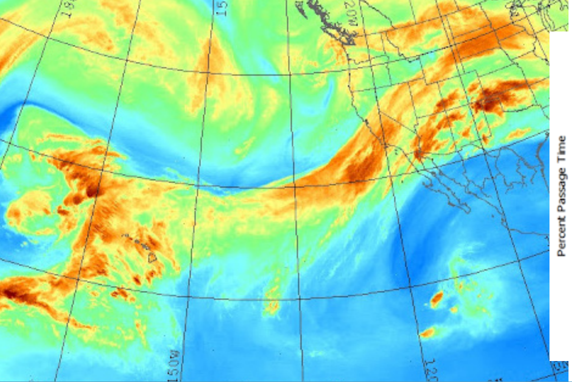

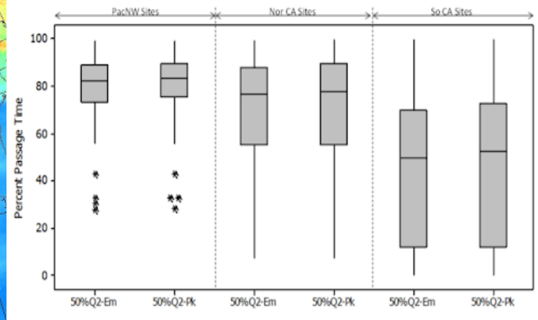

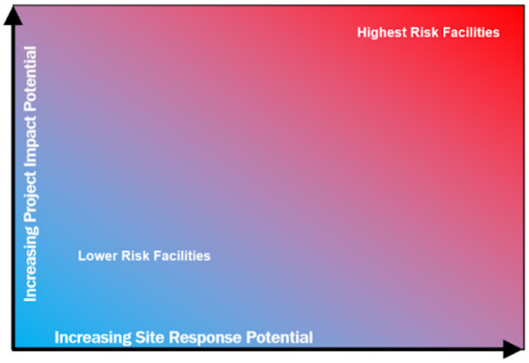

NOAA Fisheries Pre-Design Guidelines for California Fish Passage Facilities

NOAA FISHERIES

NOAA FISHERIES PRE-DESIGN GUIDELINES FOR CALIFORNIA FISH PASSAGE PROJECTS

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Acknowledgements

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Definitions

Adaptive Management Plan: A plan that includes what and when certain actions will be done to meet biological goals and objectives if an implemented project fails to perform as expected. It is a process to apply information learned to improve management decisions if biological goals and objectives are not met.

Anthropogenic Limiting Conditions: Any anthropogenic structure or activities that prevent a watershed from achieving the abundance and diversity that existed under historic watershed conditions.

Application Package: The information provided to NMFS for project review. Seeking NMFS' technical assistance prior to submitting an application package is strongly recommended.

Attraction Flow: The flow emanating from all fishway entrances is defined as attraction flow. All flow emanating from technical fishway entrances, including the auxiliary water supply, is considered attraction flow. All flow contained in a ramp is considered attraction flow. Flow coming from nearby spillways, penstocks, etc., is not considered attraction flow.

Barrier: Any condition within a stream that reduces the historic migration opportunity of fishes within the stream. Anthropogenic barriers may be created by infrastructure such as dams and culverts or the alteration of stream flows. A barrier may delay or reduce migration opportunity, or prevent migration altogether.

Basis of Design Report: A report providing information supporting the design. The report describes the process used to arrive at a proposed project design and also demonstrates how the proposed design, operations, and monitoring and maintenance plans will lead to the conservation of fish. A set of design plans (engineering drawings) should also be included. Working with NMFS during basis of design report drafting is recommended.

Biological Goals: The intended biological conditions or outcomes for a proposed project. For example, some biological goals and objectives may focus on increasing anadromous fish abundance, diversity, and resiliency. These should be developed in consideration of the biological needs of the target species, and the conditions of the project site and watershed in which the project is located.

Biological Objectives: The steps and actions needed to achieve a project's biological goals.

Biological Performance Metric: Any numeric metric used to determine how effectively a project is meeting its biological goals and objectives. Examples of potential biological performance metrics include the maximum amount of time a fish may be delayed, the maximum percentage of fish that can be injured passing through/around a facility, the amount of spawning, rearing, habitat available, and the timing, frequency and duration of time which fish have access to specific habitats.

Consultation/Consultation Process: Federal action agencies consult with the federal consulting agencies (i.e., NMFS and the U.S. Fish and Wildlife Service) under section 7(a)(2) of the Endangered Species Act (ESA) for projects with the potential to affect ESA-listed species or their designated critical habitats.

Delay: Any increase in the amount of time that fish need to migrate from one location to another due to an anthropogenic barrier or activity that prevents fish from moving as quickly as they would under historical watershed conditions. Examples of delay include time fish may spend trying to find fishway entrances, time leaping against spillway flows that are not passable, and time resting due to fishways with difficult passage conditions.

Design Alternatives: Different means of achieving a project's goals and objectives. This may be in the form of different facilities, different fishway types, different project operations or a combination thereof. The purpose of comparing design alternatives is to find the design alternative that best meets the overall project goals and objectives.

Design Attraction flow: The attraction flow that is recommended for fish passage when the stream discharge equals the high fish passage design flow.

Design Plans: Engineering drawings showing the layout, physical dimensions and specifications for a project.

Effectiveness Monitoring: A component of a project's monitoring and maintenance plan that focuses on measuring how well a project is meeting the biological goals and objectives of a project.

El Niño-Southern Oscillation (ENSO): is a recurring climate pattern involving changes in the temperature of waters in the central and eastern tropical Pacific Ocean. This oscillating warming and cooling pattern directly affects rainfall distribution in California and can have a strong influence on weather across the United States and other parts of the world.

Engineering Criteria: Numerical specifications that NMFS recommends for the design, maintenance, or operations of a fishway or fish passage appurtenance.

Extirpation: The local or regional extinction of a species. For the purposes of these Pre-Design Guidelines, the elimination of a fish species from a specific stream or watershed.

Facility/Facilities: Any infrastructure that stores water, diverts water or alters a stream's hydrologic or sediment regime (e.g., dams, pumps, diversions, and infiltration galleries).

Facility Components: All of the structural elements of a facility that are necessary to meet the non-biological goals and objectives of a project (e.g., dam, spillway, turbines, penstocks, diversions, pumps, etc.).

Facility Design: The physical layout of all the facility components of a facility.

Facility Goals: The conditions or outcomes that need to be achieved by the facility that are not biological goals of the project. Facility goals include such things as the desired timing and amounts of water to be stored, diverted or used to generate hydropower at a proposed or current facility.

Facility Objectives: The steps and actions needed to achieve a project's facility goals.

Facility Operations: The timing, frequency, duration and amounts of flow being stored, diverted, released or flowing over spillways, through penstocks, sluice gates, etc.

Fish: Anadromous fish, unless specified differently.

Fish Passage: The conditions that allow for fish to move past a barrier. To 'provide fish passage' refers to the act of providing hydraulic conditions, instream flow and water quality sufficient to provide fish a means of accessing crucial habitats at the times, frequencies and duration of time required to provide for their life cycle needs. Fish passage and fish passage engineering is primarily concerned with eliminating or reducing the impact of anthropogenic barriers and other anthropogenic limiting conditions impairing fish migration.

Fish Passage Appurtenance: Any mechanical structure or electrical device that is used in conjunction with a fishway to collect and transport fish or allow fish to volitionally pass around or over a facility. Fish passage appurtenances also include any mechanical or electrical devices intended to protect fish from disease, injury or death (e.g., fish screens preventing fish from entering irrigation canals, etc.). Examples of fish passage appurtenances include: gates, traps, pumps, pickets; fish counting/sorting areas, etc.

Fish Passage Design Flows: The low and high fish passage design flow, and all discharges between.

Fish Passage Engineering: The design, construction, operation, monitoring and maintenance of artificial fishways and fish passage appurtenances that allow fish to either volitionally, or by collection and transport, move upstream or downstream of a particular location within a stream. Fish passage engineering also includes evaluating and prescribing the instream flows needed for fish to access the various habitats they need to complete their life cycle.

Fishway: A ladder, flume, channel or ramp used to allow fish to swim around/over a facility or into a trap/collection and transport area.

Fishway Operations: The timing, frequency, duration, range of discharge/river stages and other conditions (e.g., amount of attraction flow) that support fish passage at fishways.

Geomorphic Assessment: A study of a watershed's hydrologic regime, sediment regime, geology, land use, topography, and temporal changes to help determine the current stability of streambeds within a watershed, as well as how channel beds within a watershed are likely to change over time and under various watershed disturbance scenarios.

Guidelines: Guidance for developing a project that will provide fish passage. Guidance may be general, specific, qualitative, and/or qualitative, depending on the specific condition or component being addressed. Quantitative guidance is referred to as "criteria" or "criterion."

High Fish Passage Design Flow: The highest stream discharge at which a fishway is designed to provide safe, timely and effective fish passage.

Historical/Historically: Refers to watershed conditions/times prior to European watershed development.

Historical Limiting Conditions: The condition(s) within a watershed that limited the maximum abundance and diversity of fish prior to European development in the watershed.

Hydraulic Design: A type of fishway designed to allow target fish species and life stages to pass based on their swimming abilities. Specifically, the fishway is designed such that depth, velocity, turbulence, hydraulic drops and other hydraulic parameters are within the tolerances for which the target fish species can swim through.

Hydrologic Regime: The hydrologic conditions relative to aquatic habitat that are intrinsically related to connectivity between surface and subsurface water. Attributes of a hydrologic regime include the timing, frequency, and duration in which various amounts of discharge or volumes of water occur in aquatic environments as dictated by the climate, watershed land cover, seasonal distribution of precipitation, and human water use.

Limiting Conditions/Factors: The conditions within a watershed that limit the abundance and diversity of fish.

Low Fish Passage Design Flow: The lowest stream discharge at which a fishway is designed to provide safe, timely, and effective fish passage.

Migration: The movement of fish to/from and within any habitats which are crucial for fish to successfully complete their life cycles.

Migration Opportunity: The timing, frequency and duration of time that fish have the physical ability to move to, from, and within any habitat(s) needed to complete their life cycle.

Monitoring and Maintenance Plan: A plan describing what monitoring and maintenance activities will be conducted to ensure that fishways and fish passage appurtenances are performing as expected at all times when fish are migrating. A monitoring and maintenance plan also includes descriptions of the biological performance metrics and effectiveness monitoring activities implemented to ensure that a project's biological goals and objectives are met.

Pacific Decadal Oscillation (PDO): A robust, recurring pattern of ocean-atmosphere climate variability centered over the mid-latitude Pacific basin, affecting coastal sea and continental surface air temperatures from Alaska to California.

Partial Width Fishway: A fishway that does not span the entire width of the stream. For fish to use a partial width fishway, they must be able to locate the fishway entrance(s) to move upstream.

Population: In this document, a group of fish of the same species that spawn in a particular location at a given season and do not interbreed substantially with fish from any other group (Bjorkstedt et al. 2005; NMFS; 2012a, 2012b, 2013, 2014a, 2014b, 2016).

Population Abundance (Abundance): The total number of individual organisms in a population. For this document, abundance refers to the total number of spawning adults within a population. (McElhany et al., 2000; NMFS; 2012a, 2012b, 2013, 2014a, 2014b, 2016).

Population Diversity (Diversity): The underlying genetic and phenotypic (life history, behavioral, and morphological) variation providing for population resilience and persistence across space and time (McElhany et al., 2000; NMFS; 2012a, 2012b, 2013, 2014a, 2014b, 2016).

Population Productivity (Productivity): The measure of a population's ability to sustain itself overtime (*e.g.*, returns per spawner); also known as a population growth rate (McElhany et al., 2000; NMFS; 2012a, 2012b, 2013, 2014a, 2014b, 2016).

Population Spatial Structure (Spatial Structure): Geographical arrangement of populations based on dispersal factors and quality of habitats (McElhany et al., 2000; NMFS; 2012a, 2012b, 2013, 2014a, 2014b, 2016).

Population Viability (Viability): Refers to a population having a negligible risk (< 5%) of extinction due to threats from demographic variation, natural environmental variation, and genetic diversity changes over a 100-year time frame. A viable Distinct Population Segment (DPS) consists of a sufficient number of viable populations spatially dispersed, but proximate enough to maintain long-term (1,000-year) persistence and evolutionary potential (McElhany et al., 2000; NMFS; 2012a, 2012b, 2013, 2014a, 2014b, 2016). The four parameters that form the key to evaluating population viability are: population abundance, population productivity (growth rate), population spatial structure, and population diversity (McElhany et al., 2000).

Project Components: All project infrastructure (e.g., dam, pumps, turbines, spillway, fishway, and fish passage appurtenances, collectively).

Project Goals and Objectives: Both the facility (non-biological) goals and objectives and the biological goals and objectives of a project.

Project Operations: All facility operations, including fishway and fish passage appurtenance operations.

Ramp/Roughened Ramp: A partial or channel spanning grade control reach used for fish passage that is steeper than adjacent stream reaches. A ramp can take many different forms (e.g., step-pool, cascade, chute and pool, etc.). A ramp can be constructed of natural material or have concrete/steel baffles as part of its design. Roughened ramps are also referred to as roughened channels or rocky ramps.

Recovery Plan: A document that the federal services (i.e., NMFS and USFWS) produce under ESA Section 4, which describes the most important actions needed to conserve and recover a particular listed species.

Reference Reach: A stream reach that is evaluated to help develop and assess suitable passage at a project location. A reference reach should be adjacent to or near the project reach and should provide fish passage and maintain or promote desirable geomorphic processes. The ideal reference reach is one that has limited anthropogenic influences, reflects historical channel conditions and is of sufficient length to accurately characterize the stream's average slope, cross-sectional shape, bed features, streambed material, and hydraulics. In impaired watersheds, finding a reference reach reflecting historical channel conditions may require identifying a reach that is representative of the current geomorphic processes and provides fish passage.

Resiliency/Robustness: Refers to the ability of fish or ecosystems to persist and has two key aspects: (1) resistance to change; and (2) the ability of the system to recover. These aspects are supported by flexibility - the amount of perturbance a system can experience without that change being essentially irreversible, and developmental robustness - "the capacity to stay 'on track' despite the myriad vicissitudes that inevitably plague a developing organism" (Keller, 2002; Leven and Lubchenco, 2008).

Run-of-the-River Dam: Run-of-the-river dams have the same or nearly the same flow entering the reservoir as passing the dam at any given time. Their primary purpose is increased head for diversion or hydropower generation, not flood control or water storage.

Sediment Regime: The spatial and temporal distributions of the type, amount, and sizes of sediment being transported, deposited, and eroded along a stream. A watershed's sediment regime is dictated by its climate, hydrologic regime, geology, geomorphology, and land use, or watershed condition.

Site-Specific Conditions: The location within the watershed a project is being proposed and the specific conditions at that location affecting the project's design alternatives and biological goals and objectives (e.g., local topography, infrastructure, channel width, channel slope, bed material, etc.). **Stream Simulation Design:** A fishway designed to allow target fish species and life stages to pass based on matching reference reach conditions (e.g., average slope, cross-sectional shape, geomorphic features and hydraulic conditions at various discharges).

Surface Collector: A means of providing outmigrants passage over barriers. A surface collector typically consists of a platform which has a set of vee-screens attached to it that lead fish either to a trap or a bypass pipe. Flow between the vee-screens leading to the trap/smolt bypass pipe is produced either by pump or gravity flow.

Technical Assistance: Services provided by NMFS to project proponents prior to a project proponent requesting consultation. The purpose of technical assistance is to help a project proponent develop a project that reduces impacts to trust species and/or supports trust species.

Volitional Passage: Fish passage whereby fish transit a fishway under their own swimming capability, using timing and behavior they choose. Volitional passage means fish can enter, traverse, and exit a passage facility under their own power, instinct, and swimming capability. The fish pass through the fishway without the aid of any apparatus, structure, or device (i.e., they are not trapped, mechanically lifted or pumped, or transported).

Watershed Approach: Using a watershed assessment to guide the selection of biological goals and objectives that are needed to provide fish passage and guide the selection of appropriate project design and operation alternatives for a specific project.

Watershed Assessment: An assessment of the significant factors influencing anadromous salmonids within a project watershed at all relevant spatial and temporal scales. A watershed assessment supports the identification of appropriate biological goals and objectives and helps set appropriate facility, fishway and fish appurtenance designs based on the watershed's historical and current limiting conditions, hydrologic regime, sediment regime, geomorphic processes, climate, ecology and project site-specific conditions.

Watershed Conditions: The state of the physical and biological characteristics and processes within a watershed that affect the soil and hydrologic functions supporting aquatic ecosystems, both current and historic.

