structure and diversity associated with those lost habitats. Depending on the importance of the upper river to individual species or populations, the loss of habitat may also reduce overall basin-wide abundance or productivity of those affected species.

The effects of construction and reservoir filling are tentatively considered as short-term, transient risks (considered independently of Project operations and the existence of the Project) because, as described, they may only influence one or two generations of salmon. Similarly, the catastrophic failure of the Project is hypothetical and is based on several major assumptions: 1) the failure of the Project would be similar in scope to a natural catastrophic disturbance event (e.g., major landslide, volcanic eruption, or earthquake); 2) the actual failure process would transpire over a short period of time (e.g., days or weeks); and 3) natural habitat processes would be allowed to proceed thereafter.

The available literature concerning impacts of construction and catastrophic failure is largely theoretical because the current construction plans lack sufficient detail for comparison to historical dam construction and a catastrophic failure has not occurred on a scale comparable to the Project. That said, the combined construction and reservoir filling operations, as described, are on the outer edge of being considered "short-term" from a number-of-salmon-generations perspective and will have considerable effects on habitat processes. In particular, the reduction of flow during reservoir filling appears to be one of the most intense Project effects contemplated and is anticipated to cause significant reductions in salmon productivity for the 1 to 2 years that filling is expected to occur.



ΔTemperature-Altered thermal regime may affect growth rates and migration cues for juveniles and adults, and suitability of rearing and spawning habitats

Δ Turbidity and dissolved gasses-Reservoir and hydro operations will cause immediate downstream effects that attenuate further downstream

Δ Flow-daily and seasonal fluctuations will affect accessibility and diversity of available rearing /spawning habitats and propagate other complex habitat process interactions. Flow regulations will influence exposure to stranding and dewatering events

Δ Between microhabitats-flow, temperature, and sediment changes will alter existing microhabitat connections

↓ Among macrohabitats –channel simplification and floodplain reduction will decrease connectivity between existing macrohabitats

↓ At watershed level –habitat access eliminated above Project

Δ Instream and riparian cover-reduced disturbance regime will stabilize riparian communities but limit recruitment of LWD

↓ Channel and floodplain diversity-reduced channel complexity and flood regime will reduce quantity and diversity, but will stabilize new habitats structure

Δ Food sources-temperature, flow, and sediment changes will impact availability and diversity of prey

↓ Seasonal ephemeral habitats-reduction of summer /peak flows will reduce habitat quantity

ΔSubstrate heterogeneity-bed coarsening may affect suitability of spawning gravels in mainstem

↓Space-channel simplification and loss of uptream habitat will reduce physical space

Δ Ice-Change in ice regime will cause complex but poorly understood impact to habitat structure

Figure 5

Initial Summary of Ecological Interactions between Project Activities, Habitat Attributes, and Salmon Life Histories

5.3 Next Steps

The formal analysis and risk characterization components of the ERA would be the subject of a Phase 2 report. The availability of data and reports from environmental studies prior to development of a large hydroproject will be important to establish baseline population parameters and link potential habitat alterations to a measurable level of response by species and life history. Ultimately, these will be necessary to reduce Project uncertainty and to inform the acceptance or mitigation of specific risks.

6 RECOMMENDED BEST PRACTICES

This chapter identifies recommended best practices for reducing risks to Pacific Salmon during the planning, design and implementation of large-scale hydropower Projects in Alaska. The recommendations provided for each phase are focused on establishing processes and broad goals that lead to sustainable populations rather than prescriptions for specific measures or actions. They are also intended to show how recommended best practices for maintaining sustainable salmon populations can be integrated into the development process (Figure 6).

