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ANADROMOUS SALMONID PASSAGE FACILITY GUIDELINES AND CRITERIA

Developed by
National Marine Fisheries Service
Northwest Region
Portland, Oregon

FOREWORD

The task involved in successfully passing fish upstream or downstream of an in-river impediment is a dynamic integration of fish behavior, physiology and bio-mechanics with hydraulic analysis, hydrologic study and engineering. Installing a fish passage structure does not constitute providing satisfactory fish passage, unless all of the above components are adequately factored into the design. The following document provides criteria, rationale, guidelines and definitions for the purpose of designing proper fish passage facilities for the safe and timely upstream and downstream passage of anadromous salmonids at impediments created by man-made structures, natural barriers (where provision of fish passage is consistent with management objectives), or altered in-stream hydraulic conditions. This guidance is provided to provide regional guidance for the National Marine Fisheries Service (NOAA Fisheries) fishway policies and guidelines, and is to be used for actions pertaining to the various authorities and jurisdictions of NOAA Fisheries, including Section 18 of the Federal Power Act, and for consultation under the Endangered Species Act and the Magnuson-Stevens Act. Section 13 (Juvenile Fish Screen and Bypass Criteria) supercedes previous criteria published by NOAA Fisheries, including Juvenile Fish Screen Criteria (February 16, 1995) and Juvenile Fish Screen Criteria for Pump Intakes (May 9, 1996). If passage facilities are designed and constructed in a manner consistent with these criteria, adverse impacts to migration will be minimized.

Instances will occur where a fish passage facility may not be a viable solution for correcting a passage impediment, due to biologic, sociologic, or economic constraints. In these situations, removal of the impediment or altering operations may be a suitable surrogate for a constructed fish passage facility. In other situations, accomplishing upstream fish passage past a project may not be an objective of NOAA Fisheries because of factors such as limited upstream habitat, or lack of naturally occurring runs of anadromous fish upstream of the site. To determine whether NOAA Fisheries will use its various authorities to promote or to prescribe fish passage, NOAA Fisheries will rely on a collaborative approach, considering the views of other fisheries resource agencies, Native American Tribes, non-government organizations and citizen groups, and will strive to accomplish the objectives in sub-basin plans for fisheries restoration and enhancement.

In general, NOAA Fisheries requires volitional passage, as opposed to trap and haul, for upstream passage facilities. This is primarily due to the risks associated with the handling and transport of adult upstream migrants, in combination with the long term uncertainty of funding, maintenance and operation of the trap and haul program. However, there are instances where trap and haul may be the only viable option for a particular site. In particular, at high head dams where thermal stratification occurs in the reservoir, higher water temperatures in the fishway (as opposed to water temperatures below the dam) may dissuade fish from utilizing volitional passage facilities.

The fish passage facilities described in this document include various fish ladder designs, exclusion barriers, trap and haul facilities, fish handling and sorting facilities, in-stream structures and road crossings structures such as culverts or bridges, juvenile fish screens, tide gates, upstream juvenile passage facilities and specialized criteria for mainstem Columbia and Snake River passage facilities. Passage facilities for projects under NOAA Fisheries jurisdiction should be consistent with the details described in this document, with the facility design developed in close coordination with NOAA Fisheries fish passage specialists. This document does not address any aspect of design other than those that provide for safe and timely fish passage. Structural integrity, public safety and other aspects of facility design are the responsibility of the principal design engineer, who should assure that the final facility design meets all other requirements in addition to the fish passage criteria contained in this document.

Proposed facilities which could have particularly significant impacts on fish, and new unproven fish passage designs require: 1) development of a biological basis for the concept; 2) demonstration of favorable fish behavioral response in a laboratory setting; 3) an acceptable plan for evaluating the prototype installation; and 4) an acceptable alternate plan developed concurrently for a screen and bypass system satisfying these criteria, should the prototype not adequately protect fish. Additional information on unproven fish passage devices can be found in "Experimental Fish Guidance Devices," Position Statement of the National Marine Fisheries Service, Northwest Region, January 6, 1995 (Appendix A). Since these criteria are general in nature, there may be cases where site constraints or extenuating biological circumstances dictate that certain criteria be waived or modified without delaying or otherwise adversely impacting upstream migrants. It is the responsibility of the applicant to provide compelling evidence in support of any proposed waiver. Conversely, where NOAA Fisheries deems there is a need to provide additional protection for fish, more restrictive site-specific criteria may be added. These circumstances will be considered by NOAA Fisheries on a project-by-project basis.

The following document is hereby designated as NOAA Fisheries Northwest Regional Policy for fish passage responsibilities under the ESA, FPA and Magnusen-Stevens Act, for the purpose of providing project proponents with NOAA Fisheries perspective on properly designed fish passage facilities. As new knowledge in fish passage is gained, these guidelines and criteria will be updated as necessary. This document was created by NOAA Fisheries Hydro Program Staff, who can be reached for questions at 503-230-5400.

Adopted,

Regional Director

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Section 1. Upstream Passage Impediments

1.1 An **upstream passage impediment is defined** as any manmade structural feature or project operation that causes adult or juvenile fish to be injured, killed, blocked or delayed on their upstream migration, to a greater degree than in a natural river setting. This definition is provided for the purpose of describing situations where NOAA Fisheries will utilize these criteria in reviewing mitigative measures aimed at ameliorating an impediment. Any upstream passage impediment requires approved structural and/or operational measures to mitigate for adverse impacts to upstream fish passage. In addition, this criteria is applicable where passage over a natural barrier is desired, consistent with sub-basin or recovery plans.

1.2 It is important to note that not every upstream passage facility can fully compensate for an unimpeded natural channel. As such, additional mitigation measures could be required and will be established on a case-by-case basis.

1.3 Examples of upstream passage impediments include, but are not limited to:

1.3.1 Permanent or intermittent dams where either adult or juvenile upstream migrants are present, if fish cannot readily pass at any streamflow.

1.3.2 Static head over a manmade instream structure in excess of 1.5 feet.

1.3.3 Apron with shallow depth (less than 10 inches), or high flow velocity (greater than 6 ft/s).

1.3.4 Hydraulic jumps immediately downstream of a dam.

1.3.5 Diffused or braided flow that impedes the approach to the impediment.

1.3.6 Flow depths of less than 10 inches or velocities in excess of 12 feet per second for stream channels approaching the impediment.

1.3.7 Road crossing culverts not achieving the criteria specified in Section 9.

1.3.8 Project operations that lead upstream migrants to impassable routes or cause excess migration delays

1.3.9 Improperly designed fish passage (see Section 5) or fish collection facilities (see Sections 7 and 8)

1.3.10 Headcut control or bank stabilization measures

1.3.11 Insufficient bypass reach flows to induce upstream migrants to move upstream into the bypass reach adjacent to a powerhouse or wasteway return.

1.3.12 Degraded bypass reach discharge water quality, relative to that downstream of the confluence of bypass reach and return discharges.

1.3.13 Instream or bypass reach ramping rates that delay or strand upstream migrant fish.

1.3.14 Return discharges to the stream that may be detected and ascended by fish, with no certain means of continuing their upstream migration

1.3.15 Return discharges to the stream that are attractive to upstream migrating fish (eg. turbine draft tubes, shallow aprons and flow discharges) that have the potential to cause injury.

1.3.16 Water diversions.

Section 2. Definition of Key Terms

Active Channel - A waterway of perceptible extent that periodically or continuously contains moving water. It has definite bed and banks which serve to confine the water and includes stream channels, secondary channels, and braided channels. It is often determined by the "ordinary high water mark" which means that line on the shore established by the fluctuations of water and indicated by physical characteristics such as clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas.

Active screens - juvenile fish screens equipped with an cleaning system with proven cleaning capability, and are automatically cleaned as frequently as necessary to keep the screens free of any debris that will restrict flow area. An active screen is the required design in most instances.

Approach velocity - the vector component of true water velocity perpendicular to and in front of the screen face, calculated by dividing the maximum diverted flow amount by the effective screen area.

Apron - a flat, usually slightly inclined slab below a weir that provides for erosion protection and produces hydraulic characteristics suitable for energy dissipation or fish exclusion.

Attraction flow - the flow that emanates from a fishway entrance in sufficient quantity and location to attract upstream migrants into the fishway.

Auxiliary water system - a hydraulic system that augments fish ladder flow at various points in the upstream passage facility. Typically, large amounts of auxiliary water flow are added in the fishway entrance pool in order to increase the attraction of the fishway entrance.

Bankfull - The point on a streambank at which overflow into the floodplain begins. The floodplain is a relatively flat area adjacent to the channel constructed by the stream and overflowed by the stream at a recurrence interval of about one to two years. If the floodplain is absent or poorly defined, other indicators may identify bankfull. These include the height of depositional features, a change in vegetation, slope or topographic breaks along the bank, a change in the particle size of bank material, undercuts in the bank, and stain lines or the lower extent of lichens and moss on boulders. Field determination of bankfull should be calibrated to known stream flows or to regional relationships between bankfull flow and watershed drainage area.

Baffles - physical structures designed to dissipate energy and provide nearly uniform flow.

Bedload - Sand, silt, and gravel, or soil and rock debris rolled along the bottom of a stream by the moving water. The particles of this material have a density or grain size which prevents movement far above or for a long distance out of contact with the streambed under natural flow conditions.

Bifurcation (Trifurcation) pools - pools where two or three sections of fish ladders join.

Braille - a device that moves upward through the water column, crowding fish into an area for collection.

Bypass reach - the portion of the river between the point of flow diversion and the point of flow return to the river.

Bypass System - the component of a downstream passage facility that transports fish from the diverted water back into the body of water from which they originated, and consists of a bypass entrance, a bypass conduit and a bypass outfall.

Coarse trash rack - a rack of vertical bars, designed to catch large debris and preclude it from entering the fishway, while providing sufficient opening to allow the passage of fish.

Conceptual design - an initial design concept, based on the site conditions and biological needs of the species intended for passage.

Crowder - a combination of static and/or movable picketed and/or solid leads installed in a fishway for the purpose of moving fish into a specific area for sampling, counting, brood stock collection or other purposes.

Diffuser - a set of horizontal or vertical bars, designed to introduce flow to a fishway in a nearly uniform fashion.

Distribution flume - a channel used to route fish to various points in a fish trapping system.

Effective screen area - the projection of the total submerged screen area (excluding major structural members) onto a vertical plane.

End of pipe screens - juvenile fish screening devices attached directly to a diversion intake pipe.

Exclusion barriers - upstream passage facilities that prevent upstream migrants from entering areas with no upstream egress, or areas that could lead to fish injury.

Exit control section - the upper portion of an upstream passage facility that serves to provide suitable passage conditions to accommodate varying forebay water surfaces through means of pool geometry, weir design and the capability to add or remove flow at specific locations.

False weir - a device that adds pressurized flow to the top of a denil or steeppass ladder, normally used in conjunction with a distribution flume that routes fish to a specific area for management or other purposes.

Fish ladder - the structural component of an upstream passage facility that dissipates the potential energy into discrete pools or uniformly dissipates energy in a baffled chute to provide passage for upstream migrants.

Fish lift - a mechanical component of an upstream passage system that provides fish passage by lifting fish in a water-filled hopper or other lifting device into a conveyance structure that delivers upstream migrants past the passage impediment.

Fish lock - a mechanical and hydraulic component of an upstream passage system that provides fish passage by attracting or crowding fish into the lock chamber, activating a closure device to prevent fish from escaping, introducing flow into the enclosed lock and raising the water surface to forebay level and then opening a gate allowing the fish to exit.

Fish weir (or picket weir) - a device with closely spaced pickets to allow passage of flow, but not targeted adult fish. This device is commonly used in conjunction with an adult fish trap, for the purpose of brood stock collection. It is also used for sorting of both wild and hatchery adult fish in the trap. This is not a weir in the hydraulic sense.

Fishway - the set of facilities, structures, devices, measures, and project operations that together constitute, and are critical to the success of, any upstream or downstream fish passage system.

Fishway entrance - the component of an upstream passage facility that discharges attraction flow into the tailrace, where upstream migrant fish enter (and flow exits) the fishway.

Fishway exit - the component of an upstream passage facility where flow from forebay enters the fishway, and where fish exit into the forebay upstream of the passage impediment.

Fishway entrance pool - the pool immediately upstream of the fishway entrance(s).

Fishway weir - a term frequently used to describe the partition between adjacent pools in a fishway.

Flood frequency - the frequency with which a flood of a given discharge has the probability of recurring. For example, a "100-year" frequency flood refers to a flood discharge of a magnitude likely to occur on the average of once every 100 years or, more properly, has a one-percent chance of being exceeded in any year. Although calculation of possible recurrence is often based on historical records, there is no guarantee that a "100-year" flood will occur at all within the 100- year period or that it will not recur several times.

Flood prone zone - spatially, this area generally corresponds to the modern floodplain, but can also include river terraces subject to significant bank erosion. For delineation, see definition for floodplain.

Floodplain - the area adjacent to the stream constructed by the river in the present climate and inundated during periods of high flow.

Flow duration curve - a statistical summary of river flow information over a period of time that describe cumulative percent of time for which flow exceed specific levels (exceedence flows), exhibited be a cumulative frequency curve that shows the percentage of time that specified discharges are equaled or exceeded. Flow duration curves are usually based on daily streamflow and describe the flow characteristics of a stream throughout a range of discharges without regard to the sequence of occurrence. If years of data are plotted the annual exceedance flows can be determined.

Flow egress weir - a weir used to route excess flow from a fish facility.

Forebay - the water body impounded above a dam.

Hatchery supplementation - a hatchery propagation approach utilizing the progeny of local wild brood stock. Typically, the progeny are released into acclimation ponds at underused habitat locations.

High passage design flow - the maximum river flow that fish can be expected to approach and pass an upstream passage system. (See Section 4)

Hopper - a device used to lift fish (in water) from a collection or holding area, for release upstream of the impediment.

Hydraulic drop - the energy difference between an upstream and downstream water surface, considering potential (elevation) and kinetic energy (velocity head). Also referred to as the total energy head differential as defined by Bernoulli=s equation.

Low passage design flow - the lowest stream discharge for which upstream migrants are expected to be present, migrating, and dependent on the proposed facility for safe passage. (See Section 4)

Ordinary high water mark - The mark along the bank or shore up to which the presence and action of the water are common and usual, and so long continued in all ordinary years, as to leave a natural line impressed on the bank or shore and indicated by erosion, shelving, changes in soil characteristics, destruction of terrestrial vegetation, or other distinctive physical characteristics.