1 INTRODUCTION

The successful conservation of fish is a central design goal of anadromous fish passage projects. Incorporating fish conservation into fish passage design requires understanding life cycles, habitat needs, and the complex interactions between biological and physical processes that determine overall population abundance and diversity. Considering these factors during project conceptualization, design and implementation can result in projects that help conserve fish populations by improving conditions that support increased abundance and diversity.

NMFS is mandated by U.S. Congress to manage, conserve, and protect living marine resources under the authority of various Federal statutes, including the Endangered Species Act (ESA), and the Magnuson-Stevens Fishery Conservation and Management Act (MSA). This guidance document highlights the complex interactions between anadromous fish life cycles, watershed conditions, and limiting conditions, and guides project proponents through the process of considering these factors when designing projects. This guidance is based on first principles and established science and is generally applicable to any region, although the examples used to support the document are focused on California. NOAA's National Marine Fisheries Service's (NMFS) prior guidance on fish passage focused predominantly on providing engineering design criteria for different types of fishways and fish passage appurtenances across the west coast of the United States (California, Oregon, Idaho, and Washington). While the prior guidance often resulted in successful projects in California, the hydrology and watershed drivers of many California watersheds warrants additional consideration during project design. To help practitioners develop projects well-suited to California, we provide these *Pre-Design Guidelines for California Fish Passage Facilities.* The Pre-Design Guidelines offer an overview of the design phases of project development, support early engagement with NMFS, and highlight important considerations for projects implemented in California.

1.1 AUDIENCE

This document is written for biologists, engineers, hydrologists, ecologists, geomorphologists, and anyone interested in better understanding the factors that NMFS considers when evaluating proposed fish passage projects. More specifically, the document describes how numerous factors directly or indirectly related to fish life cycles, along with current and historical watershed conditions, influence the type of facility, the facility operations, the fishways, the fish passage appurtenances, and the monitoring and maintenance plans appropriate for a particular project. NMFS hopes that this guidance helps project proponents efficiently develop and implement fish passage projects that optimize the conservation of anadromous salmonids.

1.2 SCOPE

This document provides a framework to assist in the development of facilities, fishways, and fish passage appurtenances, as well as operational, monitoring, and maintenance plans necessary for the successful operation of such facilities. Within this framework approach, design factors are discussed, but specific engineering criteria for various fishways and fish passage appurtenances is generally not provided. For engineering criteria on facility fishways and fish passage appurtenances, see NOAA Fisheries West Coast Region Anadromous Salmonid Passage Design Manual (NMFS 2022b).

Recognizing that many projects may need to conserve both anadromous and non-anadromous fish species, this guidance presents broad scientific principles and general terms wherever possible. To support this, we highlight how NMFS guidance might integrate with guidance from other agencies for non-anadromous fish species. For example, when conserving any fish species, it is crucial to understand their life cycles, biological needs, factors that create limiting conditions for those species, and how climate, geomorphology, hydrology and other watershed process drivers work in a dynamic and interactive way to create habitat and limiting conditions. It is important to identify all of the species of concern and set inclusive biological goals and objectives early in a project's development. Therefore, while this document focuses on anadromous fish, project proponents are encouraged to consider impacts on other species of concern and seek input from the agencies responsible for conserving those species.

1.3 USING THIS GUIDANCE WITH OTHER NMFS GUIDELINES

In 2013, the Northwest and Southwest regions of the National Oceanic and Atmospheric Administration's (NOAA) NMFS merged to form the WCR. The NOAA Fisheries West Coast Region Anadromous Salmonid Passage Design Manual (2022b) was developed to integrate fish passage design criteria and guidelines of the two former regions. That document supersedes the following documents:

- Northwest Region's Anadromous Salmonid Passage Facility Design, dated July 2011
- Southwest Region's Fish Screening Criteria for Anadromous Salmonids, dated January 1997
- Southwest Region's Experimental Fish Guidance Position Statement, dated January 1994
- Southwest Region's Water Drafting Specifications, dated August 2001

The WCR also released three other guidance documents:

- NOAA Fisheries WCR Guidance to Improve the Resilience of Fish Passage Facilities to Climate Change;
- Guidelines for Salmonid Passage at Stream Crossings in Oregon, Washington, and Idaho;
- Guidelines for Salmonid Passage at Stream Crossings in California.

To assist project proponents with navigating this suite of fish passage guidance documents, the WCR developed a flow chart for how these documents work together (Figure 1).

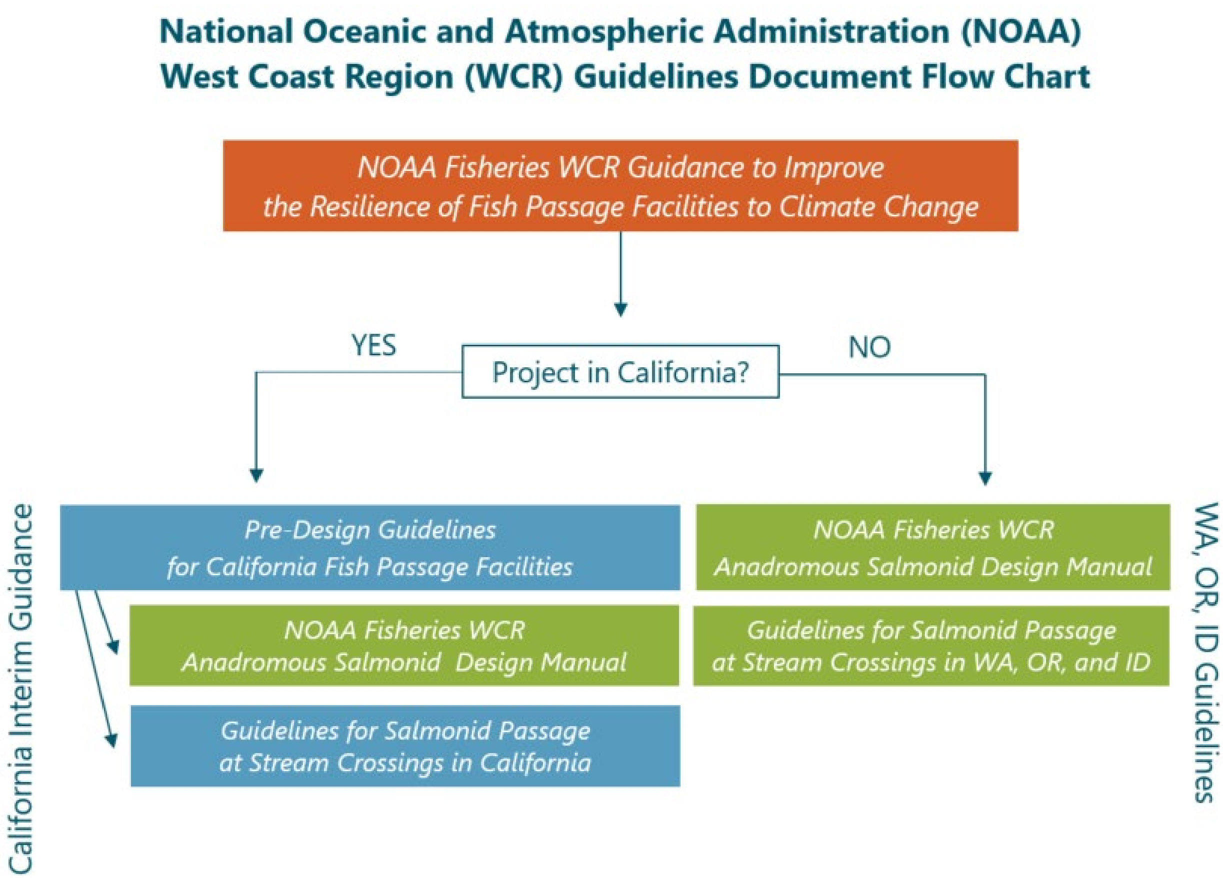


Figure 1. Flow chart of NMFS guidelines documents applicable for the West Coast Region.

When proposing or designing fish passage projects in California, project proponents should familiarize themselves with this document and with:

1. The "*NOAA Fisheries WCR Guidance to Improve the Resilience of Fish Passage Facilities to Climate Change*" (NMFS, 2022a), which provides guidance on accounting for climate change in the planning, design, and operation of facilities;
2. *NOAA Fisheries WCR Anadromous Salmonid Passage Design Manual* (NMFS, 2022b), which describes typical engineering criteria for common fishways and fish passage appurtenances used at facilities (e.g., trash racks, auxiliary water supply systems, fish screens, etc.); and
3. *Guidelines for Salmonid Passage at Stream Crossings in California* (NMFS, 2023), which provides guidance specific to achieving fish passage at road crossings.

Applying these documents and obtaining technical assistance from NMFS throughout the design process (see Section 5 – Interacting with NMFS) will help project proponents design and implement fish passage projects well suited to California's regional hydrologic, geomorphic, and ecologic conditions.

1.4 DOCUMENT LAYOUT

To help project proponents apply the concepts presented in these pre-design guidelines, this document is organized around six main sections:

- **Key Concepts of Fish Passage at Facilities** provides a high-level overview of several topics that underpin the design, evaluation and selection of project alternatives. The purpose of this section is to provide the context that project proponents need in order to have a basic understanding of how facilities can affect fish, what types of projects typically have the most risk, and how watershed and site-specific conditions influence the overall risk of a project. This section also highlights the importance of understanding historic and limiting conditions along with using a watershed approach to develop projects that meet biological goals and objectives and represent a "low risk" to fish.
- **Watershed Conditions affecting Anadromous Fish** considers information on various hydrologically-related trends found within the West Coast Region (WCR) that can play a significant role in determining what types of projects and what types of operations may, or may not be acceptable based on watershed and site-specific conditions. Specifically, this section briefly describes how regional differences in climate and hydrology result in watersheds having different migration opportunities for fish; hydrologic alterations by major dams; sediment regimes and geomorphic responses to perturbations; and biological goals and objectives that need to be met in order to conserve trust species. A basic understanding of this information is important to prevent a project proponent from inadvertently pursuing a project that is inappropriate for their particular watershed, even

though the same project may be acceptable in another watershed with a different set of prevailing conditions.

- **Developing Biological Goals and Objectives** considers biological goals on par with facility goals by considering the limiting conditions, watershed conditions, facility effects, engineering criteria, and risk to fish. Developing biological goals and objectives at the outset of the project design process is necessary for developing an acceptable final design.
- **Interacting with NMFS** provides general recommendations for how NMFS prefers project proponents interact before and during the development of their project. This section includes recommendations on how to identify appropriate project goals and objectives, lists typical information needed by NMFS to evaluate the suitability of a project, and offers recommendations for when a project proponent may want to seek technical assistance and feedback from NMFS.
- **Recommendations for California's Climate and Watershed Conditions** provides recommendations for some specific design topics that are of special concern in California's watersheds.
- **Summary and Checklist** provides a synopsis of the main themes of this guidance document and a list of questions we recommend project proponents carefully consider before and during the development of facility projects in California.

2 KEY CONCEPTS OF FISH PASSAGE AT FACILITIES

This section provides a high-level overview of several concepts that significantly influence the selection, design and evaluation of projects that represent low risk to anadromous fish. Section 3 then expands on watershed conditions within California that are integrally related to limiting conditions and how these watershed conditions can influence a project's design.

2.1 FACILITY GOALS AND OPERATIONS

Facility goals describe the purpose of a facility (e.g., water storage, power generation, water diversion/transfer, flood control, etc.). Facility operations detail how a facility will be operated in order to achieve its goals (e.g., the timing, duration, and amounts of water to be stored and used to generate electricity, etc.). Facility goals and facility operations may conflict with the measures needed to conserve fish. Where such conflicts arise in a project, NMFS will provide recommendations, when possible, that are likely to allow a project proponent to meet their facility goals while conserving NMFS' trust species. These recommendations may include using different types of fishways or different operational schemes that would meet both NMFS' biological goals and the facility goals. In some situations, it may not be possible to fully meet facility goals while simultaneously supporting fish passage needs. In such situations, NMFS will work with a project proponent to develop a project that comes as close as possible to meeting facility goals and facility operations while still conserving NMFS' trust species. It is crucial that NMFS fully understands a project proponent's facility goals and operations plan before design commences on facility, fishway, and fish passage appurtenances. Likewise, if a project proponent understands NMFS' biological goals and objectives for a particular watershed and location before pursuing a project design and operation and maintenance plan, they are much less likely to propose a project that NMFS will not find acceptable without major alterations. An iterative process will be needed to understand and accommodate project proponent and agency goals.

2.2 ENGINEERING CRITERIA

The *NOAA Fisheries WCR Anadromous Salmonid Passage Design Manual* (NMFS, 2022b) provides engineering criteria for fishways and fish passage appurtenances commonly used at dams. The purpose of providing criteria is to help ensure that various types of fishways and fish passage appurtenances perform appropriately if they are selected and needed as part of a project. Specifically, those guidelines provide various numerical criteria for the proper design and functioning of fishways and fish passage appurtenances. Examples of engineering criteria include the recommended minimum water depth, maximum water velocity, and energy dissipation factor for fish ladders, and the mesh size, porosity, and approach velocity for fish screens.

A common misunderstanding among project proponents is that a project design and operating plan considered acceptable at one location is automatically acceptable at another location. The standard design criteria apply in many circumstances, and are a good reference for what has been shown to work well in a general sense; however, they are not universally applicable without site-specific considerations. Some reasons that the standard design criteria may not protect fish at particular project locations include: differences in species or life stages present, variations in hydrologic and geomorphic processes, spatial and temporal effects of a facility on fish migration to-and-from crucial habitats. For these reasons there is a need to select a fishway type that is well suited to unique watershed conditions in which the project is located. Additionally, NMFS' engineering criteria, while adequate at many locations, may need to be modified at other locations for biological, geomorphic, or hydrologic reasons in order to conserve fish in a project watershed with unique characteristics. There is no substitute for site-specific analysis and customized project-specific design criteria, particularly for projects that are complex or represent a high risk to fish. To help project proponents develop projects that are well-suited to the particular site, watershed, and salmonid population need, NMFS recommends project proponents see Section 3, which highlights many watershed and site-specific conditions that can affect facility design.

2.3 PROJECT RISK

Meeting project goals and objectives, and adhering to appropriate engineering criteria, is key to a successful project outcome. Minimizing project risk to fish is equally important. Frequently there may be multiple alternatives to minimize and mitigate the facility's impacts on fish. In such cases, it is advisable to select the alternative with the lowest risk. Watershed conditions should be considered during alternative selection. For example, some dams and water diversions are located in watersheds where high sediment or organic debris loads potentially interfere with both fishways and facility operations. In these situations, careful thought is required to design the project in a manner that prevents sediment and debris from preventing fish passage during the migration seasons. Finally, it is important to understand that minimally meeting or achieving multiple biological goals, objectives, and engineering criteria significantly increases project risk. For example, the additive effects of designing a fishway to operate according to minimal performance criteria (e.g., the shallowest flows, highest velocities, and highest turbulence values that the strongest swimming fish are capable of navigating) significantly increases the probability that the project will fail to provide consistent migration opportunities for all fish species and age classes. Consistent migration opportunity directly supports migration behavior in fish as they attempt to traverse multiple habitat types throughout their life cycle.

2.4 LIMITING CONDITIONS

The factors that prevent fish from increasing in abundance and diversity are known as limiting conditions/factors (see Booth et.al., 2016). First proposed by Reeves et al. (1989), the concept of limiting factors is useful for planning when habitat required by a species during a particular season or life stage is in short supply. The shortage of this habitat thus limits the system's full potential for supporting the selected organism, and thus limits the population of that organism. Watersheds all had naturally occurring historically limiting conditions that controlled the abundance and diversity of fish within the watershed. However, over the past century, limiting conditions are becoming more widespread and increasingly anthropogenic in origin. Introducing additional limiting conditions may result in an insufficient amount of suitable habitat to provide the resiliency needed for long-term population viability.

2.4.1 HISTORICAL AND ANTHROPOGENIC LIMITING CONDITIONS

Restoring habitat where it has been lost may seem to be the obvious solution to addressing limiting conditions. However, such an approach often misses the population-scale analysis necessary to identify the habitat types most limiting for species or ecosystem recovery, or the determination of whether those identified limiting factors are symptomatic of more fundamental impairments. An example is fixing a fish passage barrier (a hydraulic change) but not addressing the effect of drainage changes related to timber harvest (a hydrologic limiting factor), or changes in hydrology due to climate change. Simply building more habitat without a clear understanding of the physical process drivers and the role habitats play in the life history of the target species is unlikely to be biologically successful. Case studies have typically emphasized the poor success in achieving measurable biological gains solely through manipulation of physical habitat, particularly in the absence of any broader analysis of whether that habitat is truly limiting from a population perspective. Such outcomes have been reported from a variety of locations and watershed contexts, particularly channels in highly disturbed urban watersheds where altered flow regimes and water chemistry are more impacted than physical habitat. In less disturbed watershed settings, results are commonly more biologically successful, but rarely do they approach full recovery of the instream and biological conditions found in unimpaired settings (see Booth et.al., 2016).