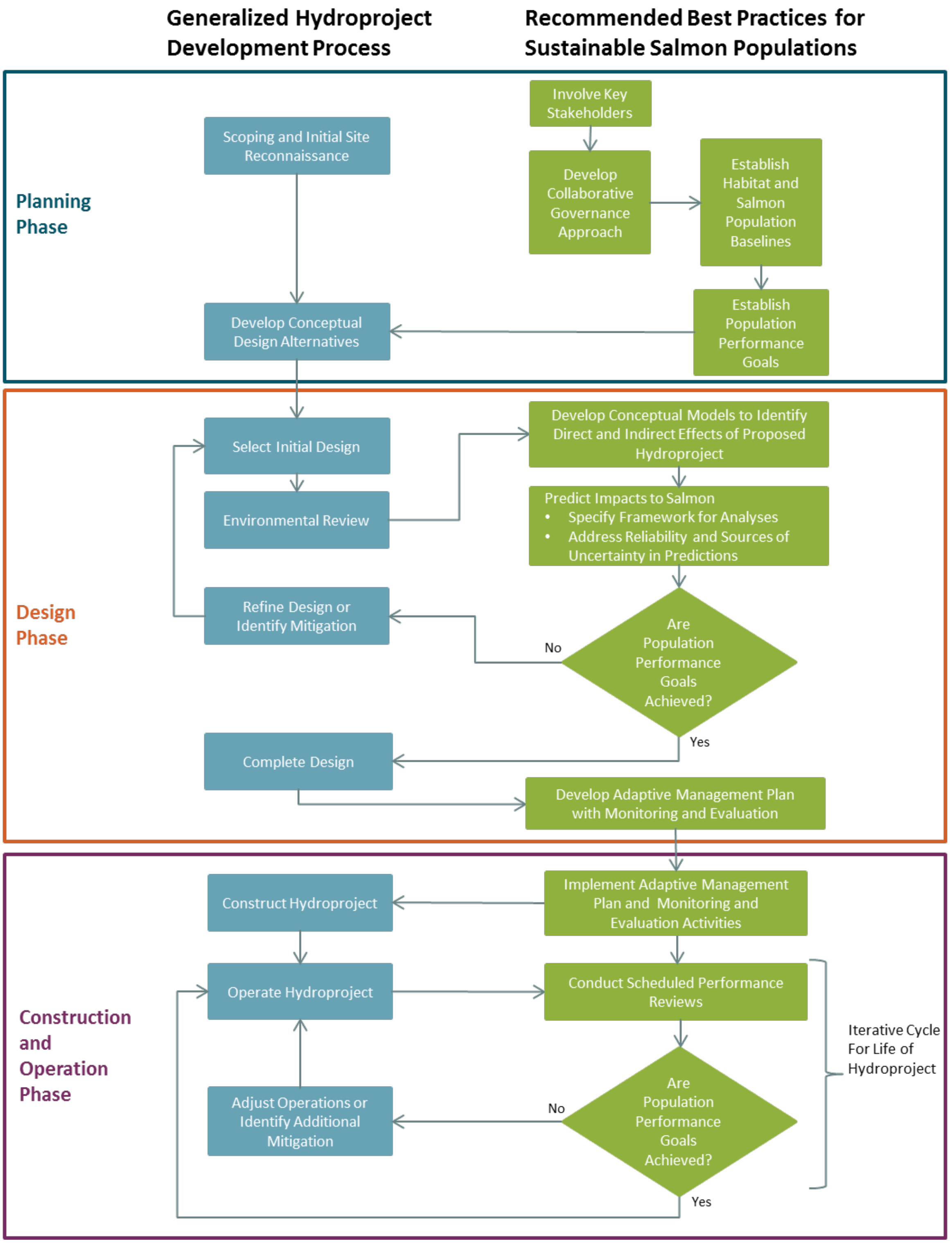


Figure 6

Recommended Steps and Integration between Best Practices for Salmon Populations and the Generalized Development Process for Large-scale Hydroproject

6.1 Planning Phase

The planning phase represents the best opportunity for preserving sustainable salmon populations when scoping, site evaluations, and preliminary hydroproject design alternatives are being considered. During the planning period, recommendations include the following: 1) focusing on stakeholder involvement; 2) identifying collaborative decision-making processes; 3) establishing salmon and habitat population baselines; 4) identifying population performance goals for salmon that are affected by the proposed hydroproject; and, finally and most importantly, 5) incorporating performance goals into the hydroproject design.

The participation of key stakeholders that place a high priority on sustainable salmon matters in setting the trajectory of sustainability for a project. We recommend adopting a "collaborative governance" approach to maximize the contributions of each stakeholder towards achieving sustainable salmon populations (Ansell and Gash 2008):

> *A governing arrangement where one or more public agencies directly engage non-state stakeholders in a collective decision-making process that is formal, consensus-oriented, and deliberative and that aims to make or implement public policy or manage public programs or assets.*

Ideally, the distribution of responsibility among stakeholders can build trust, promote more effective management (Brody 2003), and shift stakeholder interactions from adversarial to cooperative (Armitage et al. 2008).

Conducting a baseline inventory of the species and habitat processes provides a reference point from which impacts can be predicted, monitored, and evaluated. In the Report, we identified four metrics or "population parameters"—abundance, productivity, diversity, and spatial structure—that are commonly used to characterize Pacific Salmon populations. The baseline should also depict how the population parameters vary over time, ideally based on decadal timeframes or longer, recognizing that detecting meaningful population changes is complicated by natural variation on seasonal or annual timescales (NOAA 2011).

Stakeholder collaboration and baseline data provide the foundation to explicitly define the population performance goals that are necessary to maintain sustainable salmon populations. If sustainability is defined by quantifiable goals, such as acceptable levels of change in abundance, productivity, spatial structure, and diversity parameters, the "sustainability target" can be scientifically evaluated and reviewed by stakeholders. Scientific review, in turn, provides an opportunity to reinforce the credibility and durability of sustainability goals that may require stakeholder approval and will be in place for multiple decades. A final benefit of defining explicit population performance goals during the planning process is their potential role in shaping the design of a hydroproject to minimize impacts to Pacific Salmon. Under this scenario, population performance goals become "design criteria" at a point where design modifications are still feasible.