Passive screens - juvenile fish screens with no automated cleaning system.

Picket leads - a set of vertically inclined flat bar or circular slender columns (pickets), designed to lead fish to a specific point of passage.

PIT tag detector - a device that passively interrogates a fish for the presence of a passive integrated transponder (PIT) tag.

Plunging flow - flow over a weir which falls into the receiving pool with a water surface elevation below the weir crest elevation. Generally, flow at the receiving pool water surface is in the upstream direction.

Porosity - the percent flow-through open area of a mesh, screen or rack relative to the entire gross area.

Preliminary design - see Section 3.

Rating curve - the graphed data depicting the relationship between water surface elevation and flow amount.

Redds - depositions of fish eggs in gravels

Section 10 and 404 Regulatory Programs - The principal federal regulatory programs, carried out by the U.S. Army Corps of Engineers, affecting structures and other work below mean high water. The Corps, under Section 10 of the River and Harbor Act of 1899, regulates structures in, or affecting, navigable waters of the U.S. as well as excavation or deposition of materials (e.g., dredging or filling) in navigable waters. Under Section 404 of the Federal Water Pollution Control Act Amendments (Clean Water Act of 1977), the Corps is also responsible for evaluating application for Department of the Army permits for any activities that involve the placement of dredged or fill material into waters of the United States, including adjacent wetlands.

Static Head - the upstream to downstream difference in water surface elevation over an hydraulic control structure.

Streaming flow - flow over a weir which falls into a receiving pool with water surface elevation above the weir crest elevation. Generally, flow at the receiving pool water surface is in the downstream direction.

Tailrace - the river immediately downstream of an instream structure.

Total project head - the difference in water surface elevation from upstream to downstream of an impediment such as a dam. Normally, total project head encompasses a range based on river flows, and/or the operation of flow control devices.

Transport Channel - a hydraulic conveyance designed to pass fish between different sections of a fish passage facility.

True velocity - the velocity of flow in a water diversion, usually parallel to the bankline.

Sweeping velocity - the vector component of true velocity parallel and adjacent to the screen face.

Upstream fish passage - fish passage relating to upstream migration of adult and/or juvenile fish

Upstream passage facility - a fishway system designed to pass fish upstream of a passage impediment, either by volitional passage or non-volitional passage.

Upstream passage impediment - see Section 1.

Wasteway - a channel (or other conveyance) which returns water originally diverted from an upstream location back to the diverted stream, whether for agricultural, power, or other uses.

Waters of the United States - Currently defined by regulation to include all navigable and interstate waters, their tributaries and adjacent wetlands, as well as isolated wetlands and lakes and intermittent streams.

Weir - a hydraulic term for an obstruction over which water flows (see also fish weir and fishway weir).

Section 3. Preliminary Design Development

3.1 In the case of applications for a FERC license, ESA consultation or ESA permit, a preliminary design for an upstream passage facility shall be developed in an interactive process with NOAA Fisheries Hydro Program staff. The preliminary design should be developed on the basis of synthesis of the required site and biological information listed below. In general, NOAA Fisheries will review fish facility designs in the context of how the required site and biological information was integrated into the design. Submittal of all information discussed below may not be required in writing for NOAA Fisheries review. However, the applicant should be prepared to describe how the biological and site information listed below was included in the development of the preliminary design. NOAA Fisheries will be available to discuss these criteria in general or in the context of a specific site. The applicant is encouraged to initiate coordination with NOAA Fisheries fish passage specialists early in the development of the preliminary design to facilitate an iterative, interactive, and cooperative process to facilitate ESA consultation or to develop FPA Section 18 prescriptions.

3.2 Site Information: The following site information should be provided for the development of the preliminary design.

3.2.1 Functional requirements of the proposed upstream passage facilities as related to all anticipated operations and river flows. Describe median, maximum, and minimum monthly diverted flow rates, plus any special operations (eg. use of flash boards) that modify forebay or tailrace water surface elevations.

3.2.2 Site plan drawing showing location and layout of the proposed fishway relative to existing project features facilities.

3.2.3 Topographic and bathymetric surveys, particularly where they might influence locating fishway entrances and exits, and access to the site.

3.2.4 Drawings showing elevations and plan view of existing flow diversion structures, including details showing the intake configuration, location and capacity of project hydraulic features.

3.2.5 Basin hydrology information, including daily and monthly streamflow data, and flow duration exceedence curves at the proposed upstream passage facility site based on the entire period of available record. Where stream gage data is unavailable, or if a short period of record exists, appropriate synthetic methods of generating flow records may be used.

3.2.6 Project operational information that may affect fish migration (eg. powerhouse flow capacity, period of operation, etc.)

3.2.7 Project forebay and tailwater rating curves encompassing the entire operational range.

3.2.8 Tailrace degradation potential - If the upstream passage facility is at a new or modified diversion, determine the potential for channel degradation that may lower tailwater and compromise fishway performance. Address potential adverse effects of stream channel gradient in this reach, and whether bedrock is present in the tailrace channel.

3.2.9 Special sediment and/or debris problems - Describe conditions that may influence design of the upstream passage facility, or present potential for significant problems.

3.2.10 River morphology trends - Describe whether the river channel is stable or meandering, and how much recent meandering has occurred. Also, describe what effect the proposed upstream passage facility may have on river alignment and the potential for future meandering.

3.3 Biological Information: The following biological information should be provided for the development of the preliminary design.

3.3.1 Type, life stage and run size of anadromous species present.

3.3.2 Run size, period of migration, spawning location, spawning timing and run duration of for each life stage and species present at the site.

3.3.3 Identify non-anadromous species present at the proposed upstream passage site (including life stage), that may impact the facility design.

3.3.4 High and low design passage flow for periods of upstream fish passage (Section 4).

3.3.5 Identify any known fish behavioral aspects that affect salmonid passage. For example, most salmonid species pass readily through orifices, but other species unable to pass through orifices may impede salmonid passage.

3.3.6 Identify what is known and what needs to be researched about fish migration routes approaching the site.

3.3.7 Document, or estimate, minimum streamflow required to allow upstream migration to the impediment during low water periods (based on past site experience)

3.3.8 Predation/poaching -describe the degree of human activity in immediate area and need for security measures.

3.3.9 Identify water quality factors that may affect fish passage at the site. Fish may not migrate if water temperature and quality are marginal, seeking to find holding zones until water quality conditions change.

3.4 Design Development Phases: A description of steps in the design process is presented here to clarify the *preliminary design* as it contrasts with often-used and related terms in the design development process. While many of the following design products are not required by NOAA Fisheries, they are commonly used terms (especially in the context of larger facilities) by many public and private design entities.

3.4.1 A *reconnaissance study* is typically an early investigation of one or more sites for suitability of design and construction of some type of facility.

3.4.2 A *conceptual alternatives study* lists types of facilities that may be appropriate for accomplishing objectives at a specific site, and does not entail much on-site investigation. It results in a narrowed list of alternatives that merit additional assessment.

3.4.3 A *feasibility study* includes an incrementally greater amount of development of each design concept (including a rough cost estimate), which enables selection of a most-preferred alternative.

3.4.4 The *preliminary design* includes additional and more comprehensive investigations and design development of the preferred alternative, and results in a facilities layout (including some section drawings), with identification of primary feature sizes and discharges. Cost estimates are also considered to be more accurate. Completion of the preliminary design commonly results in a preliminary design document that may be used for budgetary and planning purposes, and as a basis for soliciting and subsequent collation of design review comments by other reviewing entities. The preliminary design is commonly considered to be at the 20% to 30% completion stage of the design process.

3.4.5 The *detailed design phase* uses the preliminary design as a springboard for preparation of the final design and specifications, in preparation for the bid solicitation (or negotiation) process. Once the detailed design process commences, NOAA Fisheries shall have the opportunity to review and provide comments at the 50% and 90% completion stages. These comments usually entail refinements in the detailed design that will lead to operations, maintenance, and fish safety benefits.

Section 4. Design Streamflow Range

4.1 **Description, purpose and rationale:** The design streamflow range constitutes the operational bounds of the upstream passage facility. Each upstream passage facility shall be designed to pass upstream migrants throughout a design streamflow range, bracketed by a designated high and low design passage flow. Within this range of streamflows, upstream migrants should be able to pass safely and quickly. Outside this flow range, fish shall either not be present or not be actively migrating, or shall be able to pass safely without need of an upstream passage facility. Site specific information is critical to determine the time period and river flows for which the passage facility is designed. In addition, the upstream passage facility should be of sufficient structural integrity to withstand the maximum expected flow. It is beyond the scope of this document to specify structural criteria for this purpose.

4.2 **Low Fish Passage Design Flow** is the mean daily average stream discharge which is exceeded 95% of the time during periods when upstream migrating fish are normally (historically) present at the site, as determined by a flow-duration curve summarizing at least the previous 25 years of daily discharges, or by an appropriate artificial streamflow duration methodology if discharge records are not available. The design low passage flow is the lowest stream discharge for which upstream migrants are expected to be present, migrating, and dependent on the proposed facility for safe passage. This could also be the minimum instream flow, as determined by state regulatory agencies, or by ESA consultations with NOAA Fisheries, or by an article in a FERC license.

4.3 **High Fish Passage Design Flow** is the mean daily average stream discharge which is exceeded 5% of the time during periods when upstream migrating fish are normally (historically) present at the site, as determined by a flow-duration curve summarizing at least the previous 25 years of daily discharges, or by an appropriate artificial streamflow duration methodology if discharge records are not available. This is the highest stream discharge for which upstream migrants are expected to be present, migrating, and dependent on the proposed facility for safe passage.

4.4 The fishway design shall have **sufficient river freeboard** to minimize overtopping by flood flows. Fishway operations may include shut down of the facility at very high flow or flood flow, in order to allow the facility to quickly returned to proper operation when the river drops to within the range of passage design flows.

Section 5. Upstream Passage System Criteria

5.1 Fishway entrance design criteria

5.1.1 Description, purpose and rationale: The fishway entrance is composed of an entrance gate or slot, through which fishway attraction flow is discharged and through which fish enter the upstream passage facility, and is possibly the most critical component in the design of an upstream passage system. Placing a fishway entrance in the correct location(s), with optimal fishway entrance hydraulic characteristics and geometry are key design parameters that will allow a passage facility to provide a good route of passage throughout the design range of passage flows. The most important aspects of a fishway entrance design are: 1) location of the entrance; 2) shape and amount of flow emanating from the entrance; 3) approach channel immediately downstream of the entrance; and 4) flexibility in operating the entrance flow to accommodate variations in tailrace elevation, stream flow conditions and project operations.

5.1.2 The fishway entrance gate configuration and operation will vary based on site specific project operations and streamflow characteristics. Entrance gates are usually operated in either a fully open or fully closed position, with the operating entrance dependent on tailrace flow characteristics. Sites with limited tailwater fluctuation may not require an entrance gate to regulate entrance head. Adjustable weir gates that rise and fall with tailwater elevation may also be used to regulate fishway entrance head. Other sites may accommodate maintaining proper entrance head by regulating auxiliary water flow through a fixed geometry entrance gate.

5.1.3 Fishway entrances shall be located at points where fish can easily locate the attraction flow and enter the fishway. When choosing an entrance location, high velocity and turbulent zones in a powerhouse or spillway tailrace should be avoided, in favor of relatively tranquil zones adjacent to theses areas. At locations where the tailrace is wide, shallow and turbulent, excavation to create a deeper, less turbulent holding zone adjacent to the fishway entrance(s) may be required.

5.1.4 Attraction flow from the fishway entrance should be between 5% and 10% of high design passage flows for streams with mean annual discharges exceeding 1000 cfs. For smaller streams, where feasible larger percentages (up to 100%) of streamflow should be used. Generally speaking, the higher percentage of total river flow used for attraction into the fishway, the more effective the facility will be in providing upstream passage.

5.1.5 The fishway entrance head (hydraulic drop) shall be maintained between 1 to 1.5 feet.

5.1.6 The minimum fishway entrance width shall be four feet, and the entrance depth at least six feet, although the shape of the entrance is dependant on attraction flow requirements. (See Section 11 requirements for mainstem Columbia and Snake River)

5.1.7 If the site has a multiple zones where fish accumulate, each tailrace accumulation location will require a minimum of one entrance. For long powerhouses, additional entrances are required. Since tailrace hydraulic conditions usually change with project operations and hydrologic events, it is often necessary to provide two or more fishway entrances.

5.1.8 Closure gates shall be provided to provide flow to the appropriate entrance gate, and shall not conflict with any potential path of fish migration. Fishway entrances shall be closed by downward-closing slide gates, unless otherwise approved by NOAA Fisheries.

5.1.9 Fishway entrances can be either adjustable submerged weirs, vertical slot, or orifices, provided that the hydraulic requirements specified in 5.1.3, 5.1.4 and 5.1.5 are achieved. It is noted that some non-salmonid species will avoid use of orifices.

5.1.10 The desired entrance weir and/or slot discharge jet hydraulic condition is streaming, not plunging, for submerged weir discharges. Plunging flow induces jumping and can cause injuries, and presents hydraulic conditions which some species may not pass.

5.1.11 In general, low flow entrances should be oriented more or less perpendicular to streamflow, and high flow entrances should be oriented more or less parallel to streamflow. Site specific assessments are required.

5.1.12 The fishway entrance design shall include staff gages to allow for a simple determination of whether entrance head criterion (see 5.1.4) is being met. Staff gages shall be located in the entrance pool and in the tailwater just outside of the fishway entrance in a area visible from an easy point of access. Care should be taken in the design when locating staff gages, avoiding turbulent areas and areas where velocity is increasing in front of the fishway entrance. Gages should be readily accessible to facilitate in-season cleaning.

5.2 **Fishway entrance pool criteria**

5.2.1 Description, purpose and rationale: The fishway entrance pool is at the lowest elevation of the upstream passage system. It discharges flow into the tailrace through the entrance gates for the purpose of attracting upstream migrants. In many fish ladder systems, the entrance pool is the largest and most important pool, in terms of providing proper guidance of fish to the ladder section of the upstream passage facility. It combines ladder flow with auxiliary water system flow through diffuser gratings to form entrance attraction flow (see 5.3). The entrance pool shall be configured to readily guide fish toward ladder weirs or slots.

5.2.2 The minimum transport velocity (between entrance and first weir, and over submerged weirs) is 1.5 ft/s.

5.2.3 The fishway entrance pool shall be designed to optimize attraction to the lower ladder weirs. This can be accomplished by angling vertical AWS diffusers toward and terminating near the lowermost ladder weir.