When designing fish passage facilities, it is important to consider the limiting factors within a watershed and not just on a reach scale. This helps identify causes rather than symptoms. For example, it may be possible to address one or more limiting factors with facility design and operations (e.g., by providing passage, sediment transport, and flows necessary for species and habitat). To help ensure comprehensive consideration of limiting conditions when developing a project, a watershed approach is recommended to give context to reach scale analysis and project design.

2.4.2 FACILITY EFFECTS

Facilities can change the local hydraulics or the stream's hydrologic regime, depending on the scale of the facility relative to the stream flow or relative to the watershed. The same is true for sediment transport, where a small-scale facility can create a local sediment problem while a large-scale facility can affect the entire downstream fluvial system. Facility effects can have numerous direct and indirect effects on the ability of fish to complete the freshwater phase of their life cycle. Effects can be immediate and proximal to the installation, and also delayed and distant, depending on the scale of the facility relative to the watershed hydrology and sediment transport processes. Facilities which significantly affect the hydrology or sediment transport processes of streams may:

- Alter the timing, frequency, duration, magnitude, and rate of change of flows downstream of the facility;
- Disconnect floodplains and access to rearing habitat for juvenile fish;
- Disconnect the river from the ocean and estuary, or affect the timing and duration of such connectivity;
- Disconnect the main stem of the river from its tributaries;
- Deplete downstream aquifer storage that affects both base flows and the surface flow response to rainfall and runoff events;
- Eliminate or degrade the biological value of mainstem and tributary habitats, including spawning, rearing, sheltering, migratory and refugia habitats;
- Alter the timing, frequency and duration of time fish have access to main stem and tributary habitats of important biological value;
- Degrade water quality to a point where it cannot support fish and a sustainable assemblage of native aquatic organisms that constitute a healthy, resilient food web;
- Alter sediment and/or wood routing processes that create and maintain salmonid habitat downstream and upstream of the facility, and may create costly and untimely facility maintenance requirements;
- Increase predation rates and human poaching;
- Introduce or promote the spread and abundance of invasive species;
- Strand or isolate fish in unsuitable habitats, or artificially concentrate fish and spawning activity; and
- Degrade riparian habitat.

If one or more of the aforementioned processes is sufficiently impaired, the ability for anadromous fish to move to and from the ocean, estuary or within important freshwater habitat maybe compromised, potentially creating anthropogenic limiting conditions. The number and types of anthropogenic limiting conditions that a facility might create depends on the type of facility, along with its operations and maintenance practices, which effect the spatial and temporal scales over which the facility is affecting hydrology, hydraulics, geomorphic processes, and habitat. In some cases, avoiding the creation of additional limiting conditions may be accomplished simply by not materially reducing migration opportunity to any habitats used by fish. In other cases, particularly when water impoundment or withdrawals are involved, a project may need to take measures to avoid creating one or more limiting conditions. Such limiting conditions are often related to changes in water quality, instream flow, habitat changes (due to disturbance of historic fluvial processes), increased predation, negative food web interactions, and loss of riparian habitat, among other effects.

The aforementioned list of potential facility effects highlights that fish passage is not simply about providing a means for adult anadromous fish to migrate past a facility, but that facilities and their operations can create life cycle problems for aquatic species at a wide variety of spatial and temporal scales. Consequently, all of the potential effects that a facility may have on fish in all of their life stages (throughout the watershed) need to be identified and evaluated prior to selecting design alternatives to compare, and prior to selecting a preferred design. After identifying all of the existing limiting conditions, and new project effects, including those that may rise to the level of anthropogenic limiting conditions, biological goals and objectives can be set to eliminate or effectively minimize those effects. See section 4 below for more information on developing biological goals and objectives.

2.5 PROJECT RISK ANALYSIS

The overall risk that a proposed project represents depends on several factors that the project proponent can control. Those factors include: the type of facility; the degree to which the facility alters a stream's historic hydrology and/or geomorphology; the operating, monitoring, and maintenance plan for the facility; the facility's location within the watershed (site selection); the type and severity of the facility's effects; and the effectiveness, safety (for fish), and reliability of the fishway and fish passage appurtenances. Some types of facilities represent a much greater risk to fish than others. Facilities that often have the greatest risk are those that store or divert large amounts of water in drier climates. The overall risk of a proposed project to negatively impact fish also depends on factors that the project proponent does not control. These factors include the regional climate and hydrology, and the watershed geomorphology, geology, and vegetation. The latter factors often determine the historical limiting conditions and migration opportunities within a watershed and play an important role in how much and how fast a watershed will respond to any project disturbances. Streams in drier climates typically offer much less migration opportunity than those in wetter climates. Any further loss of migration opportunity in drier climates has a proportionally larger impact on fish than in a wetter climate. Facilities can also negatively affect channel forming processes which create suitable habitats such as pools and riffles, and the distribution and sorting of spawning gravel patches. As a general rule, regardless of climate conditions, the larger the amount of water being stored or diverted relative to the stream's unimpaired yield, the greater the risk to fish. Therefore, when considering the design and operation of a facility, the hydrologic regime in which the facility is located and the amount and timing of water diverted or stored needs to be carefully considered.

Figure 2 shows a generalized schematic of 'risk factors' associated with project type and watershed conditions that projects need to consider. The y-axis shows several parameters that project proponents have control over that heavily influence a project's overall risk. The x-axis shows watershed conditions that influence the overall risk of a project site independent of the decisions a project proponent makes regarding a proposed facility. Thorough instructions for using the project risk screening matrix can be found in Skidmore et al. (2011). NMFS will use this matrix as a visual tool to help evaluate a proposed project to obtain an initial understanding of the risks, and we recommend that project proponents also plot their project on the matrix. Differences in plotting positions can catalyze productive discussions between NMFS and project proponents about site response potential and project impact potential. The assessment should be approached with a watershed perspective in mind. Depending on where a particular project falls on this conceptual matrix, a better understanding of the anticipated scope and level of detail required in the regulatory review can be gained. For projects involving higher risk, a more thorough scientific and engineering review will likely be required.

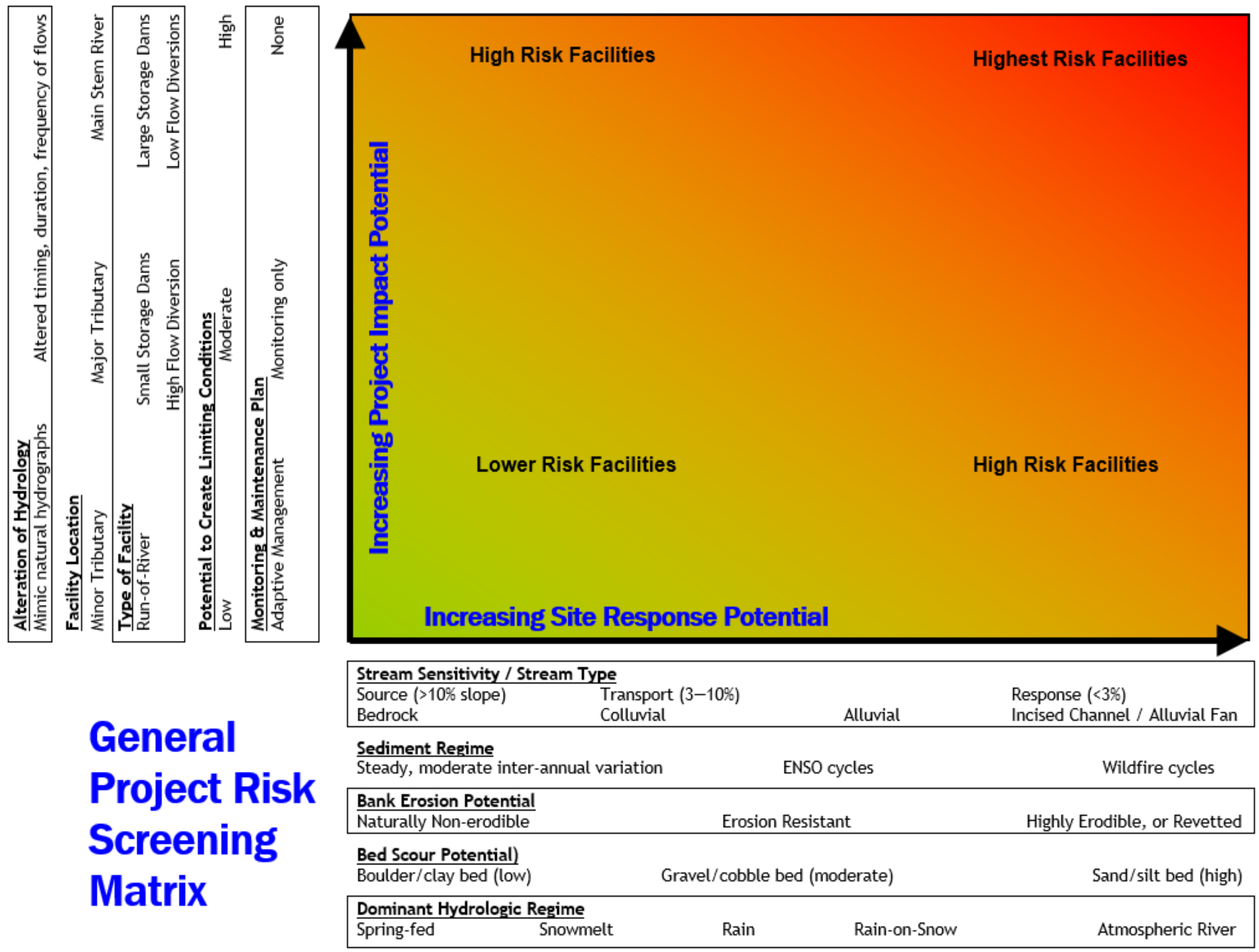


Figure 2. General project risk screening matrix showing site considerations and project considerations that indicate the overall risk a proposed project represents to fish. In general, the higher the risk a project poses, the greater the information needs and deeper technical review are likely necessary. Adapted from Skidmore et al., 2011.

3 WATERSHED CONDITIONS AFFECTING ANADROMOUS FISH

The variability expressed by California's different hydrologic regimes provides ecological benefits and constraints that must be considered. This section explains the appropriate temporal and spatial consideration of climate and hydrologic variability in the design and operation of facilities. Many of the watershed conditions included in the x-axis of Figure 2 are discussed in the following Sections.

3.1 HYDROLOGIC REGIMES AND VARIABILITY WITHIN CALIFORNIA AND THE WEST COAST REGION

Climate throughout the coastal watersheds of the western United States varies from humid mild maritime along coastal Washington, Oregon and northern California, to semi-arid subtropical along the Southern California Coast, to arid warm temperate in the southern portions of California's Central Valley (Figure 3). Strong annual average precipitation gradients occur from north to south, as well as from west to east (Figure 4). These precipitation gradients are driven by temperature patterns arising from the eastern Pacific basin's California Current interacting with topographic variability.

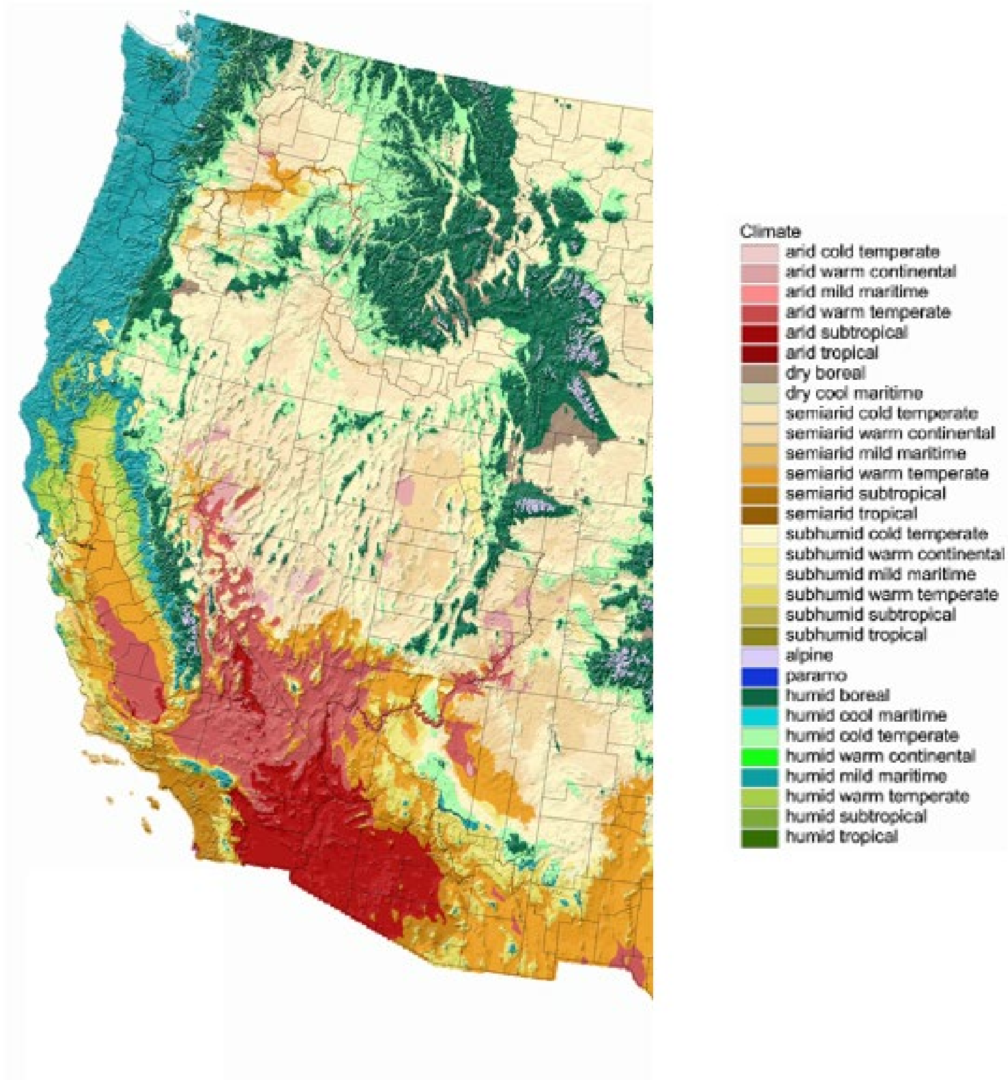


Figure 3. Climate zones of the western U.S. Adapted from source: http://www.bonap.org/Climate%20Maps/climate48shadeA.png