6.2 Design Phase

The design phase covers the period between the selection of a preferred conceptual design and the completion of the design process. During this period, licensing studies are implemented and environmental review processes are conducted. Ideally, this early design is developed with salmon population performance goals as a portion of the design criteria. During the design phase, recommendations include: 1) using conceptual models to identify direct and indirect effect pathways between project activities and impacts to salmon; 2) predicting impacts to salmon; 3) evaluating whether predicted impacts allow achievement of salmon population performance goals; 4) developing adaptive management and monitoring and evaluation plans; and 5) identifying mitigation needs.

Developing conceptual models of direct and indirect effects before engaging in quantitative analyses of these effects is important. Specifically, conceptual models would allow stakeholders to evaluate the pathways of anticipated direct and indirect effects prior to allocating resources to specific in-depth licensing studies, ensure that project effect pathways lead to population performance metrics, and enhance communication of anticipated project impacts among stakeholders.

Formalizing project-related impacts in a simulation model framework can inform decision-making by providing estimates of the population-level outcomes associated with different hydroproject scenarios. The generalized framework that we suggest involves two stages: the first stage maps project impacts to habitat in a physical river simulation model and the second stage maps habitat impacts to salmon populations through a life-cycle simulation model.

Because rivers and salmon populations are complex and interact dynamically, uncertainty always accompanies management decisions. Adaptive management is a philosophy of natural resource management that begins by recognizing that knowledge of ecological systems is incomplete and provides a structure for making decisions under uncertainty while simultaneously reducing the uncertainty (Holling 1978; Williams and Johnson 1995). Within this structure, stakeholders seek to develop management actions, then implement actions as one would a scientific experiment, followed by monitoring the system and rigorously measuring and documenting results. The final step is to evaluate the system to determine if the management actions had the predicted effect.

As the design phase progresses and the predicted impacts from a large-scale hydroproject become clearer, mitigation may be necessary to minimize negative impacts and help achieve population performance goals. Hydroproject mitigation that clearly addresses a population-limiting factor or a specific mechanism causing mortality may substantially improve the performance of an affected wild population. Not all mitigation results in a clear benefit, however, if mitigation actions create additional conservation issues that can challenge the performance or recovery of the mitigated species.

6.3 Construction and Operation Phase

The construction and operation phase represents the culmination of planning and design efforts and the active on-the-ground portion of the project. The construction and operation phase begins when the construction activities commence, and continues through the operational life of the hydroproject. Ideally, the population performance goals identified at the initial planning phase would be fully realized upon construction and operation of the project, and stakeholders and collaborative governance would remain important as adaptive management is actually implemented. The simplified adaptive management process is iterative and would continue for the duration of the project. The adaptive management approach contemplates a simplified dichotomy: if performance goals are met, operations continue; if they are not met, operations are modified or additional mitigation is identified.

The iterative process keeps performance goals and sustainability in focus over the life of the project. This approach relies on the existence of clear linkages between performance metrics and specific management actions identified during the development of the adaptive management plan and as informed by the accumulation of data and knowledge over multiple performance review cycles.

The following examples represent success stories where new collaborative approaches and adaptive management during the operation phase have led to successful outcomes for salmon. In each example, salmon populations have rebounded following the major declines attributed in part to hydropower developments:

- Improved flow management resulted in better survival of incubating sockeye salmon in the Okanogan River
- Different combinations of operational and infrastructure improvements reduced juvenile dam passage mortality through Upper Columbia dams
- Coordination of hydroproject operations improved the flow regime to support fall Chinook salmon incubation and rearing objectives in the Hanford Reach, the only free-flowing stretch of the Middle Columbia River

There is a considerable body of knowledge related to the development and implementation of adaptive management plans and the use of collaborative processes. Our recommendation is to use both from the beginning of the project and to consider previous case studies to guide the development of specific plans for future large-scale hydroprojects in Alaska.

7 CONCLUSION

Large–scale hydroprojects can significantly alter the habitat processes and attributes, which wild salmon require. In the Report, we present information and conceptual models that are intended not only to show the linkages between impacts of a hydroproject to salmon habitat and the responses of salmon populations, but also to demonstrate the complexity of those relationships.

One of the key conclusions of the Report is the importance of defining clear endpoints for analyzing population risks. Specifically, population abundance, productivity, diversity, and spatial structure are established in the Report as quantifiable endpoints for predicting and evaluating project impacts to wild salmon.

In the case of the proposed Susitna-Watana hydroproject, salmon habitat and populations would clearly be affected but there is a high degree of uncertainty about the magnitude or probability of the risks. Defining project operations and completing baseline studies will be necessary first steps to fully assess the impact or risk of a project to individual salmon populations. Moreover, once the results of baseline studies are available and an operational plan has been selected, this information should be incorporated into an analysis that provides an explicit prediction of population outcomes. To achieve the sustainability of salmon, population performance goals must be made a priority in the planning, design, and operation of a hydroproject rather than an afterthought. The overall goal should be to protect salmon at the inception of a project rather than attempt to recover impaired populations in the future. We recommend a salmon population sustainability plan that includes stakeholder collaboration and adaptive management from the beginning of developing a hydroproject, to perpetually support salmon populations after a dam is in place.

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