5.3 **Auxiliary Water System Criteria** (AWS)

5.3.1 Description, purpose and rationale: AWS flow is usually routed from the forebay through a trash rack or intake screen, through a back set flow control gate, energy dissipation zone, energy baffles, through diffusers and into the fishway. An AWS provides flow to the entrance pool and/or upstream of weirs that on occasion become back-watered, usually providing the bulk of the attraction flow through fishway entrances. In addition, the AWS is used to provide make-up flows to various transition pools in the ladder such as bifurcation or trifurcation pools, trap pools, exit control sections or counting station pools.

5.3.2 Diffusers shall consist of non-corrosive, vertically-oriented flat-bar grates with maximum one inch clear spacing between bars.

5.3.3 The maximum AWS diffuser velocity shall be less than1.0 ft/s for vertical diffusers and 0.5 ft/s for horizontal diffusers, based on total diffuser panel area.

5.3.4 The design shall provide access for debris removal from each diffuser.

5.3.5 All diffuser edges and surfaces exposed to fish shall be rounded during fabrication to reduce the potential for contact injury.

5.3.6 Vertical AWS diffusers shall have a top elevation at or below low design entrance pool water surface elevation.

5.3.7 A trash rack shall be provided at the AWS intake with clear space between vertical flat bars of less than one inch, and maximum velocity of less than 1 ft/s. The support structure for the trash rack shall not interfere with cleaning requirements, and shall consider access, debris raking and debris removal. Where possible, the trash rack should be installed at 1:5 (horizontal:vertical) slope (or flatter) for ease of cleaning. The trash rack design shall allow for easy maintenance, considering access for personnel, travel clearances for manual or automated raking and removal of debris

5.3.8 In instances where the majority of the instream flow passes through the AWS during periods of juvenile out-migration, the AWS intake shall be screened to NOAA Fisheries Juvenile Fish Screen Criteria (see Section 13). Trip gates or alternate intakes can be included in the design to assure that AWS flow targets are achieved if the screen reliability is uncertain at higher flows.

5.3.9 AWS flow control can consist of control gate, turbine intake flow control, or other flow control systems, located sufficiently away from the AWS intake to assure uniform flow distribution at the AWS trash rack at all AWS flows. AWS flow control is required to assure that the correct quantity of AWS flow is discharged at the appropriate location during a full range of forebay water surface elevations.

5.3.10 Excess energy shall be dissipated from AWS flow prior to passage through add-in diffusers (5.3.3). This is necessary to minimize surging and to induce relatively uniform velocity distribution (∀ 10%) at the diffusers. Surging and non-uniform velocities may cause adult fish jumping and associated injuries or excess migration delay. Examples of methods to dissipate excess AWS flow energy include: 1) routing flow into pool with adequate volume (see 5.3.11), then through a baffle system (porosity less than 40%) to reduce surging through entrance pool diffusers; 2) passing AWS flow through a turbine; or 3) passing AWS flow through pipeline with concentric rings or other hydraulic transitions designed to induce headloss.

5.3.11 Energy dissipation pool shall be a minimum of:

$$V \;\exists\; \frac{\text{⌛}\, Q\, H}{32 \text{ ft-lb/s}}$$

where: V = pool volume, in ft^3

⌛ = unit weight of water, 62.4 pounds (lb) per ft^3

Q = AWS flow, in ft^3/s

H= Velocity head of AWS flow, in feet

5.3.12 Staff gages shall be installed to indicate head differential across the AWS intake trash rack, and shall be located to facilitate observation and cleaning.

5.3.13 AWS intake trash racks shall be of sufficient structural integrity to avoid permanent deformation associated with maximum occlusion.

5.3.14 To facilitate cleaning, the AWS shall be valved or gated to provide for easy shut-off during maintenance activities, and subsequent easy re-set to correct operation.

5.3.15 At locations where bedload transport can cause accumulations at the AWS intake, sluicing or other simple removal devices are required.

5.4 **Transport Channels**

5.4.1 Description, purpose and rationale: A transport channel conveys flows between different sectors of the upstream passage facility, providing a route for fish to pass.

5.4.2 The range of transport channel velocities shall be between 1.5 and 4 ft/s, including weirs inundated by high tailwater.

5.4.3 Transport channel shall be a minimum of 5 feet deep.

5.4.4 Transport channels shall be a minimum of 4 feet wide.

5.4.5 Transport channels shall be of open channel design.

5.4.6 Ambient natural lighting shall be provided in all transport channels, if possible. Otherwise acceptable artificial lighting is to be used as described in 5.9.2.

5.4.7 Care must be taken in design to avoid hydraulic transitions or lighting transitions, in order to reduce the possibility of excess migration delay.

5.5 **Fish Ladder design criteria**

5.5.1 Description, Purpose and Rationale: A fish ladder converts the total project head at the passage impediment into passable increments, by providing suitable conditions for fish to hold, rest and ultimately pass upstream. The criteria provided in this section have been developed to provide conditions to pass all salmonid species upstream with minimal delay and injury.

5.5.2 The maximum hydraulic drop per pool shall be 12 inches, or 9 inches if designed for chum salmon passage.

5.5.3 The depth over ladder overflow weirs shall be at least 12 inches, and shall be indicated by locating a staff gage (with the zero reading at the overflow weir crest elevation) in an observable, hydraulically stable location.

5.5.4 The pool dimensions shall be a minimum of 8 feet long (upstream to downstream), and a minimum of 6 feet wide, and a minimum 5 feet deep. However, specific ladder designs will require specific pool dimensions which are greater than the minimums specified here.

5.5.5 Turning pools (i.e. where the fishway bends more than 90E) shall be at least double the length of a standard fishway pool.

5.5.6 Additional guidance and criteria for application of specific ladder types is located in Section 6.

5.5.7 Fishway pool volume shall be a minimum of:

$$V \geq \frac{\gamma Q H}{4 \text{ft-lb/s}}$$

where: V = pool volume, in ft^3
γ = unit weight of water, 62.4 pounds (lb) per ft^3
Q = fish ladder flow, in ft^3/s
H = energy head of pool-to-pool flow, in feet

under every expected flow condition.

5.5.8 The dimensions of orifices shall be at least 15 inches high by 12 inches wide.

5.5.9 The freeboard of the ladder pools shall be at least 3 feet at high design flow.

5.5.10 Ambient lighting is required in all fishway pools.

5.5.11 At locations where the flow changes direction more than 60 degrees, 45 degree vertical miters or vertical radius of curvature shall be included at in the outside corners of fishway pools.

5.6 **Counting Stations**

5.6.1 Description, Purpose and Rationale: A counting station provides a location to observe and enumerate fish utilizing the fish passage facility. Although not always required, a counting station is often included in a fishway design to allow fishery managers to assess fish populations, make observations on fish health or conduct scientific research. Other types of counting stations (such as submerged cameras, adult

PIT tag detectors or orifice counting tubes) may be acceptable, but shall not interfere with the normal operation of the ladder or increase fish passage delay.

5.6.2 Counting stations shall be located in a hydraulically stable, low velocity (i.e. the lower end of velocity range specified in 5.4.2), accessible area of the upstream passage facility.

5.6.3 The counting window shall be designed for complete, convenient cleaning on sufficient frequency to assure sustained visibility and accurate counts. The counting window material shall be of sufficient abrasion resistance to allow frequent cleaning.

5.6.4 Counting windows shall be of sufficient structural integrity to contain fishway flow.

5.6.5 Counting windows shall be vertically oriented.

5.6.6 The counting window sill shall be a maximum of 3 inches above the floor of the passage slot.

5.6.7 The counting window shall include sufficient indirect artificial lighting for satisfactory fish identification at all hours, without retarding upstream passage due to excessive light intensity in the path of upstream migrants..

5.6.8 The minimum observable width (i.e. upstream to downstream dimension) of the counting window shall be 5 feet, and the minimum height (depth) shall be 3 feet (also see 5.6.11).

5.6.9 A crowder may be required in the design to move fish closer to the counting window to accommodate observation during turbid water conditions. If required, the minimum counting station slot width between the counting window and vertical crowder surface should be 18 inches and should be adjustable. The counting window slot width should be maximized as water clarity allows, and when not actively counting fish.

5.6.10 To guide fish onto the counting window slot, a downstream picket lead shall be included in the design with orientation at a flow deflection angle of 45E relative to fishway flow direction. An 45E upstream picket lead shall also be provided. Picket orientation, picket clearance, and maximum allowable velocity shall conform to specifications for diffusers specified in section 5.3. Flat picket bars shall be oriented parallel to flow. Circular pickets may also be used. Maximum head differential through the pickets is 0.2 feet.

5.6.11 To minimize flow separations that may impede passage and induce fallback behavior at the counting window, transition ramps shall be included that provide gradual transitions between walls, floors and the count windows. As general guidance, these transitions shall be more than 1:8 (i.e. one foot horizontally or vertically per eight feet in the direction of flow). Water surface occlusions in the counting window slot shall be avoided.

5.6.12 The pool downstream of the counting station shall extend at least two standard fishway pool lengths from the downstream end of the picket leads. The pool upstream of the counting station shall extend at least one standard fishway pool length from the upstream end of the picket leads. Both pools shall be straight and in line with the counting station.

5.7 **Fishway Exit Section**

5.7.1 Description, purpose and rationale: The fishway exit section provides a flow channel to provide fish with egress from the fishway and continue on their upstream migration. The exit section of upstream fish passage facilities can be composed of the following features: add-in auxiliary water valves and/or diffusers, exit pools with varied flow, exit channels, coarse exit channel trash rack (for fish passage), and fine auxiliary water trash racks and control gates. One function of the exit section is to attenuate forebay water surface elevation fluctuations to assure hydraulic conditions suitable for fish passage are maintained in ladder pools. Other functions can include minimizing the entrainment of debris and sediment into the fish ladder. Different types of ladder designs (see Section 6) require specific fish ladder exit design details.

5.7.2 The exit control section hydraulic drop per pool shall range from 0.5 to 1.0 feet.

5.7.3 The length of the exit channel upstream of the exit control section control shall be a minimum of two standard ladder pools.

5.7.4 Exit section design shall utilize the requirements for auxiliary water diffusers, channel geometry and energy dissipation as specified in 5.3, 5.4 and 5.5.

5.7.5 If possible, the ladder exit should be located along a shoreline and in a low velocity zone (less than 4 ft/s), sufficiently far enough upstream of a spillway, sluiceway or powerhouse to minimize the risk of fish non-volitionally falling back through these routes. Distance depends on bathymetry near the dam spillway or crest, and associated longitudinal velocities. Public access near the ladder exit should not be allowed.

5.8 **Fishway Exit Trashrack and Debris Management**

5.8.1 Description, purpose and rationale: Coarse trash racks are required at the fishway exit, to minimize the entrainment of debris into the fishway. Floating debris can occlude passage corridors, potentially creating hazardous passage zones and/or blocking fish passage. Other types of debris, such as bedload transport into the fishway, can also adversely affect the operation of the facility.

5.8.2 The maximum allowable velocity through a clean trash rack is 1.5 ft/s.

5.8.3 The minimum submerged trash rack depth is 5 feet.

5.8.4 Where possible, the trash rack should be installed at 1:5 (horizontal:vertical) slope (or flatter) for ease of cleaning. The trash rack design shall allow for easy maintenance, considering access for personnel, travel clearances for manual or automated raking and removal of debris

5.8.5 Debris booms, curtain walls, or other provisions are required if coarse floating debris is expected.

5.8.6 If debris accumulation is expected to be high, the design should include an automated mechanical debris removal system. If debris accumulation potential is unknown, the design should include features to allow the simple retrofit of an automated mechanical debris removal system, should the need arise.

5.8.7 The fishway exit trash rack shall have a minimum clear space between vertical flat bars of 10 inches if chinook are present, and 8 inches otherwise. Lateral support bar spacing shall be a minimum of 24 inches, and shall be sufficiently back set of the trash rack face to allow full trash rake tine penetration. Trash racks shall extend to the level of the access walkway, to allow removal of raked debris.

5.8.8 The fishway trashrack shall be oriented at a deflection angle greater than 45E relative to the direction of river flow.

5.8.9 The fishway exit should be designed to minimize entrainment of sediment.

5.8.10 For AWS trashrack design information, see section 5.3

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5.9 Miscellaneous considerations

5.9.1 Fishways shall be secured to discourage vandalism and poaching and to provide public safety.

5.9.2 Ambient lighting shall be provided throughout the fishway. Where this is not possible (such as in tunnels), artificial lighting shall be provided in the blue-green spectral range. Lighting shall be designed to operate under all environmental conditions at the installation.

5.9.3 Personnel access shall be provided to all areas of the fishway, to facilitate operational and maintenance requirements. Walkway grating should allow as much ambient lighting into the fishway as possible.

5.9.4 All metal edges in the flow path used for fish migration shall be ground smooth to minimize risk of lacerations. Concrete surfaces shall be finished to assure smooth surfaces, with one-inch wide 45E corner chamfers..

5.9.5 Protrusions (such as valve stems, bolts, gate operators) shall be avoided in the flow path of the fishway.

5.9.6 All control gates exposed to fish (such as at entrances in the fully-open position) shall have a shroud or be recessed to minimize or eliminate fish contact.

Section 6. Types of Fish Ladders

6.1 **Description, purpose and rationale:** This section discusses the application and suitability for the installation of various types of fish ladders based on conditions at the proposed site. The intent of this section is to identify potential pitfalls of a particular ladder style given a particular site for a fish passage facility, and to provide additional criteria for use with a specific type of fish ladder

6.2 Vertical slot fish ladders

The vertical slot configuration is widely used for the passage of salmon and steelhead. The passage corridor typically consists of 1 to 1.25 foot wide vertical slots between fishway pools. However, slots can be wider in designs where there is no AWS, but should never be less than one foot . This type of ladder is suitable for impediments which have tailrace and forebay water surface elevations that rise and fall at nearly the same rate. Low tailwater and forebay elevations establish the baseline water surface profile, which is on average, parallel to the floor gradient. As the forebay elevation increases at higher discharges over the dam, tailwater typically rises more quickly. This produces a backwater effect in the lower ladder, which is permissible. Avoid use of this type ladder in locations where the forebay rises without an equal or greater rise in tailwater. This creates a drawdown within the ladder, and will greatly increase ladder flow, turbulence, and raise pool to pool differential in the lower ladder slots above the maximum criterion of one foot. Vertical slot ladders require fairly intricate forming for concrete placement, so initial construction costs are somewhat higher than for other types of ladders.