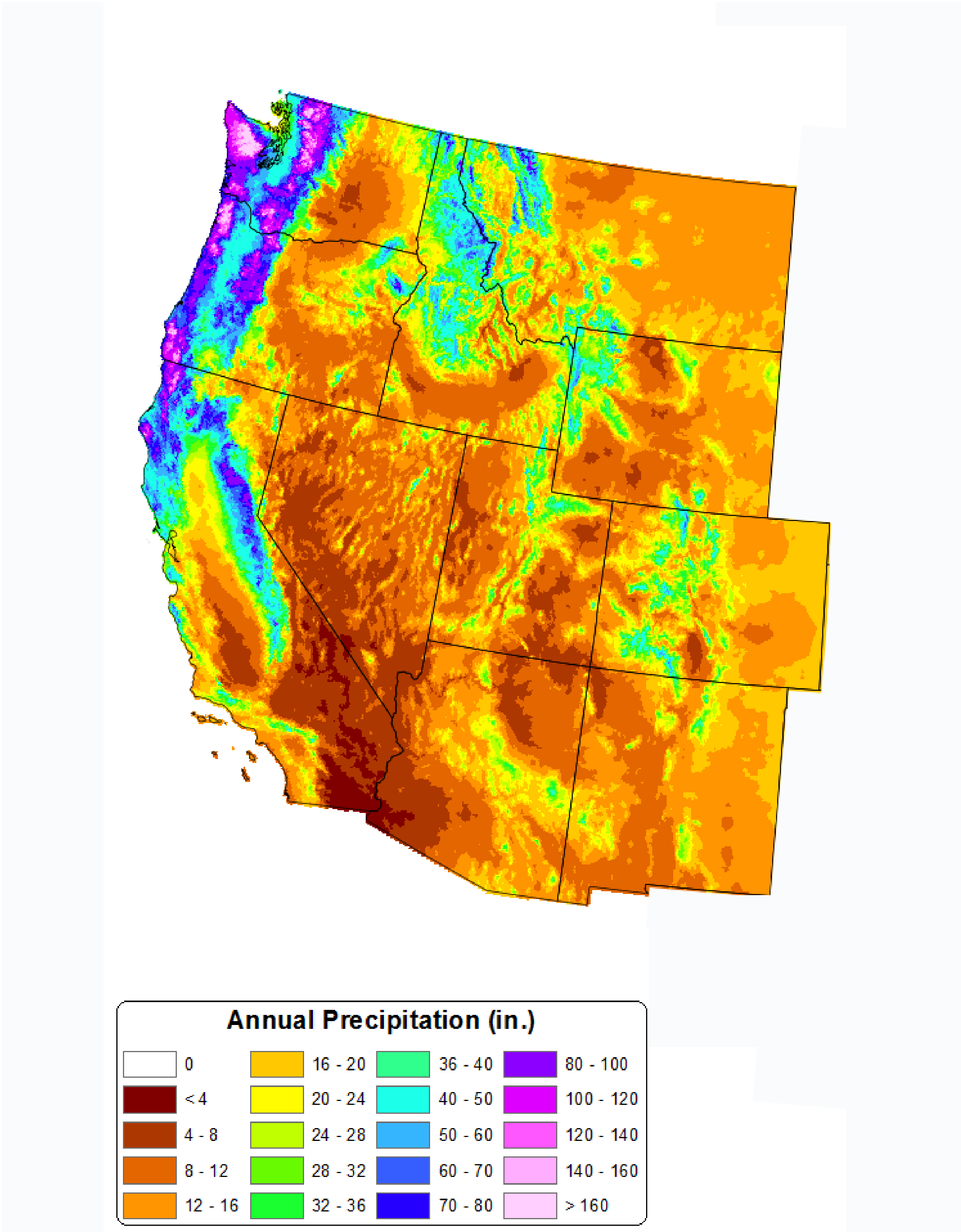


Figure 4. 30-yr annual normal precipitation for the western U.S., 1991-2020. Source: https://prism.oregonstate.edu/normals/

Because of the region's complex topography and sharp climatic gradients, the region's hydrology ranges between snowmelt dominant runoff (in the coldest basins, interior and high elevation), rainfed runoff (in the warmest basins, typically coastal), and mixed snowmelt-and-rainfed runoff basins (in intermediate climate and elevation zones). Of the region's largest watersheds (Columbia, Sacramento/San Joaquin, and Klamath) the Columbia Basin has the greatest snowmelt influence, though many tributaries are characterized by mixed snowmelt-and-rainfed runoff. The Sacramento/San Joaquin Basin is similarly composed of a mix of snowmelt dominant and mixed snowmelt-and-rainfed tributaries, while the Klamath Basin is the warmest of these large basins with most tributaries characterized by mixed snowmelt-and-rainfed runoff or rainfed runoff.

3.2 VARIATIONS IN THE TYPICAL TIMING OF HIGH FLOWS

In cool and wet years, the high elevation tributary basins to the Klamath, Sacramento and San Joaquin Rivers experience an especially large snow pack and abundant snowmelt runoff in late spring and early summer. Basins that are too warm to collect substantial snowpack instead deliver increased runoff in winter when the precipitation falls. Periods of high runoff typically deliver more turbid and higher volume discharge into rivers, estuaries and the coastal ocean, at least to the extent that this runoff is not captured in storage reservoirs.

Storage reservoirs and water conveyance systems (pipelines, aqueducts, canals, pumping facilities, etc.) are extensive in the Western U.S. and have profound effects on habitat availability, and the artificial variations and timing of instream flows. For example, reservoirs may impair sediment transport and fluvial processes necessary for the creation and maintenance of habitat, and altering the timing of flows by capturing winter and spring runoff and releasing that stored water throughout the summer and fall. This can affect fish by exposing them to impaired habitat, and water temperatures and instream flows that are out of sync with life history needs. For reservoirs without passage, fish are confined to downstream reaches affected by altered flows and water quality. For example, in California's Sacramento River and San Joaquin River watersheds, dams block approximately 90% of historical stream length and disconnect over 90% of historical floodplain (TBI, 1998). In watersheds with one or more dams, it is the reservoir and diversion operations that typically dominate the accessibility and quality of the remaining habitat.

3.3 HYDROLOGIC DRIVERS: ENSO, PDO, AND AR

Hydrologic drivers such as El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and atmospheric rivers (AR) affect stream conditions and fish access across the western U.S. These drivers are an important consideration throughout the west and particularly so in the southern portions of the region due to lesser annual rainfall and greater compression of the wet season (i.e., drier with greater concentration of rainfall). Consequently, protecting fish passage becomes increasingly important in the southern portions of the region. The following describes ENSO, PDO, and atmospheric rivers, and the importance of considering hydrologic conditions when developing fish passage designs.

NOAA's Western Regional Action Plan (2016) summarized patterns of historical climate variability for the Pacific Basin. In general, watershed climate patterns and hydrological responses are related to Pacific Ocean Basin scale systematic changes, such as ENSO, which has a cycle a few years long, and the longer cycle PDO. El Niño periods typically deliver relatively warm-dry winters in the northwest U.S. and cool-wet winters in the southwest U.S. This pattern switches during tropical La Niña periods. Variations in PDO typically resulted in relatively cool-wet northwest and warm-dry southwest winter climate in the periods ~1890 - 1924, 1947 - 1976, and 1999 - 2013, and the opposite winter patterns during 1925 - 46, 1977 - 1998, and 2014 - 2016.

Individual storm patterns are strongly influenced by AR, which are elongated corridors in the lower troposphere where water vapor is transported poleward at high rates. AR storms have been identified as the main cause of flooding in the western U.S. (Konrad and Dettinger, 2017). As a highly variable but major regional climate driver, AR storms explain much of the within year hydrologic variability between watersheds in the Western U.S.

Adult migration, spawning, and juvenile fish rearing occurs at different locations throughout the freshwater and estuarine areas of the watersheds. For example, small mountainous streams that support steelhead spawning and early life-stage development are subject to prevailing patterns in snow-pack and rain events. Mainstem rivers, whose instream flow is regulated by dams, may experience further altering of habitats as water flows through the inland valleys, affecting multiple species and life stages. Estuaries and lagoons, both large and small, are highly dynamic and important zones of ecological productivity and present a critical transitional link between the marine and freshwater life stages for anadromous fish. It is certain that sea level rise is occurring and will continue into the future. This changes the dynamics of estuaries and lagoons in various ways, and anticipated changes need to be accounted for in projects that impact this part of coastal watersheds.

In the West Coast States, the massive degradation and loss of freshwater, floodplain, and estuarine habitats, coupled with intensive human use of freshwater resources, have greatly increased the vulnerability of anadromous fishes to climate impacts (National Research Council, 1995; ISAB, 2007; Lindley et al., 2009). The combined effects of climate impacts on rivers, streams, estuaries, and the ocean lead to cumulative impacts on the full life cycle of anadromous fish populations. Considering the combined effects of human uses, hydrologic cycles, and the and status of fish populations is necessary when designing fish passage facilities.

Perennial rain-driven streams are common in the coastal portions of Washington, Oregon, and Northern California, but uncommon in the coastal streams of Central and Southern California, where a prolonged dry season is normal for summer and fall and multi-year droughts are common due to the ENSO cycle. Consequently, many of Central and Southern California's coastal salmonid streams are intermittent, providing continuity between the ocean, estuary and lower mainstem environments and salmonid spawning grounds during only the rainy season or during wet years. As one moves inland from the coasts within Washington, Oregon, and California, predominantly rain-driven streams typically give way to streams that are often predominantly rain and snow-melt driven. California generally receives significantly less precipitation on an annual basis than does the Pacific Northwest. In addition, the timing of precipitation and stream flow is strongly skewed to the winter months from November to April. This is illustrated in Figure 5, which shows regional variation in the timing of precipitation as the percentage of mean annual precipitation that falls in the warm months, between May and October.

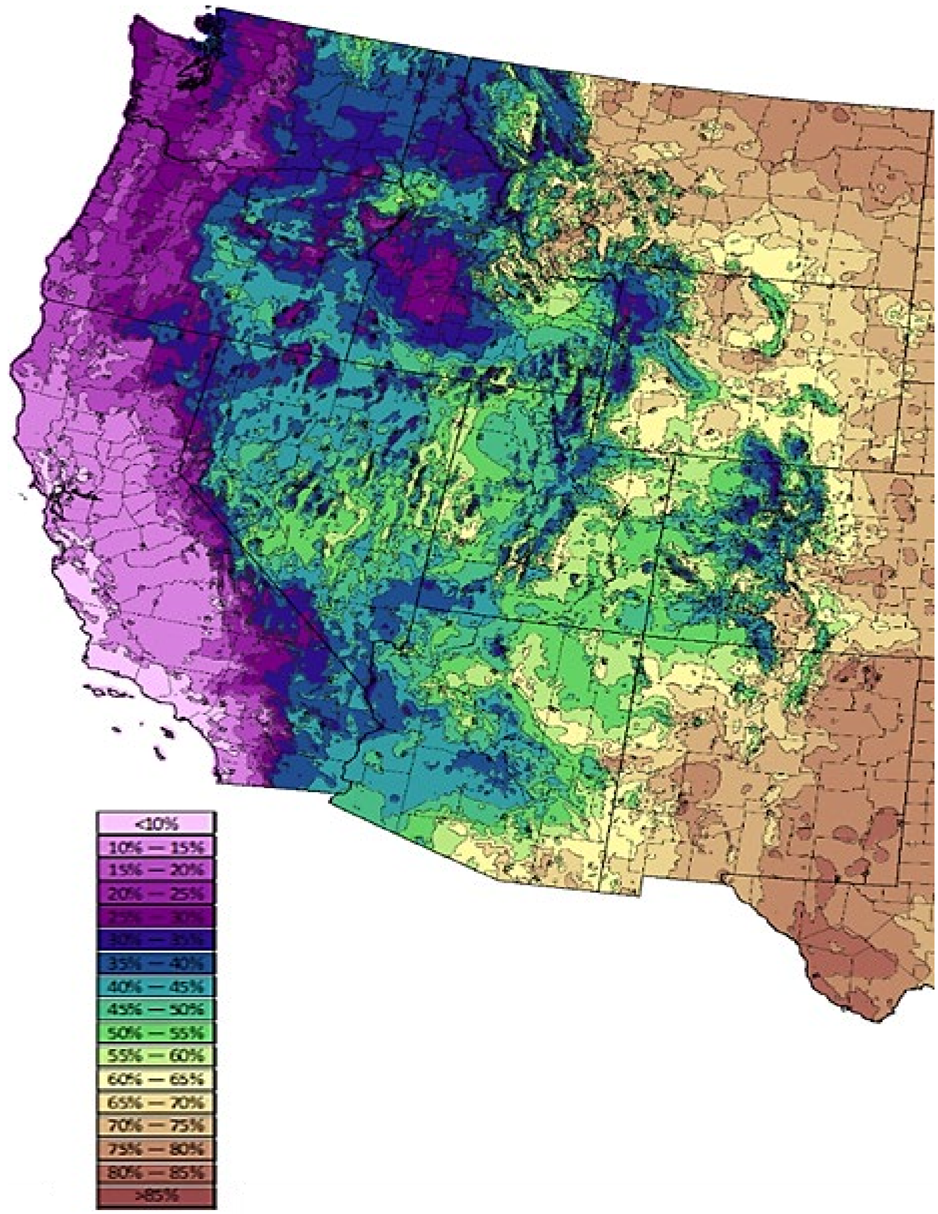


Figure 5. Percentage of mean annual precipitation that falls in the warm months, between May and October, for the western States. Light purple areas, concentrated along California's south coast, receive less than 10% of the annual precipitation during the dry ½ of the year, or more than 90% during the wet half of the year. This skewed distribution diminishes with distance both north and east. Source: bonap.org, using PRISM data.

When considering the hydrology of California, it is also important to consider the high climate variability in non-coastal California (i.e., San Joaquin River and Sacramento River Basin). The San Joaquin and Sacramento River Basin accounts for approximately 43% of the total average annual surface runoff of California; linking rivers that drain the west-slope Sierra Nevada Mountains, Central Valley region, and east-slope of the coastal mountain ranges into a common basin that flows through the Bay Delta to the Pacific Ocean (Null et al., 2014). Within this greater San Joaquin River and Sacramento River Basin, the Sierra Nevada Mountains produce an average of about 26 million acre-feet of annual streamflow that flows west into the Central Valley (Dettinger et al., 2018). In the Sierra Nevada, precipitation falls as both snow and rainfall during the wet season, and it is infrequent during the dry season except for high elevation thunderstorms (Null et al., 2010). Table 1 shows the high variability of precipitation in the Sierra Nevada due to elevation, latitude, and local weather patterns from North to South. As with the coastal basins, considering the variability in runoff patterns is important when designing fish passage facilities in non-coastal California.

Table 1. Physical characteristics in 15 west-slope watersheds of the Sierra Nevada range (north to south). Source: Null et al. (2010).

Watershed	Abbreviation	Area (km^2)	Mean Precip. (cm/yr)	Precip. Range (Min–Max) (cm/yr)	Elevation Range (m)	Northing Centroid (km)	Max Strahler Stream Order
Feather	FEA	9,412	121.5	36.6–301.4	275–2,853	4,425	7
Yuba	YUB	3,114	167.5	83.2–223.6	76–2,772	4,370	6
Bear	BAR	730	122.1	63.2–187.0	90–1,772	4,334	5
American	AMR	4,822	135.8	63.0–203.6	39–3,163	4,313	7
Cosumnes	COS	1,385	107.3	58.9–143.4	55–2,359	4,275	6
Mokelumne	MOK	1,498	123.3	57.8–164.3	72–3,162	4,261	6
Calaveras	CAL	937	86.5	55.3–142.8	212–1,851	4,231	5
Stanislaus	STN	2,341	115.9	64.8–168.1	211–3,520	4,238	6
Tuolumne	TUO	3,971	110.1	43.5–172.8	245–3,989	4,206	6
Merced	MER	2,685	104.5	50.1–159.3	245–3,990	4,174	6
San Joaquin	SJN	4,315	101.4	35.5–159.1	97–4,224	4,139	6
Kings	KNG	3,998	96.4	50.1–154.5	177–4,349	4,094	6
Kaweah	KAW	1,451	94.0	36.8–151.1	154–3,846	4,047	6
Tule	TUL	1,015	76.4	28.6–119.2	174–3,119	4,008	6
Kern	KRN	5,983	56.0	24.4–147.3	171–4,418	3,992	7

Similarly, each of California's hydrologic regimes provide different ecological benefits and constraints that should be accounted for in the design and operation of facilities. For example, Figure 6 shows how the year-to-year variability in the median annual water yield dramatically increases in small coastal watersheds as one moves from the Pacific Northwest to Southern California. This information indicates that facilities in watersheds with large fluctuations in annual water yields need to be designed to operate effectively over a wider range of water yields than a similar facility where annual water yields are less variable, in order to have similar risks to fish.

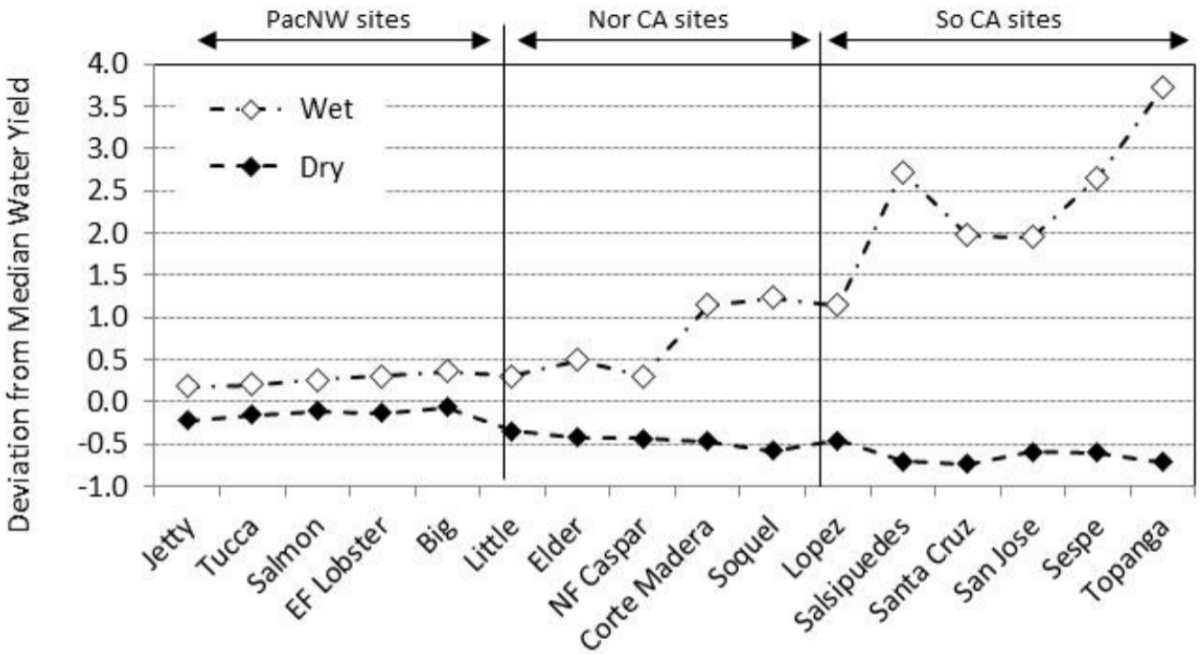


Figure 6. Deviation from median annual water yield indicating climatic and hydrologic variation along the west coast from Oregon to Southern California. Comparison of the upper 20th-percentile water yield (lower boundary of Wet year yields) and the lower 20th-percentile water yield (upper boundary of Dry year yields) expressed as the deviation from the median annual water yield. Sites are arranged from north to south moving left-to-right along the x-axis. Notice the spread between dry and wet years increases dramatically in the southern direction. Source: Lang and Love, 2014; Figure 5.