Insert Drawing showing pool dimensions, slot orientation/dimensions and slot geometry

6.3 Ice Harbor fish ladders

The Ice Harbor ladder is also widely used for salmon and steelhead passage. This ladder design was initially developed for use at Ice Harbor Dam (Lower Snake River) in the mid-1960's. It was the first ladder at a large Columbia River dam to have a (steeper) 1:10 slope. The weir consists of two orifices, centered and directly below two weirs - one on each side of the longitudinal centerline of the ladder. Between fishway weirs is a slightly higher non-overflow wall, with an upstream projecting flow baffle at each end. This type of ladder cannot accommodate much water surface elevation fluctuation in each pool, since ladder flow and pool turbulence would fluctuate excessively. Therefore, either a constant forebay elevation must be maintained, or some type of exit control section (see 5.7) must be included to achieve constant ladder flow. Slots, orifices, or a combination of both can be used in the exit section to create constant flow at the ice harbor pools. As a rule of thumb, the number of exit section pools should equal twice the difference between maximum and minimum forebay elevations. A variable flow AWS valve/diffuser adds the required additional flow immediately upstream of the ice harbor pools to maintain a constant water surface elevation and ladder flow. Tailwater fluctuations are accommodated by utilizing a series of add-in flow diffusers in the lower ice harbor pools to

maintain fishway velocity (see Section 5.4). Half- Ice Harbor ladder designs consist of one weir, one orifice and a non-overflow wall between fishway pools.
Insert Drawing

6.4 **Pool and weir fish ladders**

The pool and weir fish ladder passes a nearly constant discharge through successive fishway pools separated by weirs that break the total project head into passable increments. This design allows fish to ascend to a higher elevation when crossing a weir and provides resting zones within each pool. Pools are sufficiently sized to allow for the flow energy to be nearly fully dissipated in the form of turbulence within each receiving pool. The pool and weir ladder is not as widely used as the vertical slot or Ice Harbor ladders. Salmon and steelhead have shown a preference to swim (versus jump) between fishway pools and this option is not available with a pool and weir ladder. This type of ladder is sensitive to changing forebay elevations, and the exit section principles described above for the Ice Harbor ladder apply for pool and weir ladders.
Insert Drawing

6.5 Baffled Chutes

These types of ladders have excellent attraction characteristics while using relatively low attraction flow amounts, and are widely used in fish trap designs (steeppass) or closely monitored sites with low streamflow (denil). Baffled chute type fish ladders entail a sloped channel that has a constant discharge for a given normal depth, chute gradient, and baffle configuration and spacing. Energy is dissipated gradually (based on channel roughness) and results in a constant velocity that must be compatible with swimming ability and behavior of targeted fish.. The passage corridor consists of a high velocity chute flow between the baffles. There are no resting locations within a given length of chute. Once fish start to ascend a length of baffled chute, they must either pass or fall back. Intermediate resting pools are used between component lengths of chute to minimize fallback by weaker swimming fish. In general, baffled chutes shall not be used in areas where downstream passage occurs, or where even minor amounts of debris are expected. Usually, these types of ladders are only used where they can be closely monitored because of debris concerns.

Denil and steeppass fishways are examples of baffled chute ladders, and are of similar design. The denil fishway generally is designed with slopes up to 20%, and has higher flow capacity and less roughness than a steeppass fishway. Steeppass fishways can be used at slopes up to 28%. For either fishway, the average chute design velocity should be less than 5 ft/s. For a upstream passage facility utilizing a denil or a steeppass ladder, the horizontal distance between resting pools should be less than 25 feet. Resting pool volumes shall adhere to volume requirements specified in section 5.5.7. The minimum flow depth shall be 2 feet, and shall be consistent throughout the length of the ladder for all ladder flows. Designs shall be developed to minimize fallback of fish to limit injury potential. Insert Drawing

6.6 Full Width Stream Weirs

Full stream width weirs are fishways are used in small stream systems to incrementally backwater an impassable barrier or impediment. These structures span the entire width of the stream channel and convey the entire stream flow, breaking the hydraulic drop into passable increments. This is accomplished by incrementally stepping down the water surface elevation from the barrier to intersect the natural stream gradient downstream.

Unlike many of the fishways described herein, these structures are not designed with auxiliary water supply systems, trashracks, or a great deal of operational complexity. Weirs may be constructed from reinforced concrete, or in limited applications boulders or logs. Design of each weir must concentrate flow into the center of the downstream pool, and/or direct flow toward the downstream thalweg. This concentration is accomplished by providing a slight weir crest elevation decrease from each bank to the center (flow notch). Typically, the flow notch will be designed to pass the minimum instream flow, while higher stream flows pass over the entire weir crest. Pool volumes should be designed per the pool volume criteria specified in 5.5.7, but natural bedload movement will fill in pools providing a scour pool area below the flow notch, and shallower fringe areas.

Scour is a critical and often underestimated design issue. If sills and weirs are not anchored on bedrock, a means of preventing undermining is required. If a pool lining technique (riprap, concrete, etc) is selected to prevent undermining of the fishway, a minimum 4 feet of depth should be provided in each pool and in the tailrace below the fishway. This allows for a fish to stage or hold below each weir before proceeding upstream. In addition, the tailrace area should be protected from scour to prevent lowering of the streambed, and should be monitored after high flows occur to ensure the facility remains passable.

6.6 Pool and Chute

Pool and chute type fish ladders may a more desirable alternative to the previous options when migrating fish must pass through a greater range of streamflows. During low streamflows, the ladder can operate in the pool ladder mode. When streamflows are greater, improved attraction to the ladder can be attained by routing a proportionately higher discharge through the ladder, which acts as a cross between pool and baffled chute ladders. However, this typically requires manual adjustment of stoplogs, an operation that is cumbersome and could be dangerous. Criteria for this type ladder design are still evolving, and proposals for this type ladder will be assessed on a site-specific basis.

Section 7. Exclusion Barriers

7.1 **Description, purpose and rationale:** Exclusion barriers are designed to minimize the attraction and stop the migration of upstream migrating fish into an area where there is no upstream egress or suitable spawning area, and to guide fish to an area where upstream migration can continue. Exclusion barriers are designed to minimize the potential for injury of fish that are attracted to impassable routes.

Some examples of the use of exclusion barriers include:

- ∃ preventing fish from entering return flow from an irrigation ditch
- ∃ preventing fish from entering the tailrace of a power plant
- ∃ guiding fish to a trap facility for upstream transport, research or broodstock collection
- ∃ guiding fish to a counting facility
- ∃ preventing fish from entering a channel subject to sudden flow changes
- ∃ preventing fish from entering turbine draft tubes
- ∃ preventing fish from entering channels with poor spawning gravels, poor water quality or insufficient water quantity.

The two primary categories of exclusion barriers are picket barriers and velocity barriers. Another type of exclusion barrier is a vertical drop structure, that provides a jump height that exceeds the vertical leaping ability of fish. Other types of barriers, such as electric and acoustic fields, have very limited application because of inconsistent results most often attributed to varying water quality (turbidity, specific conductance).

7.2 **Picket Barrier - Description**: Picket barriers diffuse nearly the entire streamflow through pickets extending the entire width of the impassable route, sufficiently spaced to provide a physical barrier to upstream migrant fish. This category of exclusion barrier includes a fixed bar rack and a variety of hinged floating picket weir designs. Picket barriers usually require removal for high flow events, increasing the potential to allow passage into undesirable areas.

In general, since the likelihood of impinging fish is very high, these types of barriers can not be used in waters containing species listed under the ESA, unless they are continually monitored by personnel on-site, and have a sufficient operational plan and facility design in place to allow for timely removal of impinged or stranded fish prior to the occurrence of injury. Since debris and downstream migrant fish must pass through the pickets, sites for these types of exclusion barriers must be carefully chosen. Picket barriers must be continually monitored for debris accumulations, and debris must be removed before it concentrates flow and violates the criteria established below. As debris accumulates, the potential for the impingement of downstream migrants (eg. juvenile salmonids, kelts, adult salmon that have overshot their destination, resident fish) increases to unacceptable levels. Debris accumulations will also concentrate flow through the remainder of the open picket area, increasing the attraction of upstream migrants to these areas and thereby increasing the potential for jumping injury or successful passage into areas without egress.

Picket barrier design criteria include the following:

7.2.1 The maximum clearance between pickets and abutments is one inch.

7.2.2 Pickets shall be flat bar aligned with flow, or round columns of steel, aluminum or durable plastic.

7.2.3 The picket array shall have a minimum 40% open area.

7.2.4 Picket barriers should be sited where there is a relatively constant depth over the entire stream width.

7.2.5 The average design velocity through pickets less than 1.0 ft/s for all design flows, with maximum velocity less than 1.25 ft/s, or half the velocity of adjacent river flows whichever is lower. The average design velocity is calculated by dividing the flow by the total submerged picket area over the design range of stream flows. When river velocities exceed these criteria, the picket barrier must be removed.

7.2.6 The maximum head differential across clean pickets should be 0.2 feet.

7.2.7 A debris and sediment removal plan is required that anticipates the entire range of conditions expected at the site. Debris shall be removed before accumulations develop that violate the criteria specified in 7.2.5 and 7.2.6.

7.2.8 The minimum picket extension above the water surface at high fish passage design flow is 2 feet.

7.2.9 The minimum depth at the picket barrier at low design discharge shall be 2 feet.

7.2.10 Pickets barriers shall be designed to lead fish to a safe passage route. This can be achieved by angling the picket barrier toward a safe passage route, and providing nearly uniform velocities through the entire length of pickets, and by providing sufficient attraction flows from a safe passage route that minimizes the potential for false attraction to the picket barrier flows.

7.2.11 A uniform concrete sill, or an alternative approved by NOAA Fisheries Hydro Program staff, shall be provides to assure fish do not pass under the picket barrier.

7.2.12 Picket panels should be of sufficient structural integrity to withstand high streamflows.

7.3 **Velocity Barrier - Description:** A velocity barrier consists of a weir and concrete apron combination that prevents upstream passage by producing a shallow flow depth and high velocity on the apron, followed by an impassable vertical jump over the weir. A velocity barrier does not have the fore-mentioned problems of a picketed weir barrier, since flow passes freely over a weir allowing the passage of debris and downstream migrant fish. However, since this type of barrier creates an upstream impoundment, the designer must consider backwater effects which may induce loss of power generation or property inundation.

Velocity barrier design criteria include the following:

7.3.1 The minimum weir height relative to the maximum apron elevation is 3.5 feet.

7.3.2 The minimum apron length (extending downstream from base of weir) is 16 feet.

7.3.3 The minimum apron downstream slope is 1:16 (vertical:horizontal).

7.3.4 The maximum head over the weir crest is 2 feet.

7.3.5 The elevation of the downstream end of apron shall be greater than the tailrace high design flow water surface elevation.

7.3.6 Other combinations of weir height (7.3.1) and weir crest head (7.3.4) may be approved by NOAA Fisheries Hydro Program staff on a site-specific basis.

7.4 **Vertical Drop Structures** - Description: A vertical drop structure can function as an exclusion barrier by providing total project head in excess of the leaping ability of the target fish species. These can be a concrete monolith, rubber dam, or approved alternative.

Vertical drop structure criteria include the following:

7.4.1 The minimum height for vertical drop structure shall be 10 feet relative to the tailrace high design flow elevation.

7.4.2 To minimize the potential for leaping injuries, a minimum of 2 feet cantilevered ledge shall be provided.

7.4.3 Provision shall be made to ensure that fish jumping at the drop structure flow will land in a minimum 5 foot deep pool, without contacting any solid surface.

7.5 **Bottom Hinged Leaf Gates** - Description: A bottom hinged leaf gate is a device that can be elevated to provide an exclusion barrier by providing total project head in excess of the leaping ability of the target fish species. These can be mounted on a concrete base, where the leaf gate is raised into position by hydraulic cylinder, pneumatic bladders or by other means.

Bottom hinged leaf gate criteria include the following:

7.5.1 The minimum vertical head drop (forebay to tailwater) shall be 10 feet at high design flow.

7.5.2 Provision shall be made to ensure that fish jumping at flow over the structure will land in a minimum 5 foot deep pool, without contacting any solid surface.

7.6 **Horizontal Draft Tube Diffusers** - Description: A horizontal draft tube diffuser is a device used below a powerhouse at the turbine draft tube outlet to prevent fish from accessing the turbine runners, where injury is likely. Even if draft tube velocities are sufficiently high to prevent fish access during normal operations, ramping flow rates during turbine shut-down or start-up create velocities low enough to allow fish to swim up the draft tubes and impact turbine runners.

Horizontal Draft Tube Diffuser criteria include the following:

7.6.1 Average velocity of flow exiting the diffuser grating shall be less than 1.25 ft/s, and distributed as uniformly as possible.

7.6.2 Clear spacing between diffuser bars and any other pathway from the tailrace to the turbine runner shall be less than 1 inch.

7.6.3 Diffusers shall be submerged a minimum of two feet for all tailwater elevations.

Section 8. Adult Fish Trapping Systems

8.1 **Description, Purpose and Rationale:** Adult fish trapping systems are often included in the design of an upstream passage facility or in certain instances, can be retro-fitted into an existing passage facility. Trapping systems can also be used in tandem with exclusion barriers for the purpose of passing upstream migrants or for accomplishing various management tasks. Fish attempting to pass upstream are routed into a trap holding pool, from which they can either be truck-loaded or released directly upstream. These systems can be either the exclusive means of upstream fish passage (in which case a lift or lock may be used), or can be a parallel component of a ladder type fishway (where fish can either be routed into an adjacent trapping loop during certain periods, or allowed to pass unimpeded through the fishway). Trapped fish can be truck-loaded for brood-stock collection or upstream release, and can also be sampled, sorted, and interrogated for research and management purposes.

8.2 Trapping systems shall not be used for upstream passage at passage impediments unless site conditions preclude the use of fish ladders. Factors to be considered include the adverse effects of holding trapped fish in a potentially high-density holding pool for an excessive period, maintaining funding and trained personnel, exposure to poaching or predation in the trap, facility failures (eg. loss of water supply) and cumulative handling stresses.

8.3 In general, fish ladders shall not be designed or retrofitted with either in-ladder traps or loading facilities. Rather, trap/holding and loading facilities shall be in an adjacent, off-ladder location where fish targeted for trapping purposes can be routed (see Section 8.15).

8.4 Fish shall not be netted directly from a trapping pool.

8.5 Fish shall only be moved from the trap to another location via water-to-water transport.

8.6 Fish shall be anesthetized before being handled by any person.

8.7 Fish handling and utilization protocol shall be developed, and approved by a NOAA Fisheries biologist before commencement of trapping operations. It shall include the following:

8.7.1 Maximum allowable water temperature for fish handling,

8.7.2 Maximum fish holding time within the trap holding pool,

8.7.3 Type of anesthetic,

8.7.4 Type(s) of species to be directly or indirectly trapped, 8.7.5 Percentage of wild fish to be truck-loaded,

8.7.6 Purpose of trapping,

8.7.7 Destination of fish, distance, transport time, transport tank capacity and water treatment capability,

8.7.8 Contingency plan for fish routing (in case returning numbers are low), and

8.7.9 Frequency of removing fish from the trap.

8.8 A **trapping operations and monitoring plan** shall be developed that addresses fish safety during active and passive trapping operations.

8.9 There shall be a **designated lead technician** on site during all times in which fish are being handled or loaded to assure maximum fish safety. Either cumulative experience and/or training of this technician should be presented to assure full understanding of direct and delayed mortality potential relating to stress and handling.

8.10 **Holding pool criteria**

8.10.1 Holding pools shall be sized to hold a predetermined maximum number of fish, with a minimum allowable volume of 5 ft^3 per fish.

8.10.2 Water supplies for holding pools shall provide at least to 2 gallons per minute per adult fish for the predetermined maximum number of fish to be held.

8.10.3 The holding pool design shall include spray across the entire water surface, or back-set fencing, or other means to assure that trapped fish are not agitated by human activity in the immediate area.

8.10.4 Holding pools shall be designed with a separate water supply and drain system, with intake and exit diffusers designed to conform with Section 5.3 (AWS diffusers), and with an exit overflow weir to control holding pool water surface elevation.

8.10.5 Since fish will likely jump in a holding pool, measures such as darkening the area, or providing soft netting over the pool is required to reduce the possibility of fish injury or death.

8.10.6 Holding pools shall have a minimum of 5 feet of freeboard above the normal holding pool water surface.

8.11 The trap holding pool **trapping mechanism** (e.g., finger weir, vee-trap, false weir, steeppass ladder) allows fish to enter, but not volitionally exit, the holding pool. Criteria include:

8.11.1 All components exposed to fish shall be designed with circular bars, welds, sharp edges ground smooth, and/or other features as required to minimize injuries.

8.11.2 Bars and spacings shall conform with Section 5.3 (AWS diffusers).

8.11.3 Trapping mechanisms shall allow temporary closure to avoid conflicting with braille/crowding and loading operations.

8.11.4 Trapping mechanisms shall be designed to safeguard against fish entry into an unsafe area (such as behind a crowder or under floor braille).

8.11.5 Where possible, gravity (not pumped) flow should be routed through false-weirs and steeppass ladders to avoid potential rejection of the trapping mechanism.

8.12 **Sampling, sorting and interrogation** - If fish are to be physically handled by any person, for any reason, the following shall apply:

8.12.1 Fish shall only be handled after having been anesthetized.

8.12.2 Fish shall be routed into an anesthetic tank via a combination of any of the following: water-to-water transport and passage over a short length of separator bars (to keep from diluting anesthesia), or through a wetted distribution flume with smooth sides and bottom and no abrupt vertical or horizontal bends.

8.12.3 Anesthetic type shall be approved for use by NOAA Fisheries staff biologists in advance. In no case shall carbon dioxide be used. Anesthesia shall be treated as necessary to maintain temperature within 2E F of the ambient water, and to maintain adequate dissolved oxygen levels. Handling of fish will not be allowed at ambient water temperatures greater than 68E F.

8.12.4 Anesthetics shall be replaced in total daily, with waste removed from the trapping site without entering the stream or fishway.

8.12.5 A recovery tank shall be designed to allow anesthetized fish to fully recover before being returned to a safe river location, defined by where fallback to the tailrace is unlikely.

8.12.6 Recovery tank inflow shall be adjustable and controllable to assure adequate water quality for revival; flow should not be enough to flush un-revived fish from the recovery pool. Egress shall be volitional, and based on revival of each fish.

8.13 **Lift/Hopper** - A lift in this context includes a full-sized hopper that is capable of collecting/lifting all fish trapped in a holding pool at one time, then either routing fish to the forebay, or loading onto a truck for transport. This system is not well-suited for routing fish into a sample facility for anesthesia, interrogation, and recovery, since it requires excessive handling of fish. Criteria for the design of lift/hopper systems include the following:

8.13.1 Maximum hopper and transport truck loading density of 3 ft^3 per fish (at a design maximum fish loading).

8.13.2 Hopper freeboard during lifting (from hopper water surface to top of hopper bucket) shall be greater than the water depth within the hopper, to reduce risk of fish jumping out during lifting operations.

8.13.3 When a design includes a hopper sump (into which the hopper is lowered during trapping), side clearances between the hopper and sump sidewalls shall not exceed 1 inch, thereby minimizing fish access below the hopper. Neoprene side seals shall be used to assure that fish do not pass below the hopper at any submerged, or un-submerged hopper position.

8.13.4 Truck transport tanks, into which fish are to be loaded, shall be compatible with the hopper design to assure minimized handling stress.

8.13.5 Fail-safe measures shall be provided to prevent entry of fish into the area of holding pool to be occupied by the hopper before the hopper is lowered into position.

8.13.6 Design shall allow hopper water surface control to be transferred to the truck transport tank, so that water and fish do not plunge abruptly from the hopper into the fish transport tank during loading.

8.13.7 The hopper fish egress opening (into the transport tank) shall have a minimum horizontal cross-sectional area of 3 square ft, and shall have a smooth transition that minimizes fish injury potential.

8.13.8 The hopper interior shall be smooth, and be designed to safeguard fish.

8.14 A **Fish Lock** allows trapped fish in the trapping system holding pool to be elevated without a hopper or hopper sump.

8.14.1 When routing fish from the lock to the forebay or transport vehicle, the following procedure is to be implemented:

1) Fish are to be crowded into the lock
2) The closure gate is shut.
3) In-flow into the lock is introduced through floor diffusers below the floor braille.
4) As the water level rises within the lock, it will ultimately reach a control-weir equilibrium elevation. The floor braille shall be raised only after lock water surface elevation is at equilibrium, and shall not be used to lift fish out of the water.
5) Outflow shall be designed to pass over a control weir and through a descending slope separator (with round bars), allowing flow to pass through the separator bars, and adult fish to be routed either directly into the anesthetic tank, or into a wetted chute for routing to separate sorting/holding pools, or loading into a transport vehicle.

8.14.2 The lock inflow chamber (below the lowest floor braille level) shall be of sufficient depth and volume (see 5.5.7) to limit turbulence into the fish holding zone, immediately before lock inflow is introduced. The inflow sump shall be designed so that flow upwells uniformly through add-in floor diffusers - thereby limiting unstable hydraulic conditions within the lock that may agitate fish.

8.14.3 Depth over the egress weir shall be at least 6 inches, to facilitate fish egress from the lock for transport or anesthesia/handling.

8.14.4 Floor braille and separator bars shall be designed with a maximum clear bar space of 7/8 inch, unless accommodations are needed for other species or other life stages of fish. Side tolerances and seals shall not exceed one inch to assure that fish do not pass under the floor braille, where they could go undetected and die. The floor braille panel shall be kept in its lowest position until flow passes over the egress weir. Only then can the braille panel be gradually lifted upward toward the lock water surface and fish crowded toward the egress weir.

8.14.5 The floor braille hoist shall be designed for manual operation to allow movement of the braille in small increments (upward and downward) that will minimize stress of fish crowded between the floor braille and lock egress weir. The maximum travel rate of the braille shall be 3 feet per minute.

8.14.6 Lock side wall freeboard shall be at least six feet at high water surface elevation, so that fish are not able to jump out of the lock.

8.15 An **off-ladder trapping system** is often required for trap designs. This type of system allows intermittent trapping of fish, with normal unimpeded ladder passage occurring during other periods. The intent is to minimize adverse impacts of fish trapping by allowing rapid transition from one operational mode to the other.

8.15.1 Primary components usually include: in-ladder removable diffusers to block passage within the ladder and guide fish into the trap; an off-ladder holding pool: a transition port and trapping mechanism (through which attraction flow is discharged via one of the devices described in 8.11); a gate to prevent fish from entering the trap area during crowding operations; a holding pool fish crowder (for encouraging adult egress from the off-ladder holding pool to sorting/loading facilities); separate holding pool inflow and outflow facilities; distribution flume (used with false weir or steeppass to enable fish entry to and/or egress from the holding pool); and a lock or lift for truck-loading fish.

8.15.2 Removable diffusers shall comply with Section 5.3. Diffusers shall be completely removed from the ladder when not actively trapping.

8.15.3 Off-ladder holding pool crowders shall have a maximum clear bar space of 7/8 inch. Side tolerances shall not exceed one inch, and shall have side and bottom seals sufficient to allow crowder movement without binding, but shall also be stiff enough to prevent fish movement to behind the crowder panel.

8.15.4 Where false weirs and steeppass ladders are used to route fish into or out of a holding pool, distribution flumes or pipes are used. In cases where there are no horizontal or vertical bends, bottom flow is required to minimize friction between fish and flume invert surfaces. Where there are horizontal and vertical bends, a continuous spray is required to minimize friction between fish and side walls. Horizontal and vertical bends shall be gradual, thereby minimizing risk of fish strike injuries with outside surfaces of bends.

8.15.5 The minimum inside width (or diameter) of the distribution flume shall be 15 inches.

8.15.6 The minimum sidewall height in the distribution flume shall be 24 inches.

8.16 **Single holding pool traps** are often used in tandem with intermittent exclusion barriers (see Section 7.2) for brood-stock collection from small streams. These trapping systems are used to collect, sort, and load adult fish.

8.16.1 The barrier and trap shall be continuously monitored to minimize adverse impacts to returning adult fish.

8.16.2 The trap holding pool shall be designed to achieve relatively stable interior hydraulic conditions to minimize jumping of trapped fish.

8.16.3 Intakes shall conform with Section 5.3.7 or 5.3.8.

8.16.4 Sidewall freeboard shall be a minimum 4 feet above trap pool water surface at high design streamflow.

8.16.5 The trap holding pool interior shall use smooth surfaces to reduce the potential for fish injury.

8.16.6 The trap holding pool shall be sized to hold a predetermined maximum number of fish, with a minimum allowable volume of 5 ft^3 per fish

8.16.7 If the criteria in Section 8.12 can not be met, a description of the proposed means of removing fish from the trapping pool and loading onto a transport truck shall be submitted for approval by a NOAA Fisheries biologist.

Section 9. Fish Passage Criteria and Guidelines for Culverts and other Road Crossings

9.1 **Description, Purpose and Rationale:** This section provides criteria and guidelines for the design of stream crossings to aid upstream and downstream passage of migrating salmonids. For the purpose of fish passage, the distinction between bridge, culvert or low water crossing is not as important as the effect the structure has on the form and function of the stream. To this end, these criteria conceptually apply to bridges and low water crossings, as well as culverts.

9.2 Preferred alternatives for new or replacement culverts. The following alternatives and structure types should be considered in order of preference:

9.2.1 Nothing - Road realignment to avoid crossing the stream

9.2.2 Bridge - spanning the stream to allow for long term dynamic channel stability

9.2.3 Streambed simulation strategies - bottomless arch, embedded culvert design, or ford. Note: If a segment of stream channel where a road crossing is proposed is in an active salmonid spawning area then only full span bridges or streambed simulations are acceptable.

9.2.4 Hydraulic design method, associated with more traditional culvert design approaches - limited to low slopes (0 to 1%) for fish passage

9.2.5 Culvert designed with a external fishway - for steeper slopes

9.2.6 Baffled culvert

9.3 Active Channel Design Method: This method is a simplified design that is intended to size a culvert sufficiently large and embedded deep enough into the channel to allow the natural movement of bedload and formation of a stable bed inside the culvert. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this method since the stream hydraulic characteristics within the culvert are intended to mimic the stream conditions upstream and downstream of the crossing. This design method is usually not suitable for stream channels that are greater than 3% in natural slope or for culvert lengths greater than 100 feet. Structures for this design method are typical round, oval, or squashed pipes made of metal or reinforced concrete.

9.3.1 Culvert Width - The minimum culvert width shall be equal to, or greater than, 1.5 times the active channel width.

9.3.2 Culvert Slope - The culvert shall be placed level (0% slope).

9.3.3 Embedment - The bottom of the culvert shall be buried into the streambed not less than 20% of the culvert height at the outlet and not more than 40% of the culvert height at the inlet.

9.4 Stream Simulation Design Method: This method is a design process that is intended to mimic the natural stream processes within a culvert or under a bridge. Fish passage, sediment transport, flood and debris conveyance within the culvert are intended to function as they would in a natural channel. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this option since the stream hydraulic characteristics within the culvert or beneath the bridge are designed to mimic the stream conditions upstream and downstream of the crossing. The structures for this design method are typically open bottomed arches or boxes but could have buried floors in some cases, or a variety of bridges that span the stream channel. This method utilizes streambed materials that are similar to the adjacent stream channel. Stream simulation requires a greater level of information on hydrology and geomorphology (topography of the stream channel) and a higher level of engineering expertise than the Active Channel Design method.

9.4.1 Channel width - The minimum culvert width shall be equal to, or greater than, the bankfull channel width. The minimum culvert width shall not be less than 6 feet.

9.4.2 Channel Slope - The culvert slope shall approximate the average slope of the stream from approximately 500 feet upstream and 500 feet downstream of the site in which it is being placed. The maximum slope shall not exceed 6%.

9.4.3 Embedment - If a culvert is used, the bottom of the culvert shall be buried into the streambed not less than 30% and not more than 50% of the culvert height. For bottomless culverts the footings or foundation shall be designed for the largest anticipated scour depth. Mechanisms to retain bedload in the design configuration are required.

9.5 Hydraulic Design Method: The Hydraulic Design method is a design process that matches the hydraulic performance of a culvert with the swimming abilities of a target species and age class of fish. This method targets distinct species of fish and therefore does not account for ecosystem requirements of non-target species. There are significant errors associated with estimation of hydrology and fish swimming speeds that are resolved by making conservative assumptions in the design process. Determination of the high and low fish passage design flows, water velocity, and water depth are required for this option. The Hydraulic Design method requires hydrologic data analysis, open channel flow hydraulic calculations and information on the swimming ability and behavior of the target group of fish. This design method can be applied to the design of new and replacement culverts and can be used to evaluate the effectiveness of retrofits of existing culverts.