3.4 SEDIMENT REGIMES

Sediment is often inadequately accounted for in the design and operation of projects in California and is a key reason why many projects negatively affect habitats downstream and some projects ultimately fail. Climate, geology, and land use influence watershed erosion and sediment yield. Generally, sediment yield has more variability than does the watershed hydrology. Sediment regimes must be understood for proposed projects to perform as intended and to persist as planned.

An important contributing factor to sediment related problems and project failures is that sediment data are sparse and where there are data at gauges those records rarely cover periods of time long enough to understand temporal sediment yield dynamics. Therefore, sediment rating curves are commonly biased. Sediment rating curves are typically developed over relatively short time periods (i.e., a few years). This can result in rating curves with up to ten times the potential error compared to rating curved developed over a few decades (Gray, 2018), suggesting that the risk of falsely characterizing the long-term (inter-annual scale) suspended sediment behavior of a river through a period of elevated or depressed behavior may be much higher than expected. Further highlighting the lack of sediment yield knowledge and the associated risks, Warrick et al. (2015) emphasize that global stream flow inventories lack river sediment discharge data from small watersheds, where watershed sediment yields were highly variable in space and time. Small steep coastal watersheds in south-central California experience roughly half the annual sediment discharge in one day per year.

In addition to the general lack of sediment yield knowledge in many watersheds, climate change coupled with changes in wildfire frequency, magnitude and intensity are likely to increase erosion rates and sediment yields in western watersheds over the next several decades. The Sankey et al. (2017) model synthesis predicts at least a 10% increase in post-fire sedimentation for nearly nine tenths of western U.S. watersheds by mid-21st century. Furthermore, Sankey et al. (2017) projects post-fire sedimentation to increase by >100% for more than one third of watersheds by mid-21st century. Many watersheds with projected increases in fire and sedimentation are important surface water supply for downstream human communities.

Along the west coast, the Southern California watersheds experience the most variation in sediment delivery and transport events (Andrews and Antweiler, 2012; Pfeiffer and Finnegan, 2018), driven by the regionally variable ENSO and PDO climate cycles, combined with geology and vegetation. Vegetation growth is linked to these climate cycles and wildfire events are known to coincide with wet high-growth periods (Florsheim et al., 1991). Although hard to predict, these watershed-wide sediment delivery patterns do repeat and can have significant implications for water supply (Maina and Siirila-Woodburn, 2019) and, therefore, for fishes and water infrastructure as well. Because sediment delivery events related to wildfire and ENSO do occur in cycles that repeat, it is important to account for these cycles in the design and operational and maintenance plans of facilities, fishways and fish passage appurtenances. For example, roughened ramps and channel spanning fishways are more likely to pass sediment and debris than are partial width fishways.

NMFS suggests that project proponents design facilities and develop maintenance plans to address the uncertainty of sediment yield data and the adverse effects of sediment events on facilities, fishways and fish passage appurtenances, and incorporate those plans into their application packages. This improves design, helps facilitate timely maintenance actions, and supports efficient regulatory actions following sediment events.

3.5 LAND SUBSIDENCE

Excessive groundwater extraction from alluvial basins leads to irreversible aquifer compaction and associated land subsidence. In parts of California's Central Valley, particularly the San Joaquin Valley, groundwater over-drafting has led to substantial land subsidence (e.g., Sneed et al., 2018). Concentrated groundwater depletion in the Central Valley has caused as much as 9 meters of land subsidence in the last century (Herrera-Garcia et al., 2021). More recently, Vasco et al. (2022) found the highest rate of subsidence in the Tulare Basin (approximately 1 foot per year) and evidence that groundwater storage losses are even greater in the northern Central Valley, although subsidence is not expressed there yet.

The effects of climate change on rainfall patterns is expected to exacerbate the demand for groundwater extraction, likely resulting in further irreversible subsidence. To ensure consideration of land subsidence in project design and operation, NMFS recommends that for all of the Central Valley, existing and future subsidence be incorporated in the design and operation of proposed projects. NMFS further recommends that projects consider potential subsidence in all alluvial basins where groundwater extraction occurs.

3.6 EFFECTS OF INTER-ANNUAL FLOW VARIABILITY ON FACILITY DESIGN AND FACILITY OPERATIONS

Water supply and related water development infrastructure can vary dramatically based on the watershed's climate, land use history, and extent of water development.

In California, where annual precipitation is seasonal and variable, a primary purpose of many large dams is water storage. Specifically, the dams are often designed to store as much water as possible during the wet season and then release the water at a later time (based on water demand). Hydroelectric power generated during the water's release is sometimes an ancillary purpose of the dam.

Large water storage dams typically create more migration challenges for fish than do run-of-the-river dams. These challenges include reservoir water surface elevations that can change dramatically from year to year, seasonally, or within a storm event. From an upstream fish passage standpoint, this may result in the need for a fish ladder with multiple entrances and exits to provide passage over a wide range of reservoir surface elevations. Similarly, when little or no water is being released from a storage dam, a lack of current within the upstream reservoir may prevent surface collectors from functioning as well as they would at a run-of-the-river dam. This is a result of having insufficient current generated from reservoir releases to help attract fish toward the location of a surface collector. Finally, water storage dams dramatically alter flow patterns, predation, and water quality (e.g., water temperature, dissolved oxygen levels, pH, etc.).

The magnitude, timing, duration, and rate of change of flows that occur downstream of a dam can significantly alter fish behavior and habitat far downstream. Some of these impacts will be exacerbated in the future by the effects of climate change.

Project proponents must recognize that some fishways and fishway operations typically used in wetter parts of the range of Pacific salmonids may not be suitable in drier locations due to climatic, watershed conditions, and site-specific conditions. Therefore, on projects capable of impacting watershed conditions, a systematic and scientific process is necessary for helping identify appropriate fish migration and in-stream flow solutions. These solutions should be developed in the context of project goals and objectives, local hydrologic and sediment regimes, watershed geomorphology, current and historical limiting conditions, fish behavior and any existing federal and state recovery or conservation plans.

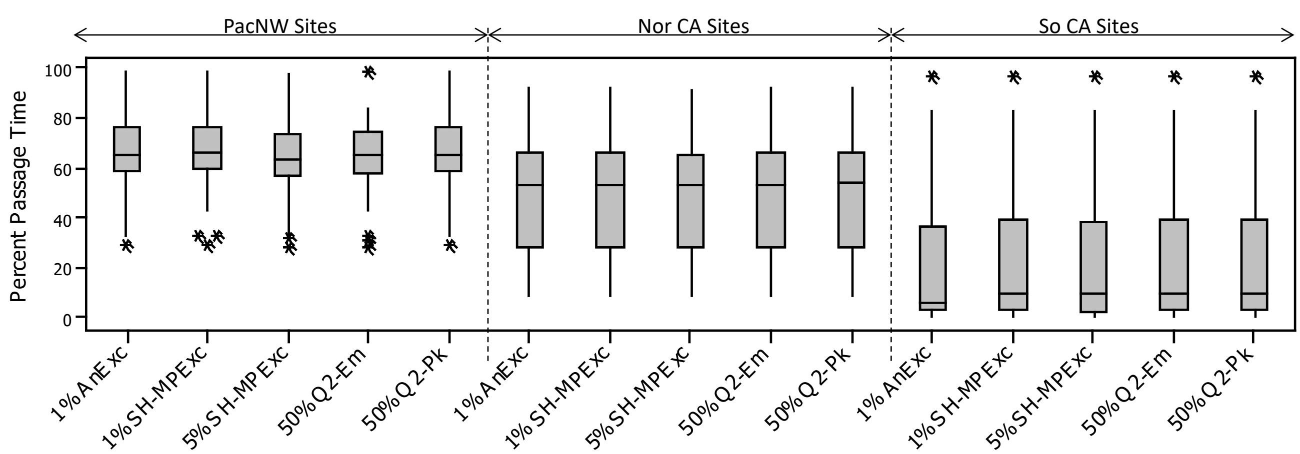
3.7 MIGRATION OPPORTUNITY

Fish have different migration and habitat needs at different stages of their life. Anadromous juvenile fish emerge from their redds and need an accessible migration route to rearing habitats such as floodplains, oxbows, estuaries and lagoons where they have protection from predators and access to food to grow as quickly as possible and prepare to undergo smoltification, whereupon they will migrate to the ocean. Additionally, adult anadromous fish need to migrate from the ocean back to freshwater spawning grounds to complete their life cycle. Steelhead and sturgeon, in particular, need the opportunity to return to the ocean after spawning. In some watersheds, fish need enough time and sufficient opportunity to swim dozens or even hundreds of miles to return to their natal streams for spawning. To provide resiliency against the risk of extirpation or extinction, fish need access to multiple watersheds; watershed-level events (such as wildfires) can periodically make some watersheds, or portions thereof, inaccessible or incapable of providing adequate conditions to meet life history needs.

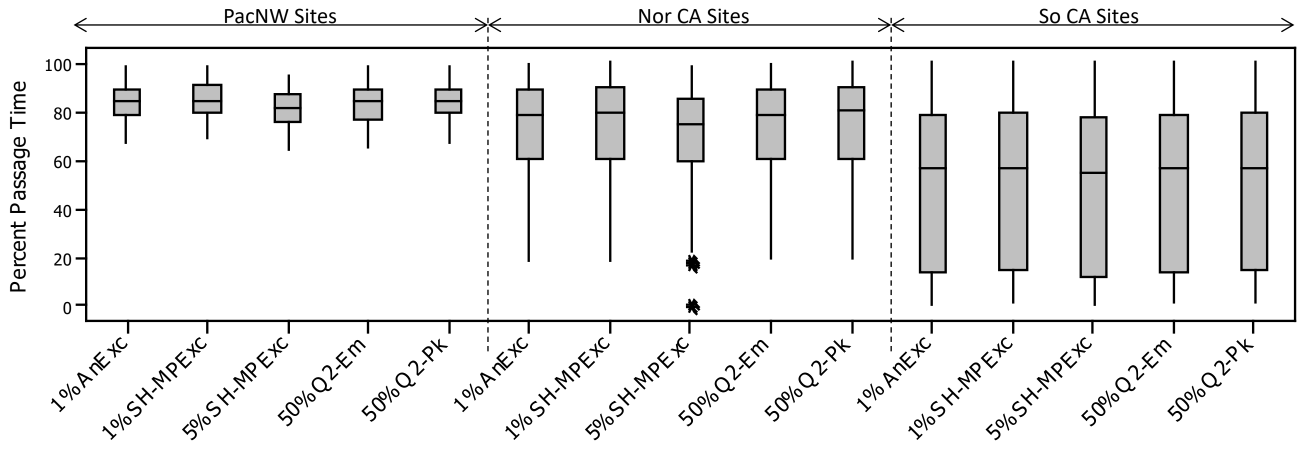
Decreasing the amount of habitat available within a watershed can reduce the abundance and diversity of fish and other aquatic organisms. Likewise, altering the timing, frequency, and duration of time that fish have access to important habitats can also reduce salmonid abundance and diversity. Consequently, it is important to understand the historical and current timing, frequency, and duration of migration to and from various habitats within a project watershed, and how a proposed project will affect those migration opportunities.

Lang and Love (2014) performed a detailed statistical analysis of the hydrologic variability and fish passage opportunity in sixteen coastal watersheds spanning from southern Oregon to southern California. The study found that migration opportunities within these watersheds can vary dramatically based on regional hydrologic conditions and annual precipitation amounts. The amount of time that adult steelhead have to migrate from the ocean to their spawning grounds varies dramatically among the small coastal watersheds. Specifically, steelhead typically have substantially more time to migrate to their spawning grounds in the Pacific Northwest than in Southern California. Unregulated streams along coastal Northern California typically have migration opportunities somewhere between the Pacific Northwest and Southern California extremes. Migration opportunity can vary dramatically from year-to-year and according to the regional climate patterns. For example, migration opportunity for adult steelhead is significantly longer during wet years than dry years in Southern California. Figure 7 illustrates how fish migration opportunity can vary enormously between different regions and watersheds.

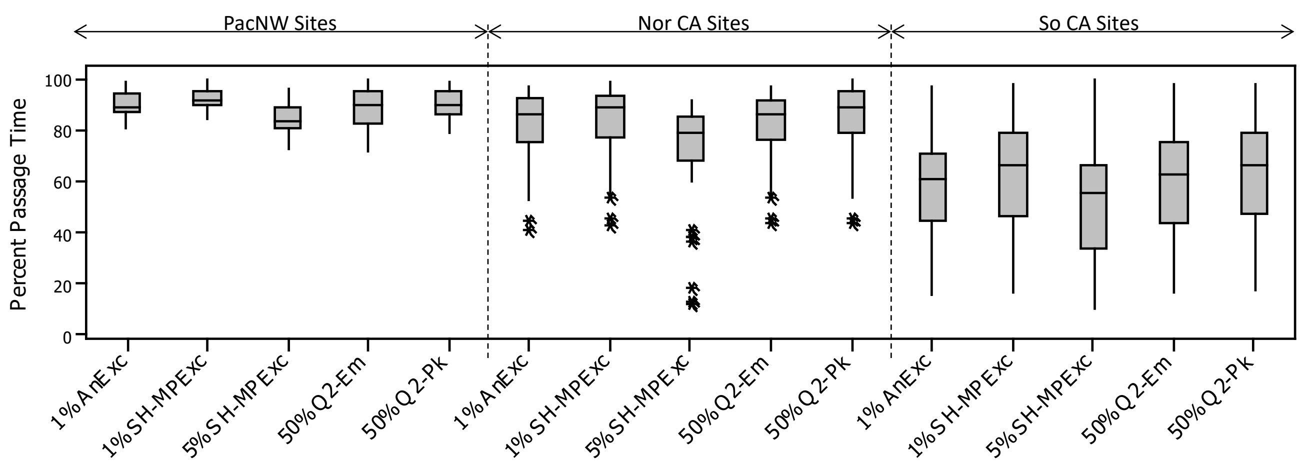
When project proponents are considering their project designs, it is important to account for the historical timing, frequency, and duration of time that fish had to migrate to/from/within all of their key habitats and how a proposed project's conditions will differ from those migration opportunities. Moreover, it is important that project proponents understand that the migration opportunities present in their watershed may differ substantially from those found in other watersheds. These differences need to be accounted for in the design and operations of facilities, fishways and fish passage appurtenances. Finally, it is important to recognize that in watersheds where historical migration opportunity was already quite limited by hydrologic conditions, the additional effect of dam and water diversion facilities generally poses a higher risk of inducing delay (see discussion in Section 6.1: Fish Passage Design Flows).



A. Dry years, percent passage time for different Q_{HFP} criteria.



B. Average years, percent passage time for different Q_{HFP} criteria.



C. Wet years, percent passage time for different Q_{HFP} criteria.

Figure 7. Percent passage time for dry, average, and wet years (A, B, and C respectively), for different high fish passage design flow criteria. As in Figure 6, the differences between the Pacific Northwest and Southern California produce fewer passage days and more variation around passage days. The different high fish passage design flow criteria (shown on the x-axes) follow: 1% annual flow exceedance (1%AnExc); 1% flow exceedance during the steelhead migration season (1%SH-MPEXC); 5% flow exceedance during the steelhead migration season (5%SH-MPEXC); 50% of the 2-year flow event estimated from regional regression equations (50%Q2-Em); and 50% of the 2-year flow event estimated from peak flow stream gaging data (50%Q2-Pk). Source: Lang and Love, 2014; figures 29-31.