9.5.1 Culvert Width - The minimum culvert width shall be 5 feet.

9.5.2 Culvert Slope - The culvert slope shall not exceed the average slope of the stream from approximately 500 feet upstream and 500 feet downstream of the site in which it is being placed. If embedment of the culvert is not possible, the maximum slope shall not exceed 0.5%.

9.5.3 Embedment - Where physically possible, the bottom of the culvert shall be buried into the streambed a minimum of 20% of the height of the culvert below the elevation of the tailwater control point downstream of the culvert. The minimum embedment shall be at least 1 foot. Where physical conditions preclude embedment, the hydraulic drop at the outlet of a culvert shall not exceed the limits specified above.

9.5.4 High Fish Passage Design Flow - The high design flow (see section 4.3) for adult fish passage is used to determine the maximum water velocity within the culvert.

9.5.5 Low Fish Passage Design Flow - The low design flow (see section 4.2) for fish passage is used to determine the minimum depth of water within a culvert.

9.5.6 The maximum average water velocity in the culvert refers to the calculated average of velocity within the barrel of the culvert at the fish passage design high flow. For juvenile fish passage, the maximum average water velocity shall be 1.0 ft/s or less for any length culvert at the fish passage design high flow. For adult salmonids use the following table to determine the maximum average water velocity allowed:

Culvert Length (ft)	Velocity (ft/s)
<60	6.0
60-100	5.0
100-200	4.0
200-300	3.0
>300	2.0

9.5.7 Minimum Water Depth at the Low Fish Passage Design Flow: For non-embedded culverts, minimum water depth shall be twelve inches for adult steelhead and salmon, and six inches for juvenile salmon.

9.5.8 Maximum Hydraulic Drop - Hydraulic drops between the water surface in the culvert and the water surface in the adjacent channel shall be avoided for all cases. This includes the culvert inlet and outlet.

9.5.9 Structural Design and Flood Capacity: All culvert stream crossings, regardless of the design option used, shall be designed to withstand the 100-year peak flood flow without structural damage to the crossing. The analysis of the structural integrity of the crossing shall take into consideration the debris loading likely to be encountered during flooding. Stream crossings or culverts located in areas where there is significant risk of inlet plugging by flood borne debris should be designed to pass the 100-year peak flood without exceeding the top of the culvert inlet (Headwater-to-Diameter Ratio less than one). This is to ensure a low risk of channel degradation, stream diversion, and failure over the life span of the crossing. Hydraulic capacity must be compensated for expected deposition in the culvert bottom.

9.5.10 Other Hydraulic Considerations: Besides the upper and lower flow limit, other hydraulic effects need to be considered, particularly when installing a culvert. Water surface elevations in the stream reach must exhibit gradual flow transitions, both upstream and downstream of the road crossing. Abrupt changes in water surface and velocities, hydraulic jumps, turbulence, or drawdown at the upstream flow entrance must be avoided within the culvert. A continuous low flow channel must be maintained throughout the entire stream reach. In addition, especially in retrofits, hydraulic controls may be necessary to provide resting pools, concentrate low flows, prevent erosion of stream bed or banks, and allow passage of bedload material. Hydraulic control devices must be installed downstream of the culvert to avoid headcutting. Culverts and other structures shall be aligned with the stream, with no abrupt changes in flow direction upstream or downstream of the crossing. This can often be accommodated by changes in road alignment or slight elongation of the culvert. Where elongation would be excessive, this must be weighed against better crossing alignment and/or modified transition sections upstream and downstream of the crossing. In crossings that are unusually long compared to streambed width, natural sinuosity of the stream will be lost and sediment transport problems may occur even if the slopes remain constant. Such problems should be anticipated and mitigated in the project design.

9.6 **Retrofitting Culverts:** For future planning and budgeting at the state and local government levels, redesign and replacement of substandard stream crossings will contribute substantially to the recovery of salmon stocks throughout the state. Unfortunately, current practices do little to address the problem: road crossing corrections are usually made by some modest level of incremental, low cost Aimprovement≅ rather than re-design and replacement. These usually involve bank or structure stabilization work, but frequently fail to address fish passage. Furthermore, bank stabilization using hard point techniques frequently denigrates the habitat quality and natural features of a stream. Nevertheless, many existing stream crossings can be made better for fish passage by cost-effective means. The extent of the needed fish passage improvement work depends on the severity of fisheries impacts, the remaining life of the structure, and the status of salmonid stocks in a particular stream or watershed. For work at any stream crossing, site constraints need to be taken into consideration when selecting options. Some typical site constraints are ease of structure maintenance, construction windows, site access, equipment, and material needs and availability. The decision to replace or improve a crossing should fully consider actions that will result in the greatest net benefit for fish passage. If a particular stream crossing causes substantial fish passage problems which hinder the conservation and recovery of salmon in a watershed, complete redesign and replacement is warranted. *Consolidation and/or decommissioning of roads can sometimes be the most cost effective option*. Consultations with NOAA Fisheries biologists can help in selecting priorities and alternatives.

Where existing culverts are being modified or retrofitted to improve fish passage, the Hydraulic Design method criteria should be the design objective for the improvements. However, it is acknowledged that the conditions that cause an existing culvert to impair fish passage may also limit the remedies for fish passage improvement. Therefore, short of culvert replacement, the Hydraulic Design method criteria should be the goal for improvement but not necessarily the required design threshold. Fish passage through existing non-embedded culverts may be improved through the use of gradient control weirs upstream or downstream of the culvert, interior baffles or weirs, or in some cases, fish ladders. However, these measures are not a substituted for good fish passage design for new or replacement culverts. The following guidelines should be used:

9.6.1 Hydraulic Controls - Hydraulic controls in the channel upstream and/or downstream of a culvert can be used to provide a continuous low flow path through culvert and stream reach. They can be used to facilitate fish passage by establishing the following desirable conditions: Control depth and water velocity within culvert, concentrate low flows, provide resting pools upstream and downstream of culvert and prevent erosion of bed and banks.

9.6.2 A entrance pool must be provided that is *at least* 1.5 times the stream depth height, or a minimum of two feet deep, whichever is deeper.

9.6.3 Baffles may provide incremental fish passage improvement in culverts with excess hydraulic capacity that can not be made passable by other means. Baffles will increase the potential for clogging and debris accumulation within the culvert and require special design considerations specific to the baffle type. Culverts that are too long or too high in gradient require resting pools, or other forms of velocity refuge spaced at increments along the culvert length.

9.6.5 Fishways may be required for some situations where excessive drops occur at the culvert outlet. Fishways require specialized site-specific design for each installation. A NOAA Fisheries fish passage specialist should be consulted.

9.6.6 Multiple Culverts - Retrofitting multiple barrel culverts with baffles in one of the barrels may be sufficient as long as low flow channel continuity is maintained and the culvert is reachable by fish at low stream flow.

9.7 Miscellaneous recommendations

9.7.1 Trash racks and livestock fences shall not be used near the culvert inlet. Accumulated debris may lead to severely restricted fish passage, and potential injuries to fish.

9.7.2 Where fencing cannot be avoided, it shall be removed during adult salmon upstream migration periods. Otherwise, a minimum of 9 inches clear spacing shall be provided between pickets, up to the high flow water surface. Timely clearing of debris is also important, even if flow is getting around the fencing. Cattle fences that rise with increasing flow are highly recommended.

9.7.3 Natural or artificial supplemental lighting shall be provided in new and replacement culverts that are over 150 feet in length. Where supplemental lighting is required the spacing between light sources shall not exceed 75 feet.

9.7.4 NOAA Fisheries and State Fish & Wildlife Officials commonly set in-stream work windows in each watershed. Work in the active stream channel shall be avoided during the times of year salmonids are present.

9.7.5 Temporary crossings, placed in salmonid streams for water diversion during construction activities, shall meet all of the guidelines in this document. However, if it can be shown that the location of a temporary crossing in the stream network is not a fish passage concern at the time of the project, then the construction activity only needs to minimize erosion, sediment delivery, and impact to surrounding riparian vegetation.

9.7.6 Culverts shall only be installed in a de-watered site, with a sediment control and flow routing plan acceptable to NOAA Fisheries.

9.7.7 The work area shall be fully restored upon completion of construction with a mix of native, locally adapted, riparian vegetation. Use of species that grow extensive root networks quickly should be emphasized. Sterile, non-native hybrids may be used for erosion control in the short term if planted in conjunction with native species.

9.7.8 Construction disturbance to the area shall be minimized and the activity shall not adversely impact fish migration or spawning.

9.7.9 If salmon are likely to be present, fish clearing or salvage operations shall be conducted by qualified personnel prior to construction. If these fish are listed as threatened or endangered under the federal or state Endangered Species Act, consult directly with NOAA Fisheries biologists to gain authorization for these activities. Care shall be taken to ensure fish are not chased up under banks or logs that will be removed or dislocated by construction. Return any stranded fish to a suitable location in a nearby live stream by a method that does not require handling of the fish.

9.7.10 If pumps are used to temporarily divert a stream to facilitate construction, an acceptable fish screen must be used to prevent entrainment or impingement of small fish. Contact NOAA Fisheries hydraulic engineering staff for appropriate fish screen specifications.

9.7.11 Unacceptable wastewater associated with project activities shall be disposed of off-site in a location that will not drain directly into any stream channel.

Section 10. Tide gates

10.1 Description, Purpose, and Rationale

This section provides guidelines and criteria to be utilized in the design of tide gates for the purpose of providing passage for juvenile and adult salmonids. This material is applicable for projects that are undergoing consultation with NOAA Fisheries, pursuant to Section 7, Section 10 or 4(d) rule responsibilities for protecting fish under the Endangered Species Act (ESA).

Since these guidelines and criteria are general in nature, there may be cases where site constraints or extenuating circumstances dictate that certain criteria be waived or modified. Conversely, where there is a need to provide additional protection for fish, including species of fish not directly under NOAA Fisheries jurisdiction, site-specific criteria may be added. These circumstances will be considered by NOAA Fisheries on a project-by-project basis.

10.2 General Procedural Guidelines

In designing for fish passage at tide gates, the ability of the fish to swim past the open tide gate and through the connected culvert is an important consideration. Research has shown that swimming ability of fish varies and may depend upon a number of factors relating to the physiology of the fish, including species, size, duration of swimming time required, behavioral aspects, migrational stage, physical condition and others, in addition to water quality parameters such as dissolved oxygen concentrations, water temperature, lighting conditions, and others. For this reason, tide gate design criteria must be expressed in general terms.

A functional design should be developed that defines type, location, size, hydraulic capacity, method of operation, and other pertinent juvenile fish screen facility characteristics. In the case of applications and consultations under the ESA, a functional design for juvenile (and adult) fish passage facilities must be developed and submitted as part of the application or of the Biological Assessment for the facility. It must reflect NOAA Fisheries input and design criteria and be acceptable to NOAA Fisheries. Functional design drawings must show all pertinent hydraulic information, including water surface elevations and flows through various areas of the structures, throughout the tidal cycle or river stage fluctuation. Functional design drawings must show general structural sizes, cross-sectional shapes, and elevations. Types of materials must be identified where they will directly affect fish. The final detailed design shall be based on the functional design, unless changes are agreed to by NOAA Fisheries.

To minimize risks to anadromous fish at some locations, NOAA Fisheries may require investigation (by the project sponsors) of important and poorly defined site-specific variables that are deemed critical to development of the screen and bypass design. This investigation may include factors such as fish behavioral response to hydraulic conditions, weather conditions (ice, wind, flooding, etc.), river stage-discharge relationships, seasonal operational variability, potential for sediment and debris problems, resident fish populations, potential for creating predation opportunity, and other information.

10.3 Applicability of Criteria
These criteria should be used only for the replacement or modification of existing tide gates. Installation of new tide gates at sites where none presently exist should only be done as part of an overall enhancement project or for restoration of baseline conditions. This section is intended to provide general criteria in which tide gates may be replaced or modified to improve fish passage and habitat functions. Tide gate projects that operate in conjunction with other water control methods, such as pumps or diversions, should also account for other NOAA Fisheries criteria (i.e. fish screens), as appropriate. NOAA Fisheries believes that site specific variability can dramatically alter the design and performance of tide gates, and that innovative designs can be utilized to meet the criteria outlined here.

10.4 Habitat Functions that are Altered by Tide Gates
Tide gates can disrupt habitat function in the following ways:

- Impair or prevent fish passage for adult and juvenile migrating salmonids,
- Reduce the volume of estuarine habitat,
- Change groundwater levels,
- Impede the movement of woody debris,
- Modify natural flooding processes landward of the tide gate,
- Create severe water temperature gradient across the tide gate,
- Create severe salinity gradient across the tide gate, and
- Modify sediment transport regimes upstream and downstream of the tide gate.

The biological and engineering design of modified or replacement tide gates must take the above effects into account to minimize the adverse effects to the extent possible.

10. 5 Criteria
The tide gate-culvert system should be designed to meet the following criteria:

10.5.1 The permit application package must document how the effects listed in Section 10.4 were addressed in the design.

10.5.2 The tide gate-culvert structure must meet the applicable NOAA Fisheries culvert criteria and provide upstream and downstream passage for adult and juvenile migrating salmonids during 90% of the migration season.

10.5.3 Achieve maximum inundation levels that facilitate drainage and habitat requirements, and maximize the fish passage time window.

10.5.4 The maximum water surface drop at the entrance and exit of the culvert and tide gate is 0.5 feet throughout tidal cycle/river stage.

10.5.5 The bottom lip of a top-hinged flap gate shall be open at least 1.5 feet from the end of the culvert during 90% of the time that the tide gate is open. Side-hinged tide gates shall provide a minimum opening width of at least 1.5 feet during 90% of the time that the tide gate is open.

10.6 Other Design Considerations

The following design features should also be included:

10.6.1 The design should provide sufficient sediment transport to minimize dredging requirements.

10.6.2 The flow in the culvert should have a free water surface for at least 90 % of the migration season.

10.6.3 It should be possible to adjust the elevation at which the gate closes if necessary to meet habitat and passage goals.

Section 11. Specialized Criteria for Main-Stem Columbia and Snake River Upstream and Downstream Fish Passage Facilities

11.1 Description, Purpose and Rationale

The following criteria are specially adapted to Columbia and Snake River upstream and downstream fish passage facilities. Where referenced below, criteria in this section shall apply at main-stem hydroelectric projects. Where not referenced in this section, criteria elsewhere in this document apply.