3.8 EFFECTS OF STORAGE RESERVOIRS ON MIGRATION OPPORTUNITY

California has an extensive statewide system of reservoirs that profoundly affect anadromous fish and their habitats. For non-coastal California, anadromous fish must pass through the Bay-Delta to migrate between the Pacific Ocean and freshwater systems in the Central Valley (San Joaquin River and Sacramento River basins) (Null et al., 2014). Historically, migration to spawning grounds in the Sacramento and San Joaquin rivers was between 100-300 miles depending on species and spawning location. However, these large storage dams create barriers along river corridors that restrict, and in many cases completely block, access to upstream habitat for anadromous fish species (Grantham and Moyle, 2014). Schick and Lindley (2007) describe how the installation and continued presence of these major dams has blocked and restricted access to much of spring-run Chinook salmon historical habitat in the Central Valley. Figure 8 depicts the location of all major Central Valley "rim dams," both publicly and privately owned. In addition to the major dams, there are numerous high head dams that affect downstream habitat and preclude anadromous salmonid access to headwater habitat throughout California (NMFS, 2012a; 2012b; 2013; 2014a; 2014b; and 2016).

Figure 8. Depicted are the two river basins in the Central Valley, California (Sacramento River and San Joaquin River), the major rivers within those basins that historically contained anadromous salmonids, and the rim dams. Keystone dams are depicted as open circle nodes and are labelled with the year they were installed. Inferred spawning habitat above 500 meters elevation is shown in thick black lines. For clarity, the Sacramento River Delta is omitted from the map. The numbers in parentheses following the river name refer to population ID's that are not used in this document. Source: Schick and Lindley (2007).

In addition to blocking or impairing passage to headwater habitat, large dams also reduce the magnitude and frequency of high-flow events, particularly in the winter and spring months when juvenile salmonid outmigration peaks. Grantham and Moyle (2014) noted that streamflows below dams are often increased in the summer through late-fall to support irrigated agriculture and to expand the winter flood retention capacity of reservoirs. This "flattening" of the seasonal flow regime, resulting from decreased high flows and increased base flows, has been observed in the Sacramento and San Joaquin River basin and all their major tributaries. For example, Figure 9 shows pre-dam and post-dam mean monthly flows for the American River, Sacramento River Basin. This pattern is typical for other large water storage dams as well. These effects have significantly altered instream flow, and disconnected historical floodplain rearing habitats important to juvenile salmonids. Consequently, migration opportunities to the various habitats of biological importance that remain accessible downstream of these reservoirs are often significantly impacted by altered timing and patterns of flow, altered temperatures during migration, and disconnected floodplain rearing habitat.

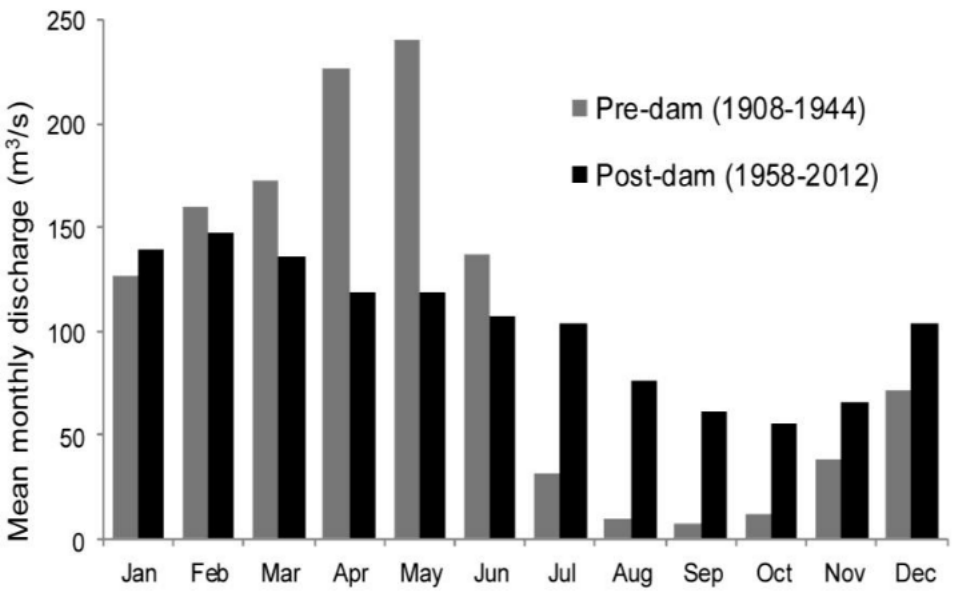


Figure 9. Pre-dam and post-dam mean monthly flows for the American River at Fair Oaks (USGS gage #1144650). Source: Grantham and Moyle, 2014.

Habitat downstream from dams is also affected by reservoirs trapping sediment and wood. This commonly results in channel incision, bed armoring, and habitat simplification. Sediment depletion can extend downstream for miles. For example, Grantham and Moyle (2014) reported that *"since the construction of major dams in the Sacramento-San Joaquin Basin, annual bedload transport has fallen by an average of 45%"* for the mainstem Sacramento River. Reservoirs also trap large wood, depleting habitat structure and wood supply and ecosystem functions related to organic carbon driven processes. This magnitude of change in sediment and large wood supply downstream from dams has significant ecological effects that must be evaluated on a project-by-project basis.

In addition to interrupted sediment and large wood supply, flood plains downstream from large reservoirs are often developed and the associated streams are channelized (straightened) and leveed to support land drainage and flow conveyance. These practices alter the geomorphology of the channels and connectivity with floodplains. Combined with the effects of interrupted sediment, large wood supply and altered flows, the processes necessary for creation and maintenance of habitat downstream from large dams is often fundamentally altered. When project proponents are considering their project designs and impacts, it is important to properly account for sediment and large wood transport and the condition of the downstream channel and floodplain. Project proponents are encouraged to minimize these effects by maintaining continuity of sediment and wood transport, and habitat connectivity.

3.9 CLIMATE CHANGE

Predicting the effects of climate change on rivers, habitat, reservoir operations, and instream flows is quite complex. An in-depth treatment of climate change planning is beyond the scope of this document. However, climate change and associated water management are topics that deserve appropriate pre-design study and assessment, particularly for larger projects, because they may dictate certain changes in facility design and operations or require an adaptive management strategy over the life of the facility.

This document compliments the Guidance to Improve the Resilience of Fish Passage Facilities to Climate Change (Improving Resilience) (NMFS, 2022a). The general trends in the majority of West Coast climate change projections are for increased intensity of climate cycles (longer dry periods and more intense wet periods), more rain-on-snow events in snow-melt dominated watersheds (shifting the timing of runoff), and increased wildfire frequency and magnitude (NMFS, 2022a). The Improving Resilience document should be reviewed and any climate questions or solutions to incorporate climate change into the design and recommendations should be discussed at the time biological goals and objectives are being evaluated following the guidance in the document herein. If certain climate change scenarios are evaluated, one of the products of the climate change scenario plan should be a fish migration opportunity assessment for wet, dry, and average years for each of the anticipated climate conditions being considered. The Fish Element Risk Pathway tables found in NMFS 2022a identify risks associated with different climate change factors and provide actions to consider for each risk. Reviewing the tables is recommended to understand the effects of climate change on the fish passage facility.

4 DEVELOPING BIOLOGICAL GOALS AND OBJECTIVES

Biological goals and objectives often play the most important role in determining what types of facilities can be built and what types of operations can be conducted without negatively impacting fish. The degree and certainty to which various facilities, fishways, fish passage appurtenances and operations meet a project's biological goals and objectives is also important for evaluating the total project risk and serves as a means of comparing different alternatives. NMFS strongly recommends that project proponents: (1) seek technical assistance from agency experts before developing conceptual project designs; and (2) develop biological goals and objectives in parallel with their facility goals and objectives. This helps to ensure that the project includes features and operations that support biological goals and objectives, which in turn helps to streamline the review and permitting process. The following sections identify how case-by-case evaluations, watershed assessments, and analyses can be useful for setting biological goals and objectives. Examples of biological goals and objectives are provided at the end of Section 4.

4.1 ANALYSES TO IDENTIFY BIOLOGICAL GOALS AND OBJECTIVES

To identify appropriate biological goals and objectives, it is important to look holistically at the watershed and to consider all project impacts, not just passage impacts. Some of the information and data analyses that may be required to establish appropriate biological goals and objectives include:

- A **watershed assessment** to help identify relationships between the project site and the larger watershed. This assessment should consider drivers of ecology, hydrology, hydraulics, geomorphology, etc., and the relationship of these drivers to the quality, diversity, and persistence of habitats, and the condition of anadromous fish populations. This starts with a review of available information about the watershed and the physical and biological needs of the anadromous fish during the freshwater portion of their life cycle, and should include historical and contemporary hydrology, geology, geomorphic processes, habitat, ecology, and land and stream alterations.
- **Hydrologic assessments** provide an understanding of the precipitation and runoff patterns in response to rainfall and/or snowfall, the infiltration rate of rainfall into soil and ultimately groundwater basins, and the interaction between groundwater and stream flow (including, but not limited to base flows). Hydrologic assessments must include an analysis of historical flows and the level of impairment at the project site. The analysis should show the effect of the existing hydrologic impairments and the proposed

hydrologic impairments on the habitat needs and migratory behavior of the species in the particular watershed relative to historical wet, dry, and average hydrographs.

- **Limiting conditions assessments** identify what, if any, limiting conditions are within the watershed and to what extent a proposed action could alleviate or exacerbate limiting conditions. For example, a project could alleviate or exacerbate limiting conditions by altering the amount (or types) of habitat, water quality, water temperature, riparian conditions, flow conditions, habitat connectivity, predation rates, etc. Sometimes it is necessary to conduct studies to determine both historical and existing migratory conditions and behavioral characteristics of the population(s) within the watershed in order to identify any anthropogenic limiting conditions within the watershed. Climate change predictions should be included when assessing future limiting conditions (see Section 3.9 Climate Change).
- A **geomorphic assessment** of the watershed to describe a watershed's historical and existing geomorphic processes (e.g., channel dynamics, sediment transport, etc.) that explain various geomorphic reaches and the processes that created and maintained habitat. This provides information necessary to predict future channel adjustments.
- A **migration opportunity study** to quantify the current and historical frequency, timing, and duration of time that fish migrated and have/had access to specific types of habitat within the watershed. This helps inform the extent to which limited access to certain habitats would be a limiting condition under the proposed project.

4.2 PRE-DESIGN STUDIES

In some cases, existing information is insufficient to develop biological goals and objectives and additional studies may be needed to fill information gaps. Such studies may include fish surveys, habitat surveys, fish migration/tagging studies, water quality studies, geomorphic assessments, sediment yield and sediment transport studies, and modeling studies involving hydrology, hydraulics, surface water-groundwater interactions, and sediment transport processes.

Key pre-design study needs for nearly every project include: historical migration opportunity and watershed conditions studies; and existing conditions (e.g., migration opportunity, watershed conditions) studies. To prevent delays in project review and implementation, NMFS recommends that all necessary pre-design studies be identified and started as soon as possible, as some studies could take more than a year to complete.

4.2.1 HISTORICAL CONDITIONS

The first step in understanding how existing and proposed anthropogenic activities may cause limiting conditions is to determine what historical habitats and historical migration opportunities existed within a watershed, and how the species used those opportunities prior to the impairment/development of the watershed. Good sources for this information can be found in NMFS' Recovery Plans, including the related NMFS' Technical Memoranda, as well as in NMFS' Intrinsic Potential Habitat and Critical Habitat maps.[1] With this information it is possible to identify the amounts and types of habitats that have been lost or degraded as a result of anthropogenic activities, and how a proposed action would increase or decrease access to the habitats fish need to maintain a self-sustaining population.

To estimate the historical migration opportunities of anadromous fish it is important to consider:

- Amounts and types of habitats that existed before watershed development (estuary, braided channels, oxbows, floodplain, confined channels, refugia, etc.);
- How those habitats supported salmonid populations (feeding, breeding, sheltering, etc.);
- Amounts and types of vegetation that historically covered the watershed and the river corridor in particular;
- Timing, frequency, magnitude, and duration of the discharges at which fish historically initiated and completed migration to and from biologically important habitats (e.g., tributaries, estuaries, floodplains, backwater habitats, rearing habitats, refugia, and spawning grounds within the project watershed); and
- Description of adult and juvenile fish migration opportunity/patterns across a representative span of wet, dry and average water-year types.

The information described above can typically be obtained by conducting a watershed assessment, along with performing hydrologic and hydraulic modeling in certain cases. The information obtained in the watershed assessment, and hydrologic/hydraulic modeling results provides the information needed to quantify the migration opportunities that anadromous fish historically had within the watershed.

4.2.2 EXISTING (ONGOING) CONDITIONS

After the historic/unimpaired/baseline conditions of the watershed have been identified, it is important to compare those conditions to existing conditions. This provides a basis for identifying any existing anthropogenic limiting conditions within the watershed and how an

[1] Find critical habitat resources at: https://www.fisheries.noaa.gov/national/endangered-species-conservation/critical-habitat

existing facility (if one exists) may be contributing to those limiting conditions. Accordingly, this helps identify appropriate biological goals and objectives.

Some types of information that may be necessary to adequately characterize existing conditions within a project's area of influence include:

- A detailed description of any existing facilities and how they are operated and maintained, including specific records of water diversions and water management practices;
- Existing geomorphic and habitat conditions within the watershed and how they compare to historical conditions;
- How the watershed's existing hydrologic regime differs from historical hydrologic regime during wet, average, and dry years; and
- How migration opportunities during wet, average and dry years have changed due to existing conditions and facility operations (if any).

4.3 EXAMPLE BIOLOGICAL GOALS AND OBJECTIVES

A specific project will have several goals including at least one facility goal such as diverting water, but also biological goals such as passing fish. Goals are often high-level statements of what a project aims to achieve. Objectives are identified conditions, operations, activities or parameters intended to achieve the goals of a specific project. Just like facility goals, biological goals and objectives will vary from project to project. Examples of common biological goals and objectives follow.

- GOAL: Minimize fish passage delay.

  OBJECTIVES:

  - Provide volitional upstream and downstream passage for all species and life stages of concern (this may include non-fish species);
  - Adopt channel-spanning fish passage solutions when possible;
  - Provide passage at all times and discharges when fish are migrating;
  - For fish ladders, maximize attraction flow and provide multiple fishway entrances that are located where fish are most likely to encounter/ find them;
  - Provide hydraulic conditions within fishways which fish can easily swim;
  - Set high and low fish passage design discharges that are similar to the minimum and maximum discharges at which fish can pass within a nearby reference reach, and consider more conservative design discharges where multiple projects and anthropogenic barriers exist.

- GOAL: Insure anadromous fish can complete their lifecycles.

  OBJECTIVES:

  - Provide the instream flows (amount, timing, frequency, and duration) needed to provide access to the watershed and each type of habitat within the watershed that fish need to complete their life cycles (e.g., spawning, rearing, refugia, over-summering, floodplain, and estuarine);
  - Provide multiple locations where fish can access lateral floodplain and backwater habitats.

- GOAL: Develop designs, operations and maintenance protocols that maintain/create desirable geomorphic processes.

  OBJECTIVES:

  - Provide flow hydrographs that mimic historical hydrographs;
  - Provide periodic high flows capable of maintaining or improving geomorphic conditions and inundating floodplains;
  - Prevent alteration of geomorphic processes (such as the passage of spawning gravels and large wood) that create and maintain properly functioning habitat;
  - Maintain (or improve if degraded) spawning and rearing habitat within the watershed by not disrupting historic rates and magnitudes of sediment transport and sorting within the stream;
  - Divert or store water during relatively high stream discharges (i.e., refrain from or reduce diversions at moderate to low stream discharges), but not so much that it affects geomorphic processes or flow connectivity between the mainstem, tributaries, floodplains and estuary/ocean are impacted.

- GOAL: Protect fish from injury, predation and poor water quality.

  OBJECTIVES:

  - Prevent entrainment of fish into diversion canals, plunging over dams, entering penstocks, or going down any flow path (e.g., spillways, sluice gates, weir crests) that may injure, strand, or trap a fish; subject it to delay; or increase predation rates;
  - Prevent the introduction or spread of non-native invasive or predatory species;
  - Maintain (or improve if degraded) good water quality (e.g., appropriate temperatures, dissolved oxygen);
  - Avoid quick reductions in discharge from reservoir impoundment facilities (to prevent the stranding of fish, undesirable suspended sediment concentrations, and other harmful effects).

Some biological goals and objectives are measurable and time bound, and those metrics should be stated (e.g., provide passage with no more than "x" minutes of delay on average). NMFS refers to these as biological performance metrics. A useful description and examples of creating goals and objectives is found in Skidmore et al. (2011, Chapter 4.3).

5 INTERACTING WITH NMFS

NMFS typically evaluates proposed projects on a case-by-case basis. Evaluations are based on whether a project is likely to achieve the biological goals and objectives that are needed to address existing anthropogenic limiting conditions, and to prevent the creation of new limiting conditions. For example, how would flows controlled by a particular project provide appropriate hydrologic cues and physical conditions for anadromous fish to enter and exit the watershed, and to access rearing habitats such as floodplains? Will the project maintain sufficient magnitude, timing, frequency, and duration and rate of change of flow consistent with the hydrologic regime to provide fish sufficient migration opportunity to access biologically important habitats? Will the hydraulics within the localized area of the project components allow for safe, timely and effective fish passage upstream and downstream of the facility? Understanding these relationships facilitates understanding of how a proposed project will likely affect migration opportunities and lead to the identification of goals and objectives that promote the conservation of fish.

5.1 TECHNICAL ASSISTANCE

This section contains an overview of the technical assistance process and the basic information recommended when working with NMFS. Technical assistance is an opportunity for project proponents to interact with NMFS technical staff during the development of a project, from basic conceptual formulation to advanced design and operational details. Typically, this is done by contacting NMFS staff to provide input at key stages of a project's development. In addition to expertise in aquatic ecology and salmonid biology, NMFS technical staff also have expertise in hydraulic engineering, hydrology, fluvial geomorphology and sediment transport processes.

For projects that score above 'low risk' in the Project Risk Screening Matrix (Figure 2), NMFS recommends project proponents seek technical assistance on all of the following topics:

- Setting appropriate biological goals and objectives;
- Identifying any planning or pre-design study needs;

- Identification of the potential types of facilities, facility operations, fishways, and fish passage appurtenances that are most likely to meet the biological goals and objectives;
- Conceptual designs of alternatives being considered;
- Comparison of design alternatives;
- Selection of a preferred alternative;
- Review of any conceptual drawings, as well as the 30%, 60%, 90% and final engineering design drawings of the preferred alternative;
- For the preferred alternative, development of biological performance metrics, fishway operations, and a monitoring and maintenance plan;
- Identification of post-implementation studies and effectiveness monitoring needs;
- Formulation of an adaptive management plan to implement results from monitoring or post-implementation studies.

Frequently the most beneficial technical assistance that NMFS can provide is the identification of appropriate biological goals and objectives, as these often play a pivotal role in selecting appropriate facility components, facility operations, fishways, and fish passage appurtenances. Figure 10 depicts a basic technical review process recommended by NMFS. It does not reflect Endangered Species Act (ESA) Section 7 consultation, which occurs (as necessary) after NMFS'NMFS' technical assistance.

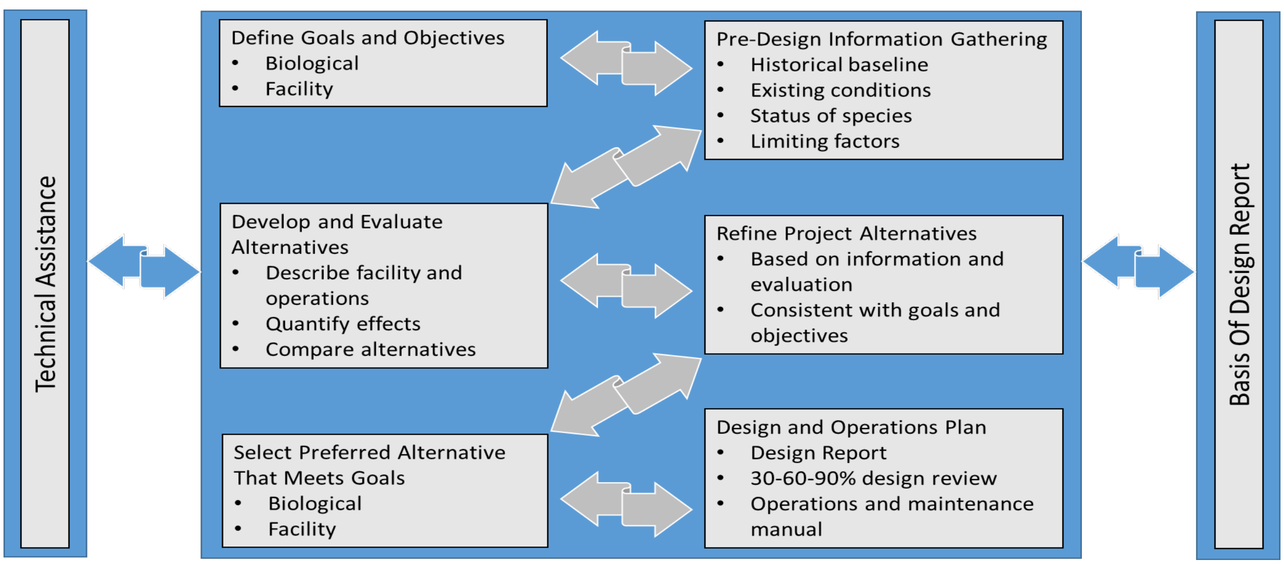


Figure 10. A simplified flow chart for NMFS technical review of project designs. Note that technical assistance occurs at all stages of project development. The process has feedback loops between steps so that the best solutions are developed iteratively, as new information becomes available. The outcome of the process is the design and basis of design report.

5.2 BASIC INFORMATION NEEDS

In general, basic project information required for NMFS' review includes:

- Project goals and objectives;
- Description of the type of facility, facility components, fishways, fish passage appurtenances, facility operations, fishway operations, monitoring and maintenance plan, and adaptive management plan being proposed;
- Comparisons of the various conceptual project designs and operations considered;
- Reasons for rejecting alternatives; and
- Analyses supporting the determination that the proposed project will meet biological goals and objectives.

Basis of design reports can be developed iteratively as a project advances, or as a compilation of the information and analyses justifying the design prior to submitting a formal application. A complete basis of design report includes (but is not limited to) the following items:

- Engineering drawings for the project, along with a detailed narrative explaining project components, functions, and operations;
- All the necessary information and supporting analyses to demonstrate that a proposed project's design and operation and maintenance will meet watershed-specific biological goals and objectives;
- Monitoring, maintenance, and adaptive management plans.

For high risk projects, this process may involve the following:

- Documentation of historic, existing, and future migration opportunities within the watershed;
- Pre-design studies to identify limiting conditions and biological goals and objectives;
- Using an iterative design process with an interdisciplinary team (involving physical and biological scientists, and engineers, as necessary); and
- Post-implementation studies and effectiveness monitoring.

5.3 DESIGN DEVELOPMENT

Design development generally follows five general steps: developing alternatives, eliminating alternatives, comparing remaining alternatives, selecting the preferred alternative, and developing the design. The following describes these steps in the context of an anadromous fish passage project. Additionally, Section 6 identifies considerations and criteria that should be folded into the alternative selection and design development steps for projects in California.

5.4 DEVELOPING ALTERNATIVES

As noted above, projects should be designed and operated to meet the project's biological goals and objectives. Thus, biological goals and objective become important for identifying project design criteria and for screening alternatives. For example, if a biological objective is to provide volitional passage, then only volitional fishways (e.g., roughened ramps, vertical slot ladders, etc.) should be considered for the project. However, if volitional passage is not a biological objective, then volitional and non-volitional solutions (e.g., collection and transport) can be considered. Similarly, if maintaining the continuity of sediment transport is a biological goal, then only fishways that allow sediment to pass through the project location should be considered (e.g., dam removal, channel spanning roughened ramps, etc.). Consequently, while a specific type of facility and facility operations may be appropriate in one watershed, the same facility and facility operations may be inappropriate in another watershed. This may be due to differences in project-specific biological goals and objectives, as driven by differences in hydrology, sediment regime, species present (including the status of those species), limiting factors, project location, channel morphology, or other factors. Project proponents are encouraged to pursue only solutions that are likely to meet all biological goals and objectives. In some cases, when working with an existing facility, removal of obsolete or marginally beneficial facilities and building a completely different type of facility may be the only way to eliminate certain limiting conditions and meet biological goals and objectives.

When identifying project designs and alternatives, the relative risk to fish and habitat should be considered (see Section 2). NMFS encourages project proponents to seek project designs that pose limited risk to anadromous fish and habitat. The measures reduce (or eliminate) a facility's risk should be proportionate to the total risk a facility has to fish within that watershed. Certain types of projects result in much less biological risk to fish than others. Such projects have the following characteristics:

- volitional passage is provided across the width of the channel and past the facility;
- instream flows and riparian habitats are sufficiently preserved to support critical biological needs for all species of concern;

- uninterrupted sediment and large wood transport are facilitated past or around the facility;
- passage of terrestrial and aquatic organisms of concern is achieved.

For higher risk projects, it is important to develop a project design that eliminates passage delay to the maximum extent possible. This can be accomplished by:

- keeping the groundwater aquifer charged in order to minimize loss of surface water continuity (i.e., where the water table is drawn down below the stream bed due to withdrawals);
- providing volitional passage routes via wide ramps and/or multiple fish ladders with multiple entrance gates;
- maximizing attraction flows within fishways; and
- providing hydraulic conditions that fish can easily navigate. NMFS recommends that project proponents demonstrate in their Basis of Design Report that they pursued a design development approach that focused on selecting the lowest biological risk alternative that met all project goals and objectives.

5.5 SELECTING ALTERNATIVES

Once the alternatives are identified, a process of screening alternatives to carry into the design process can begin. There is no set number of alternatives or clearly defined level of development that alternatives need to be developed before eliminating one or more alternatives and selecting a preferred alternative. Instead, the number of alternatives and how far each alternative is developed before a preferred alternative is selected depends on factors including:

- how easy it is to determine whether each alternative being considered will meet biological goals and objectives;
- how easy it is to determine whether each alternative being considered will meet facility goals and facility objectives;
- how much effort is needed to determine the feasibility of each alternative;
- how much effort is needed to fairly compare the pros and cons of the alternatives;
- how much effort is needed to address the risk and uncertainty in the alternatives; and
- how quickly stakeholders agree on a preferred alternative.

Brainstorming sessions or other technical working group meetings may be useful for generating a long list of potential design alternatives. Once this list is developed, several alternatives may be eliminated because they clearly cannot meet project goals and objectives, or are simply infeasible for one or more reasons. Some alternatives may warrant further consideration, but may be eliminated after conceptual drawings or preliminary computations show the alternatives are not appropriate. In some cases, more than one alternative (or variations of a promising alternative) may need to be taken to a fairly advanced level of design before it is feasible to meet project goals and objectives can be determined, risks and uncertainties can be adequately addressed, or stakeholder consensus can be achieved.

During this process, it is important to consider how the project will be built, operated, and maintained, and how those factors are likely to affect conditions within the project reach and the watershed. Reviewing historical and existing conditions studies during this analysis is suggested (see Section 4.2.1 and 4.2.2). Some of the key information needed when considering an alternative's effects include:

- a detailed description of the proposed project design and its effects on channel hydraulics and sediment transport over the entire range of flows, for normal, wet and dry years;
- how proposed facility components, fishways, and fish passage appurtenances will be operated and maintained;
- how the project's operation and maintenance procedures will address unusual, but reasonably predictable important periodic events (e.g., large floods or wildfires).

The amount of information provided on each alternative should generally be commensurate with how far the alternative was taken in design development before it was eliminated from further consideration. The reasoning for eliminating each alternative should also be given. In situations where the alternatives under consideration have significant risk or uncertainty, the pros and cons of alternatives need to be compared. Project proponents may need to provide the following information for each alternative considered beyond the brainstorming and conceptual level:

- a statement on the certainty and degree to which each alternative meets the project's biological and non-biological goals and objectives;
- identification of the entire geographic area over which the proposed project may affect a watershed's hydrology, hydraulics, sediment regime, water quality, and migration opportunity;
- a description and drawings of the facility components (e.g., dam, spillway, penstocks, pumps, etc.) and proposed fishways and fish passage appurtenances (e.g., ramps, fish ladders, surface collectors, fish screens, etc.);
- a detailed description of how the facility would be operated; this includes the reservoir size, reservoir residence time, the degree to which water surface elevations will fluctuate within a reservoir and the percent of time a reservoir is at a specific stage, and the proposed timing, frequency, duration, amount and the rate at which water is to be stored, diverted, and/or released at all river discharges;
- a detailed description of the proposed timing, frequency, duration, amount and rates at which flows with fish (non-screened flows) are directed down one or more flow paths associated with the alternative (e.g., spillways, turbines, sluice gates, fishways, etc.) at all stream discharges;

- a detailed description of how fishways and fish passage appurtenances would be operated;
- any hydraulic, hydrologic, groundwater, or sediment modeling results necessary to demonstrate that the proposed alternative is likely to provide acceptable migration conditions throughout the watershed area being affected by the project's operations;
- a description of routine maintenance needs;
- what type of maintenance (or repairs) may be necessary following flood flow events;
- a description of foreseeable, non-routine repair and maintenance, such as dredging following wildfires; and
- a description of how migration opportunity would change under each alternative, as compared to existing and historical migration opportunity.

5.6 ADVANCING THE SELECTED ALTERNATIVE

Following conceptual design review and a preferred alternative has been selected (typically by the 30% design level), advancing the project can begin. NMFS recommends that project proponents request NMFS review and comment on the 30%, 60%, 90% and final engineering facility designs, proposed facility operations plan, fishway and fish passage appurtenance operations plan, routine monitoring and maintenance plan, and adaptive management plan that should be included with the final basis of design report.

NMFS recommends that 30% designs include the following information (much of it developed in technical assistance):

- how a project will affect the timing, frequency, duration, and amount of water stored or diverted;
- instream flows needed for fish migration and appropriate habitat conditions at all river discharges, including the magnitude and timing of flows necessary to initiate fish migration into and out of the watershed and its key tributaries;
- the actual timing, frequency, duration and range of flows over which any selected fishways will need to operate based on the hydrologic and migration needs and migration opportunity analysis results;
- applicable specific guidance and likely modifications for the type of passage provisions and operations being pursued. For example, if a vertical slot ladder has been determined to be an appropriate fishway for the project, then the engineering criteria for vertical slot ladders should be followed in initial design, and anticipate design modifications as needed for site conditions.

- draft operations and maintenance plan that considers not only routine maintenance but maintenance and repairs that may be needed after episodic events such as floods or wildfires in the watershed;
- proposed biological performance metrics along with a suitable means of conducting effectiveness monitoring; and
- identify any needed post-implementation studies, effectiveness monitoring, and an adaptive management plan.

6 RECOMMENDATIONS FOR CALIFORNIA'S CLIMATE AND WATERSHED CONDITIONS

Section 5 described how watershed conditions and climate play an important role in developing biological goals and objectives and influence the design of a project. This section provides specific recommendations intended to account for California's variable climate and watershed conditions and may differ from the standard recommendations for facilities in Washington, Oregon, and Idaho. This list of recommendations does not cover all of the design topics where standard guidance may need to be adapted due to local and site-specific conditions, but does cover several key aspects of facility design.

6.1 FISH PASSAGE DESIGN FLOWS

Fish passage design flows are the low and high design flow and all discharges in between. As described in Section 3, California's varying hydrology dictates that the setting of fish passage design flows must be based not only on regional but sometimes on watershed hydrology, as the migration opportunity can significantly differ with local climate. Lang and Love (2014) demonstrated that previous guidance (NMFS, 2011) would result in providing very little migration opportunity in many locations throughout California. Consequently, for projects in California, NMFS recommends that project proponents conduct appropriate migration opportunity studies, discuss those results with NMFS, and develop fish passage design flows on a case-by-case basis. As initial guidance NMFS recommends the high flow design discharge of 50% of the 2-year flow event, or the 1% flow exceedance during the period from November 1 – May 15. NMFS further recommends that the low design flow should initially be consistent with the lowest discharge at which fish are expected to be able to migrate upstream, as observed in a nearby reference reach. Proposed adjustments to these initial recommendations should be well supported by a migration opportunity study conducted for the proposed project and its unique watershed conditions.

6.2 INSTREAM FLOWS

Instream flows are defined as the total stream discharge minus any flow stored or diverted by the proposed project. It is recommended that instream flows should be sufficient to maintain the biological goals and objectives for listed species and their habitat, and generally mimic natural hydrographs. A migration opportunity analysis should be conducted to determine what instream flows are sufficient. This analysis should compare natural migration opportunities to the migration opportunities that will be provided by the proposed instream flows and whether the proposed migration opportunities will meet biological goals and objectives. NMFS further recommends evaluating on a case-by-case basis all proposed instream flows.