11.2 Main-Stem Upstream Passage Criteria

Total attraction flow discharged from adult fishway entrances shall be either a minimum of 5% of mean annual discharge, or the discharge approved in the original design memorandum phase prior to construction. All ladder entrances shall be open during designated fish passage months, unless approved for closure by the regional forum on the basis of investigations confirming that closure of one or more entrance gates will not adversely influence upstream passage during the time in question. Under no circumstances shall adjustable weir gates at primary entrances be submerged at a depth less than 8 feet. All other design features and operations shall comply with general criteria listed in Section 5 .

11.3 Main-stem Juvenile Screen and Bypass Criteria

General - *Turbine intake screens* and *vertical barrier screens* at main-stem Columbia and Snake River hydroelectric dams are an exception to design criteria for *conventional screens* referenced in Section 13. Turbine intake screens are considered *partial* screens, because they do not screen the entire turbine discharge. They are *high-velocity* screens, because approach velocities are much higher than allowed for all conventional screens (as described in Section 13). However, since screens were retrofitted to large Columbia and Snake River turbine intakes, it was necessary to protect fish to the extent possible. The following turbine intake screen and vertical barrier screen design criteria are the product of extensive research that guides a large percentage of downstream migrating juvenile salmon into a bypass system, then routes them safely around the dam. Research to improve juvenile passage at main-stem dams continues.

11.4 **Criteria for Submerged Intake Screens** - Existing intake screens are either 20 ft, or 40 ft, long and are located in the bulkhead slot of each turbine. They are lowered into the intake, then rotated to the correct operating inclination. The following are design criteria for submerged intake screens:

11.4.1 Maximum approach velocity (normal to the screen face) = 2.75 fps

11.4.2 Intake screen porosity shall be determined on the basis of physical hydraulic modeling.

11.4.3 Stagnation point (point where the component of velocity along the screen face = 0 fps) shall be at a location where the submerged screen intercepts between 40-43% of turbine intake discharge, and shall be within 5 ft of the leading edge of the screen.

11.4.4 Gatewell flow shall be approximately 10% of intercept flow, which is flow above the intake screen stagnation point (approximately 4% of turbine discharge).

11.4.5 Intake screen face will be stainless steel bar screen, with maximum clearance between bars equal to1.75 mm.

11.4.6 Intake screen shall have an approved and proven screen cleaning device, which can be adjusted for desired cleaning frequency.

11.5 **Criteria for Vertical Barrier Screens (VBS)** - These screens pass nearly all flow entering the gatewell from the intake screen and intake ceiling apex zone. Fish and a relatively small orifice flow remain upstream of, and above, the VBS. The following criteria apply.

11.5.1 Hydraulic modeling shall be used to assure the greatest possible uniform velocity distribution across the entire VBS.

11.5.2 Variable-porosity stacked panels shall be developed using a physical hydraulic model, in order to achieve uniform velocity distribution and minimize turbulence in the upper gatewell.

11.5.3 Where gatewell flow is increased by a flow vane at the gatewell entrance, VBS=s shall be constructed of stainless steel bar screens, with upstream surface bar strands oriented horizontally, and a maximum clearance between bars of 1.75 mm.

11.5.4 A screen cleaner and debris removal system shall be features of each VBS with a gatewell flow increaser vane.

11.5.5 Average VBS through-screen velocity shall be a maximum of 1.0 fps, unless field testing is conducted to prove sufficiently low fish descaling/injury rates at a specific site.

Section 12. Upstream Juvenile Fish Passage

12.1 **Description, Purpose and Rationale:** Upstream juvenile fish passage may be necessary at some passage sites, where inadequate conditions exist downstream for rearing fish. In a ladder that uses only a portion of the river flow for upstream fish passage, juvenile passage should never be optimized at the expense of compromising adult fish passage. In some situations, it may be feasible to operate a ladder entrance with a 6 inch drop to tailwater at times when adult salmon are not present, and at 12 to18 inches during the adult salmon upstream migration. The feasibility of doing this often entails making a judgement call on the timing of adult passage when often little or no information is available, and if available, can change from year to year.

In absence of adequate data to support the need for upstream juvenile passage, it is recommended that a 12 to 18 inch hydraulic drop from entrance pool to tailwater be used for fishway entrance design. Attraction of adult salmonid to a fishway entrance is compromised with a six-inch drop at a fishway entrance, assuming that not all of the streamflow is passed through the entrance. Fishway attraction (i.e. fishes ability to locate the fishway entrance downstream of the dam) is the critical design parameter for an upstream passage facility, and fishway attraction is optimized when velocities are produced by fishway entrance drops of 12 to 18 inches. Many fishways on the Columbia River were originally designed with a six-inch drop from the entrance pool to tailwater. After extensive laboratory and field studies, it was conclusively determined that higher velocities provided better attraction of adult salmonids than did lower velocities. This resulted in making hydraulic adjustments to fishway entrances so that they operated with 12 to 18 inches of drop instead of 6 inches. Subsequent radio telemetry studies verified that passage times decreased as a result. Thus, there is a clear basis for designing entrance pool to tailwater differentials between 12 and 18 inches for adult salmonid passage.

Hydraulic design for juvenile upstream passage should based on representative flows in which juveniles typically migrate. Recent research (NOAA Fisheries, 2001, in progress) indicates that providing for juvenile salmon up to the 10% annual exceedance flow will cover the majority of flows in which juveniles have been observed moving upstream.

Providing six inch drops from pool to pool is normally required for juvenile upstream passage and is probably not an obstacle for adult fish passage. Even though twice the number of pools are required, smaller pool volumes can be used due to lower energy dissipation requirements from pool to pool.

Section 13. Fish Screen and Bypass Facilities

13.0 **Description, Purpose and Rationale**: This section provides guidelines and criteria to be utilized in the development of designs of downstream migrant fish screen facilities for hydroelectric, irrigation, and other water withdrawal projects. In designing an effective fish screen facility, the swimming ability of the fish is a primary consideration. Research has shown that swimming ability of fish varies and may depend upon a number of factors relating to the physiology of the fish, including species, size, duration of swimming time required, behavioral aspects, migrational stage, physical condition and others, in addition to water quality parameters such as dissolved oxygen concentrations, water temperature, lighting conditions, and others. For this reason, screen criteria must be expressed in general terms.

13.1 A **functional screen design** should be developed that defines type, location, size, hydraulic capacity, method of operation, and other pertinent juvenile fish screen facility characteristics. In the case of applications to be submitted to the FERC and consultations under the ESA, a functional design for juvenile (and adult) fish passage facilities must be developed and submitted as part of the application or of the Biological Assessment for the facility It must reflect NOAA Fisheries input and design criteria and be acceptable to NOAA Fisheries. Functional design drawings must show all pertinent hydraulic information, including water surface elevations and flows through various areas of the structures. Functional design drawings must show general structural sizes, cross-sectional shapes, and elevations. Types of materials must be identified where they will directly affect fish. The final detailed design shall be based on the functional design, unless changes are agreed to by NOAA Fisheries.

13.2 To minimize risks to anadromous fish at some locations, **NOAA Fisheries may require investigation (by the project sponsors) of important and poorly defined site-specific variables** that are deemed critical to development of the screen and bypass design. This investigation may include factors such as fish behavioral response to hydraulic conditions, weather conditions (ice, wind, flooding, etc.), river stage-discharge relationships, seasonal operational variability, potential for sediment and debris problems, resident fish populations, potential for creating predation opportunity, and other information. The life stage and size of juvenile salmonids present at a potential screen site usually is not known, and can change from year to year based on flow and temperature conditions. Thus, adequate data to describe the size-time relationship requires substantial sampling efforts over a number of years. For the purpose of designing juvenile fish screens, NOAA Fisheries will assume that fry-sized salmonids and low water temperatures are present at all sites and apply the appropriate criteria listed below, unless adequate biological investigation proves otherwise. The burden-of-proof is the responsibility of the owner of the screen facility.

13.3 **Acceptance criteria for existing screens**: If a fish screen was constructed prior the establishment of these criteria, but constructed to NOAA Fisheries criteria established August 21, 1989, or later, approval of these screens will be considered providing that all of the following conditions are met:

1) the entire screen facility is still functioning as designed;

2) the entire screen facility has been maintained and is in good working condition;
3) when the screen mesh wears out, it will be replaced by mesh meeting the current criterion for mesh size opening;
4) no mortality, injury, entrainment, impingement, migrational delay or other harm to anadromous fish has been noted that is being caused by the facility;
5) no emergent fry are likely to be located in the vicinity of the screen, per the advice of NOAA Fisheries biologists familiar with the site; and
6) when biological uncertainty exists, access to the site is permitted by the diverter for verification of numbers 1 through 5 by NOAA Fisheries.

13.4 **Structure Placement - Streams and Rivers:**

13.4.1 **Where physically practical and biologically desirable, the screen shall be constructed at the point of diversion** with the screen face generally parallel to river flow. Physical factors that may preclude screen construction at the diversion entrance include excess river gradient, potential for damage by large debris, and potential for heavy sedimentation. For screens constructed at the bankline, the screen face shall be aligned with the adjacent bankline and the bankline shall be shaped to smoothly match the face of the screen structure to prevent eddies in front, upstream, and downstream of the screen. Adverse alterations to riverine habitat shall be minimized.

13.4.2 **Where installation of fish screens at the diversion entrance is not desirable or impractical**, the screens may be installed in the canal downstream of the entrance at a suitable location. All screens installed downstream from the diversion entrance shall be provided with an effective bypass system approved by NOAA Fisheries, designed to collect and transport fish safely back to the river with minimum delay. The screen location shall be chosen to minimize the effects of the diversion on in-stream flows by placing the bypass outfall as close as biologically and practically feasible to the point of diversion.

13.4.3 All passage facilities shall be designed to function properly through the full range of hydraulic conditions in the river (see Section 4) and in the diversion conveyance, and shall account for debris and sedimentation conditions which may occur.

13.5 **Structure Placement - Lakes, Reservoirs and Tidal areas:**

13.5.1 **Intakes shall be located offshore** where feasible to minimize fish contact with the facility. When possible, intakes shall be located in areas with sufficient ambient velocity to minimize sediment accumulation in or around the screen and to facilitate debris removal and fish movement away from the screen face. Intakes in reservoirs should be as deep as practical, to reduce the numbers of juvenile salmonids that encounter the intake.

13.5.2 If a **reservoir outlet is used to pass fish from a reservoir**, the intake shall be designed to withdraw water from the most appropriate elevation based on providing the best juvenile fish attraction and appropriate water temperature control downstream of the project. The entire range of forebay fluctuation shall be accommodated in design.

13.6 Screen Hydraulics

13.6.1 The **approach velocity** shall not exceed 0.40 feet per second (fps) for active screens, or 0.20 fps for passive screens. For screen design, approach velocity is calculated by dividing the vertical projection of the effective screen area into the diverted flow amount.

13.6.2 The **effective screen area required** is calculated by dividing the maximum diverted flow by the allowable approach velocity.

13.6.3 For rotating drum screens, the **design submergence** shall not exceed 85%, nor be less than 65% of drum diameter except when debris, including aquatic growth, is not present.

13.6.4 The screen design must provide for **uniform flow distribution** over the screen surface, thereby minimizing approach velocity over the entire screen face. The screen designer must show how uniform flow distribution is to be achieved. Providing **adjustable porosity control** on the downstream side of screens, and/or **flow training walls** may be required. Large facilities **may require hydraulic modeling** to identify and correct areas of concern.

13.6.5 For screens longer than six feet, sweeping velocity shall be **greater than the approach velocity**. This is accomplished by angling the screen face relative to flow. This angle may be dictated by site specific canal geometry, hydraulic, and sediment conditions.

13.6.6 Sweeping velocity shall not decrease along the length of the screen.

13.7 - Screen Face Material

13.7.1 **Perforated plate:** Circular screen openings shall not exceed **3/32 or 0.0938 inches** in diameter.

13.7.2 **Profile bar screen or slotted perforated plate:** The narrowest dimension in the screen openings shall not exceed 1.75 mm.

13.7.3 **Woven wire screen:** The narrowest dimension in the screen openings shall not exceed **3/32 or 0.0938 inches** (example: 6-14 mesh).

13.7.4 The screen material shall be **corrosion resistant** and sufficiently durable to maintain a smooth uniform surface with long term use.

13.7.5 Other components of the screen facility (such as seals) shall not include gaps greater than **0.0689 inches**.

13.8 Civil Works and Structural Features

13.8.1 The face of all **screen surfaces shall be placed flush** (to the extent possible) with any adjacent screen bay, pier noses, and walls to allow fish unimpeded movement parallel to the screen face and ready access to bypass routes.

13.8.2 Structural features shall be provided to **protect the integrity of the fish screens** from large debris. A **trash rack, log boom, sediment sluice**, and other measures may be required.

13.8.3 The civil works shall be designed in a manner that **prevents undesirable hydraulic effects** (such as eddies and stagnant flow zones) that may delay or injure fish or provide predator habitat or predator access.

13.9 Bypass System

13.9.1 Bypass layout

13.9.1.1 The **screen and bypass shall work in tandem** to move out-migrating salmonids (including adults) to the bypass outfall with a minimum of injury or delay. The bypass entrance shall be located so that it can easily be located by out-migrants. Screens greater than six feet in length placed in diversions shall be constructed with the downstream end of the **screen terminating at a bypass entrance**. Screens less than six feet long may be constructed perpendicular to flow with a bypass entrance at either or both ends of the screen, or else could be constructed at an angle to flow, with the downstream end terminating at the bypass entrance. Some screen systems do not require a bypass system. For example, an end of pipe screen located in a river, lake or reservoir does not require a bypass system because fish are not removed from their habitat. A second example is a river bank screen with sufficient hydraulic conditions to move fish past the screen face.

13.9.1.2 **Multiple bypass entrances** may be required if the sweeping velocity will not move fish to the bypass within 60 seconds, assuming fish are transported along the length of the screen face at this velocity.

13.9.1.3 The bypass entrance and all components of the bypass system shall be of **sufficient size and hydraulic capacity to minimize the potential for debris blockage**.

13.9.1.4 In order to improve bypass collection efficiency for a single bank of vertically-oriented screens, a **bypass training wall** shall be located at an angle to the screens, with the bypass entrance at the apex and downstream-most point. This will aid fish movement into the bypass by creating hydraulic conditions that conform to observed fish behavior. For single or multiple vee screen configurations, training walls are not required, unless a intermediate bypass is used.