6.3 ATTRACTION FLOW AT NON-CHANNEL SPANNING FISHWAYS

Attraction flow is intended to draw upstream-migrating fish to the fishway entrance(s) and is important for supporting timely and effective migration. Attraction flow is defined as the flow emanating from all fishway entrances. More specifically, all flow emanating from technical fishway entrances, including the auxiliary water supply, is considered attraction flow. All flow contained in a partial-width ramp is also considered attraction flow. However, attraction flow and instream flow are not necessarily synonymous. Flow coming from nearby spillways, penstocks, etc., may contribute to the total instream flow, but is not considered attraction flow.

The design attraction flow is defined as the attraction flow provided for fish passage when the stream discharge equals the high fish passage design flow. The design attraction flow is often expressed as a percentage of the high fish passage design flow. To reduce migration delay at facilities NMFS recommends using the maximum design attraction flow feasible. To prevent distraction (or nuisance) flows from competing with attraction flow, NMFS further recommends that all instream flows should go to fishway(s), auxiliary water supplies and juvenile bypass systems before routing flow over dam crests, spillways or other facility flow paths.

For non-channel spanning partial width and technical fishways in Washington, Oregon, and Idaho, traditional guidance recommends setting the design attraction flow to 5-10% of the high fish passage design flow. This design criterion was originally developed during the 20th century for larger dams in watersheds where ample fish passage opportunity exists and sediment and debris are not likely to significantly impact fishway effectiveness. In that era under ‘clear-water’ conditions, it was reasoned that a certain amount of delay at any given facility would be acceptable because migrating fish could still complete their life cycle successfully. However, due to climate differences, many of California's watersheds have less fish passage opportunity than those in Washington, Oregon, and Idaho. Moreover, in California, there are many watersheds where sediment and debris loads impact the function of fishways and cause additional delay. Because fish passage opportunities in California are often short in duration, migratory fish cannot afford having passage opportunities further truncated by poor attraction or fishways that function poorly due to sediment or debris. As a consequence, the design attraction flow guidance of 5-10% of the high fish passage design flow is only recommended at locations in California where partial width and technical fishways meet biological goals and objectives, and also meet several of the following watershed and site-specific considerations:

- locations in the upper part of the watershed where a relatively low percentage of habitat (current or historic) remains upstream of the fishway;
- barriers in the watershed are minor and the number is few;
- stream channels in the watershed have low sediment and debris loads;
- streambeds in the watershed are relatively stable, and are not subject to braiding, incision or deposition;
- fish are abundant, migration opportunities are ample (e.g., perennial streams with low variability in inter-annual water yields), and migration behavior (e.g., the times fish are migrating along with the ability of the fish to find fishway entrances) can be easily quantified/determined;
- the fishway will be continuously monitored and maintained during the migration seasons;
- fishways with robust adaptive monitoring and maintenance plans;
- locations where steep and compact fishways are required (e.g., switchback ladders at high head dams).

In situations that deviate from the generalized characteristics listed above, NMFS recommends a higher design attraction flow. For example, a design attraction flow of at least 20% may be needed to offset the biological risks presented by a barrier located in the lower mainstem of a drought-prone, intermittent watershed, with a short migration season and limited fish passage opportunity. Likewise, for fishway designs on dams prone to high sediment and debris deposition, or where frequent maintenance renders entrance gates inoperable, a higher design attraction flow may be needed to provide continuous operation of an adequate number of entrance gates. Many of the locations where significantly higher design attraction flows are needed are found in semi-arid and sediment and debris prone watersheds (e.g., Central and Southern California coast, arid parts of the California Central Valley). However, similar conditions can, and do exist elsewhere – particularly in watersheds with water diversions and impoundments that diminish in-stream flows and alter historical flow patterns. The higher design attraction flow increases the chance that migrating fish quickly find and utilize a fishway. This minimizes delay and allows for a higher probability that anadromous fish will reach spawning grounds during the very limited migration opportunities that exist in some watersheds. Minimizing delay supports timely spawning, which increases the chances of timely and successful life cycle completion (e.g., egg incubation, fry emergence, juvenile growth, and smolt out-migration).

6.4 WHEN CHANNEL-SPANNING FISHWAYS ARE RECOMMENDED

NMFS generally recommends channel-spanning fishways on streams with relatively low head barriers and where channel width is less than approximately 100 feet. Channel spanning fishways provide 100% attraction flow, typically require minimal monitoring and maintenance, and provide consistent migration opportunities. Most projects of this caliber are smaller projects (i.e., not high head dams) where staff will not be present on-site most of the time, and minimizing monitoring and maintenance is a crucial component of the project. Channel spanning fishways may not be feasible in confined and incised channels due to high shear stresses during storm events. In such situations, partial width fishways may be a more structurally sound solution.

6.5 WHEN MULTIPLE FISHWAYS ARE RECOMMENDED

For locations with channel widths greater than approximately 300 feet, NMFS recommends that partial width or technical fishways be placed along both banks of the stream. The potential need for mid-channel partial width or technical fishways should also be considered under such situations. Multiple fishways on wide rivers minimize delay by providing multiple upstream passage routes. When multiple fishways are employed, the total design attraction flow should be apportioned appropriately among all independent fishways so that each fishway operates effectively. Wherever it is warranted, the design process should consider incorporating additional attraction flow capability to provide flexibility in response to actual operating conditions and fish behavior at the facility. Ideally, the distribution of flow between fishways and entrance gates should be based on observed fish preferences and delay times encountered at different discharges. In some cases, such as low head dams on wide, unconfined rivers, the engineering design may consider an ability to shift attraction flow capability among fishway entrances to react to fluctuating flows and geomorphic channel changes.

6.6 RESERVOIR SURFACE COLLECTORS

Surface collectors are a means of providing outmigrants safe downstream passage over dams rather than over spillways or through turbines. Surface collectors are used at several high head dams in the Pacific Northwest. Only one small-scale surface collector has been built and operated in California at this time, but there are proposals for more. Thus, while it is reasonable to apply the technologies developed in the Pacific Northwest regarding surface collectors at California facilities, adapting designs will likely be needed to provide timely and effective outmigration at California facilities. The reasons for this include: (1) reservoir residency time may be long and water releases may be very small for long periods of time, thus making it more difficult for fish to find the entrance to the surface collector; (2) reservoirs may have higher surface water temperatures, thus making it important to reduce the amount of time it takes for fish to locate the surface collector; and (3) anticipated future climate change impacts may increase the need to make surface collectors more efficient. Consequently, NMFS recommends that attraction flow (or pump size) for surface collectors be determined on a case-by-case basis in California.

6.7 SAFE PASSAGE OF SMOLTS AND KELTS

Fish abundance and diversity is quite low in many California watersheds, particularly in the southern-most watersheds. Consequently, there is often little information on the timing and discharge ranges that smolts and kelts use for outmigration. Where little or no information is available, NMFS recommends that safe outmigration be provided up to at least the high fish passage design flow. Fishways provide an opportunity to monitor smolt and kelt migratory behavior to assess the overall effectiveness of a project in providing safe outmigration – such monitoring should be included in project development and included in the associated monitoring, maintenance, and adaptive management plans.

6.8 EVALUATING ROUGHENED RAMPS

California has many streams that are highly flashy and designing ramps to provide juvenile passage at very low discharges and adult passage at relatively high discharges requires carefully assessing the hydraulics over a wide range of discharges as well as an understanding of how sediment may affect pools incorporated within ramps.

Roughened ramps are designed to produce hydraulic flow fields and boundary conditions mimicking channels having coarse bed material (e.g., gravel, cobbles, and boulders) and serve as a form of grade control. Ramps are sometimes constructed with grouted rock, or steel/concrete baffles, or some combination of both. Roughened ramps can also be constructed, in part or in whole, as engineered streambed material (or ESM) which is a specified mixture and placement of material ranging from fine particles up to large boulders.

A ramp is considered a hydraulic design because it is steeper than the channel reaches found near the project location. The goal of a hydraulic design is to provide hydraulic conditions that allow migrating fish to pass through the fishway in a safe and timely manner. Consequently, a ramp must have sufficient depth for fish to swim, velocities within the swimming ability of the fish, and turbulence levels that do not confuse fish, prevent fish from jumping over a hydraulic drop or impede their ability to swim.

6.8.1 HYDRAULIC ANALYSIS

Flows in coarse bed (gravel, cobble, and boulder) channels are quite heterogeneous. Consequently, roughened ramps typically need to be evaluated with a 2-D or 3-D numerical model, or a physical model, to ensure that pathways (which fish can readily navigate) exist over the entire length of the ramp at all discharges between the high and low fish passage design flows. Designing suitable passage conditions in a ramp is often an iterative process wherein changes to a ramp's geometry (baffle sizes, baffle spacing, pool size, pool spacing, thalweg configuration, cross-section shape, etc.) are made and evaluated. Such changes should be informed by modeling data and should include the evaluation of potential resting areas that would allow suitable passage even if fish may need to occasionally use burst speeds or traverse shallow water for short distances. Because all types of roughened ramps are unique in their channel geometry, evaluation of such structures is on a case-by-case basis.

6.8.2 POOL DEPTH

NMFS recommends pool depths of 2 feet or greater below any hydraulic drops at all discharges between the high and low fish passage design flows. NMFS further recommends the bed material in these pools be mobile and allow for potential scouring up to at least 4 feet of depth where feasible.

6.9 VALIDATING NOVEL HYDRAULIC DESIGNS FOR UPSTREAM/DOWNSTREAM PASSAGE

California has numerous urbanized concrete-lined flood control channels and other locations where traditional fish passage techniques may be ill suited that necessitate novel hydraulic designs which have not been tested elsewhere. On a case-by-case basis, NMFS may accept novel hydraulic designs through biological monitoring after the facility is built, or through the hydraulic modeling approach outlined below:

- perform 2-d and possibly 3-d hydraulic modeling that demonstrates a proposed fishway will produce hydraulic conditions that will allow fish to successfully pass;
- conduct physical models further demonstrating that a proposed fishway will successfully allow fish passage;
- establish performance requirements that if not met would require a project to improve the fishway, fish passage appurtenances or fishway operations and maintenance;
- expect and include an adaptive management plan so that fishway improvements can be quickly implemented;
- adopt hydraulic parameters that are more conservative than those typically recommended to ensure that hydraulic conditions will allow successful passage.

Because the swimming abilities of fish have been extensively studied, the above-mentioned measures are typically sufficient to reasonably validate the concept behind volitional hydraulic designs that have unique bathymetry configurations (e.g., unique baffle sizes and spacing).

7 SUMMARY AND CHECKLIST

7.1 Summary

Successfully providing fish passage at facilities often requires an interdisciplinary team. It also requires adopting a holistic watershed approach and an iterative design process. This design process focuses on considering and finding passage solutions that are low risk to anadromous fish. The facility operations, types of fishways, fishway operations, fish passage appurtenances, monitoring and maintenance plans and adaptive management plans that are acceptable at a particular location are dependent upon multiple factors. Such factors include: fish abundance and diversity, fish life cycle needs, historic and existing limiting conditions, facility effects (spatial and temporal), climate change, regional and local climate conditions, geomorphology, migration opportunity, and sediment and wildfire events.

Design development of facilities should only begin after setting facility goals and objectives as well as biological goals and objectives. NMFS recommends that the design process then proceed using an iterative process similar to that shown in Figure 10. NMFS further recommends that project proponents take advantage of technical assistance at key times throughout the development of the project. Taking advantage of technical assistance helps insure that all the information needed to support the project is developed during the design process. This supports the development of a complete project and reduces the need for additional information requests once the project is submitted to NMFS.

In some cases, standard engineering criteria may need to be adjusted to the climate and geomorphic conditions found in California. Attraction flow, fish passage design flows and the evaluation of ramps are examples of topics that may warrant a more conservative approach in order to conserve fish.

7.2 Checklist - Questions to Answer before Submitting a Consultation Request to NMFS

Not all projects are the same. The following questions are provided for project proponent to consider before and during the design of a project. Therefore, some questions may be applicable to a specific project while others are not. These questions need not be answered in any specific order. Instead, NMFS recommends that the relevant questions be answered in the material presented in a project's basis of design reports. The layout, scope, and detail needed in a basis of design report is project-dependent. The material presented previously in this document is meant to help project proponents critically think about what is needed for their particular project. This list is also intended to prompt interaction with NMFS throughout project development.

- ✔ Did you seek NMFS' technical assistance regarding the following key design development topics?
  - identification of biological goals and objectives, and appropriate engineering criteria based on watershed and site-specific conditions;
  - identification of needed pre-design studies;
  - identification of design alternatives;
  - the comparison of design alternatives;
  - the selection of a preferred design alternative;
  - review of the conceptual, 30%, 60%, 90%,%, and 100% preferred project design;
  - review of biological performance metrics and an effectiveness monitoring plan;
  - review of monitoring and maintenance plan, facility operations, fishway and fish passage appurtenance operations plan, and adaptive management plan.

- ✔ Does the project account for basic migration and habitat needs?
  - Do fish have the ability to migrate at the timing, frequency, and duration of time needed to complete their life cycle?
  - Are flows provided at the times, frequencies and magnitudes needed to trigger migration into and out of the watershed?
  - Is sufficient spawning habitat provided?

- Is sufficient rearing habitat provided?
- Are sufficient migration corridors provided?
- Is sufficient over-summering habitat provided?
- Is sufficient estuary habitat provided?
- Is sufficient floodplain habitat provided?
- Is good water quality provided to all habitats?

✔ Does the project identify and account for the watershed's historical, existing, and future limiting conditions at all the spatial and temporal scales that they can exist?
- Was a watershed assessment conducted?
- What is the watershed's hydrologic regime?
- What is the watershed's sediment regime?
- What are the watershed's historical limiting conditions?
- What are the watershed's existing anthropogenic limiting conditions?
- What potential anthropogenic limiting conditions could be created by the proposed project & climate change?
- What actions can be taken to eliminate existing anthropogenic limiting conditions?
- What actions can be taken to prevent the project from creating more or different anthropogenic limiting conditions?

✔ Does the project account for how the watershed's hydrologic regime, sediment regime, and water uses continuously interact over different spatial and temporal scales to create historical and anthropogenic limiting conditions and how the proposed project could change the watershed's physical processes and limiting conditions?
- What impacts will the project have on the timing, frequency, and duration which fish have access to their needed habitats?
- What impacts will the project have on the amounts of needed habitats?
- What impacts will the project have on water quality?
- What impacts will the project have on channel morphology and sediment transport rates that create and maintain critical habitats?
- What impacts will the project have on connectivity to the ocean, estuary, and tributaries within the watershed?
- What impacts will the project have on the ecosystem (predator-prey relationships, invasive species, etc.)?

✔ What are the project goals and objectives?
- Are the facility goals and facility objectives clearly defined?
- Are the biological goals and objectives clearly defined?

✔ What design alternatives were considered?

- Is a facility needed or are there alternatives to storing or diverting water from the river (e.g., reduce water use needs, improved water delivery system, alternative sources of energy)?
- If a facility is needed, what types of facilities can be used to meet project goals and objectives?
- What types of facilities and operations represent the least risk to fish?
- What types of fishways and fish passage appurtenances will work best with a given type of facility and facility operations plan?

✔ How were the design alternatives compared?

- What are the pros of each alternative considered?
- What are the drawbacks of each alternative considered?

✔ How was the preferred alternative selected?

- Does the preferred alternative meet the biological goals and objectives?
- Does the preferred alternative meet the facility goals and facility objectives?
- Does the preferred alternative represent a low or high risk to the anadromous salmonids?
- Can the risk to anadromous salmonids be further reduced and still meet facility goals and facility objectives?

✔ Was a project basis of design report developed that includes:

- watershed conditions (project setting; climate, hydrologic regime; sediment regime, ecological conditions, watershed size, land use, historical and anthropogenic limiting conditions, etc.);
- project goals and objectives;
- description of design alternatives considered;
- description of preferred design alternative and the method for selecting it;
- the project design plans;
- all supporting analyses for the justification of the project design (e.g., hydrologic analyses, hydraulic modeling results, physical modeling results, sediment erosion deposition computations, etc.;
- facility operations plan;

- fishway and fish passage appurtenances operations plan;
- monitoring and maintenance plan, which includes biological performance metrics and effectiveness monitoring; and
- an adaptive maintenance plan.

✔ Based on the guidance provided in this document, does your project's basis of design report answer all of the questions NMFS is likely to have regarding your project?

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