13.9.1.5 In cases where there is insufficient flow available to satisfy hydraulic requirements at the bypass entrance (entrances) for the main screens, a **secondary screen** may be required. This is a screen located in the main screen bypass which allows the prescribed bypass flow to be used to effectively attract fish into the bypass entrance(s) and then allows for all but a reduced residual bypass flow to be routed back (by pump or gravity) to the diversion canal for the primary use. The residual bypass flow (not passing through the secondary screen) would then convey fish to the bypass outfall location or other destination.

13.96.1.6 **Access for inspection and debris removal is required** at locations in the bypass system where debris accumulations may occur. If trash racks are used, sufficient hydraulic gradient is required to route juvenile fish from between the trash rack and screens to the bypass.

13.9.1.7 The **screen civil works floor** shall be designed to allow fish to be routed back to the river safely when the canal is dewatered. This may entail a sumped drain with a small gate and drain pipe, or similar provisions. If this can not be accomplished, an acceptable fish salvage plan shall be developed in consultation with NOAA Fisheries and included in the operation and maintenance plan.

13.9.1.7 To assure that fish move through the entire screen/bypass system, the rate of change of velocity between any two points in the screen/bypass system shall not exceed 0.2 foot per second per foot of displacement

13.9.2 Bypass Entrance

13.9.2.1. Each bypass entrance shall be provided with **independent flow-control capability**.

13.9.2.2. The **minimum bypass entrance flow velocity** must be greater than 110% of the maximum true velocity upstream of the bypass entrance. At no point should flow decelerate along the screen face or in the bypass entrance. Bypass flow amounts should be of sufficient quantity to ensure these hydraulic conditions over the entire range of operations.

13.9.2.3 **Ambient lighting conditions** are required upstream of the bypass entrance and should extend to the bypass flow control device. Where lighting transitions can not be avoided, they should be gradual, or should occur at a point in the bypass system where fish can not escape the bypass and return to the canal (i.e. when bypass velocity exceeds swimming ability).

13.9.2.4 The **bypass entrance** must extend from the floor to the canal water surface, and be a minimum of 18 inches wide.

13.9.2.5 For weirs used in bypass systems, **depth over the weir** shall be a minimum of one foot.

13.9.3 Bypass Conduit and System Design

13.9.3.1 Bypass pipes and joints shall have **smooth surfaces** to provide conditions that minimize turbulence, risk of catching debris and the potential for fish injury. Pipe joints may be subject to inspection and approval by NOAA Fisheries prior to implementation of the bypass.

13.9.3.2 Fish shall **not be pumped** within the bypass system.

13.9.3.3 Fish shall **not be allowed to free-fall within a pipe or other enclused conduit** in a bypass system. Downwells shall be designed and operated for safe and timely fish passage by proper consideration of turbulence, geometry and alignment.

13.9.3.4 In general, bypass flows should be open channel. If required by site conditions, **pressures in the bypass pipe** shall be equal to or above atmospheric pressures. In no instance shall there be pressurized to non-pressurized (or vice-versa) transitions within the pipe. Bypass pipes shall be designed to allow trapped air to escape.

13.9.3.5 **Bends should be avoided** in the layout of bypass pipes due to the potential for debris clogging and turbulence. The ratio of **bypass pipe center-line radius of curvature to pipe diameter (R/D)** shall be greater than or equal to 5. Greater R/D may be required for super-critical velocities.

13.9.3.6 Bypass pipes or open channels shall be designed to **minimize debris clogging and sediment deposition** and to facilitate inspection and cleaning as necessary. Access ports shall be provided to allow for detection and removal of debris.

13.9.3.7 The **bypass pipe diameter** should generally be a function of the bypass flow and slope but must also comply with velocity and depth criteria in 13.9.3.9 and 13.9.3.10. Generally, a bypass pipe less than 18 inches in diameter is not acceptable. However, if other hydraulic criteria cannot be reasonably satisfied with that size of pipe, the diameter can be reduced with special consideration given to management of debris. In no case can a pipe diameter of less than 10 inches be used. For bypass flows greater than 20 cfs, a 30≅ bypass pipe is recommended. Bypass flows greater than 50 cfs are special cases that need specific consultation with NOAA Fisheries engineers.

13.9.3.8 Design **bypass flow** shall be at least 5% of the total diverted flow amount.

13.9.3.9 The design **pipe velocity** should be between 6 and 12 fps for the entire operational range. If higher velocities are approved, special attention to pipe and joint smoothness is required. In no instance shall pipe velocity be less than 2 fps.

13.9.3.10 The design **minimum depth** of free surface flow in a bypass conduit shall be at least 40% of the bypass pipe diameter.

13.9.3.11 **Closure valves** of any type are not allowed within the bypass pipe unless specifically approved based on demonstrated fish safety.

13.9.3.12 **Sampling facilities** installed in the bypass conduit shall not impair operation of the facility during non-sampling operations.

13.9.3.13. There should not be a **hydraulic jump** within the pipe, unless a weak jump is specifically approved by NOAA Fisheries.

13.9.3.14 The bypass pipe design shall facilitate the **detection and removal of debris** that may lodge in the pipe.

13.10 Bypass Outfall

13.10.1 Bypass outfalls should be located where **ambient river velocities** are greater than 4.0 ft./s..

13.10.2 Bypass outfalls shall be designed to minimize predation by selecting an **outfall location** free of eddies, reverse flow, or known predator habitat. Water cannon sprinkler systems may be required in areas with high avian predation potential. Bypass outfalls should be located to provide good egress conditions for downstream migrants.

13.10.3 Bypass outfalls shall be **located where the receiving water is of sufficient depth** (depending on the impact velocity and quantity of bypass flow) to ensure that fish injuries are avoided at all river and bypass flows. The bypass flow shall not impact the river bottom or other physical features at any stage of river flow.

13.10.4 Maximum bypass outfall **impact velocity** (i.e. the velocity of bypass flow entering the river) including vertical and horizontal velocity components shall be less than 25.0 ft/s.

13.10.5 The bypass outfall discharge into the receiving water shall be designed to **avoid attraction of adult fish** thereby reducing the potential for jumping injuries.

13.10.6 The bypass outfall design must allow for the potential attraction of adult fish, by provision of a **safe landing zone** if attraction to the outfall flow can potentially occur.

13.11 Screen Operations and Maintenance

13.11.1 A reliable, ongoing **inspection, preventative maintenance and repair program** is necessary to assure facilities are kept free of debris and that screen mesh, seals, drive units, and other components are functioning correctly. A written plan should be completed and submitted for approval with the screen design.

13.11.2 Fish screens shall be **automatically cleaned** as frequently as necessary to prevent accumulation of debris. The cleaning system and protocol must be effective, reliable, and satisfactory to NOAA Fisheries.

13.11.3 A **passive screen** can only be used when:

∃ the debris load is expected to be low, and
∃ the rate of diversion is less than 1 CFS, and
∃ where sufficient ambient river velocity exists to carry debris away and eliminate debris accumulations on the screen surface, and
∃ an inspection and maintenance program is approved by NOAA Fisheries and implemented by the water user.

13.11.4 Intakes shall include a trash rack in the screen facility design which shall be kept free of debris. In certain cases, a satisfactory profile bar screen design can substitute for a trash rack. Based on biological requirements at the screen site, trash rack spacing may be specified that reduces the probability of entraining adult fish.

13.11.5 The head differential to trigger screen cleaning for intermittent type cleaning systems shall be a maximum of 0.1 feet or as agreed to by NOAA Fisheries.

13.11.6 The completed screen and bypass facility shall be made available for inspection by NOAA Fisheries, to verify that the screen is being operated consistent with the design criteria.

13.11.7 Screen and bypass facilities shall be evaluated for biological effectiveness and to verify that hydraulic design objectives are achieved. At the discretion of NOAA Fisheries, this could entail a complete biological evaluation, especially if waivers to screen criteria are granted.

13.11.8 Provision shall be made to limit the build-up of sediment, where it could impact screen operations.

13.12 - Additional criteria for end of pipe screens (including pump intake screens)

13.12.1 **End of Pipe Screen Location:** When possible, end of pipe screens shall be placed in locations with **sufficient ambient velocity** to sweep away debris removed from the screen face.

13.12.2 End of pipe screens **shall be submerged** to a depth of at least one screen radius below the minimum water surface, with a minimum of one screen radius clearance between screen surfaces and natural or constructed features. For approach velocity calculations, the entire submerged effective area can be used.

13.12.3 A **clear escape route** should exist for fish that approach the intake volitionally or otherwise. For example, if a pump intake is located off of the river (such as in an intake lagoon), a conventional open channel screen should be placed in the intake channel or at the edge of the river to prevent fish from entering a lagoon.

Section 14. Infiltration Galleries

14.1 **Description, Purpose and Rationale:** This section discusses the application and suitability for the installation infiltration galleries. In concept, infiltration galleries could provide suitable fish passage conditions at a diversion site. However, if improperly sited, failure can occur that can result in severe adverse habitat impacts and loss of habitat access in addition to the loss of the diversion. This section describes particular site conditions and criteria that should provide for satisfactory operation of infiltaration galleries to assure proper fish protection.

14.2 **Site Selection** - NOAA Fisheries intends to only permit infiltration galleries at stream sites that exhibit sufficient natural fluvial processes to preclude sediment deposition on top of the infiltration gallery. The sealing of infiltration galleries transported bedload sediments seems to be a common mode of failure. Infiltration galleries should not be installed at sites where natural sedimentation occurs that would plug a gallery - that is, avoid installations where an engineered porous rock fill cover will fail over time as sediment accumulates.

14.3 **Minimum Depths** over infiltration galleries:

14.3.1 Infiltration galleries should not be operated when the water depth over any part of the infiltration gallery is less than 0.5 feet. Use of temporary impoundments such as push-up berms and other dams to raise the water level is not permitted.

14.3.2 Infiltration galleries installed with less than 24 inches of bedload cover should meet juvenile fish screen criteria, as described in Section 13.

14.4 **Flow amount:** Infiltration galleries should be designed to discount (not consider) inflow from the area immediately above the infiltration gallery, that is, they should be designed to primarily depend upon inflow from the sides and beneath the infiltration gallery only.

14.5 **Imported Gravels**: Rock used to backfill over the infiltration gallery, within three feet of the stream bottom, should be *in situ* material excavated from the site. Imported gravels are not allowed in the top three feet. Only material excavated for installation of the infiltration galleries should be used in this zone. If the natural material is other than porous material it is likely a poor place to install an infiltration gallery, as described in section 14.2.

14.6 Induced vertical **approach velocity**, measured 3" from the stream bottom, should be

14.6.1 Less than 0.01 fps for infiltration galleries that are not automatically backflushed at least once every 12 hours.

14.6.2 Less than 0.1 fps for infiltration galleries that are automatically backflushed at least once every 12 hours.

14.6.3 If less than 24 inches of streambed cover is proposed over the Infiltration galleries, then the inlet to the infiltration gallery piping should meet the applicable approach velocity criteria described NOAA Fisheries juvenile fish criteria (see Section 13.6).

14.7 **Backflushing:**

14.7.1 For infiltration galleries relying upon backflush provisions, they should be cleaned at least once each 12 hours to avoid large batch discharges of sediment into the stream..

14.7.2 In all cases, if rearing juveniles are present turbidity should be maintained at or less than 125% of background turbidity, as measured 100 feet downstream from the infiltration gallery.

14.7.3 The backflushing flow rate should be sufficient to create a minimum 0.25 feet per second vertical water velocity, as measured 3" above the stream bottom.

14.7.4 Infiltration galleries greater than 1 cfs should have automatic backflushing systems.

14.7.5 Backwash medium may be either air or water or a combination of air and water.

14.7.6 Backflushing of Infiltration galleries elements within 300 feet upstream of a redd should not be undertaken while incubation is occurring.

14.8 **Limitations/Cessation of Use**

14.8.1 Infiltration galleries should not be constructed in areas in where spawning may occur.

14.8.2 Should spawning occur within 10' of a portion of an infiltration gallery, then use of those portions of the Infiltration galleries within 10' of the redd should be discontinued for 90 days, or as directed by NOAA Fisheries.

14.8.3 Instream excavation to repair infiltration galleries is not included in the scope of permitted work beyond 90 days from the date of commencement of initial instream construction, or the end of the approved work period, whichever is earlier, unless performed when there is no flowing water in the creek. This restriction does not apply to repairs that do not disturb the river bed or banks.

14.8.4 Infiltration galleries= design should be prepared by or under the supervision of an appropriately licensed engineer, engineering geologist and stamped with his/her seal.

Section 15. Interim Passage during Construction and/or Modifications

Where construction and/or modifications to man-made impediments (eg., dams) or upstream passage facilities are planned, upstream passage may be adversely impacted. If possible, these activities should be scheduled for periods when migrating fish are not present, as specified in the in-water work period allowable for construction of facilities in streams. However, this may not always be possible or advisable. In these cases, an interim fish passage plan shall be prepared and submitted to NOAA Fisheries for approval, in advance of work in the field. Criteria listed herein shall apply to the interim upstream passage plan. Where this is not possible, project owners must seek NOAA Fisheries approval of alternate interim fish passage design criteria, and a final interim passage plan.

Section 16. Operations and Maintenance Responsibilities

Passage facilities at impediments must be operated and maintained properly for optimum, or even marginal, success. The preceding criteria are intended for use in design of passage facilities; however, failure to operate and maintain these facilities to optimize performance in accordance with design will result in compromised fish passage, and ultimate deterioration of the entire facility. Therefore, NOAA Fisheries requires project sponsors to acknowledge and accept long-term responsibility for operations, maintenance, and repair of fish facilities described herein, to assure protection of fish on a sustained basis. This includes immediate restoration of the passage facility (including repair of damage and sediment/gravel removal) immediately after flooding. Where facilities are inadequately operated or maintained, and mortality of listed fish can be documented, the responsible party is liable to enforcement measures as described Section 9 of the Endangered Species Act.

An operation and maintenance plan shall be drafted and submitted for approval by NOAA Fisheries. This plan shall include a brief summary of operating criteria posted at the passage facility or made available to the facility operator.

Section 17. Post-construction evaluations

Post-construction evaluation is important to assure the intended results are accomplished, and that mistakes are not repeated elsewhere. There are three parts to this evaluation: 1)Verify the fish passage system is installed in accordance with proper design and construction procedures; 2) measure hydraulic conditions to assure that the facility meets these guidelines, and 3) perform biological assessment to confirm the hydraulic conditions are resulting in successful passage. NOAA Fisheries technical staff may assist in developing a hydraulic or biological evaluation plan to fit site-specific conditions and species, but in any case, evaluation plans are subject to approval by NOAA Fisheries. These evaluations are not intended to cause extensive retrofits of any given project unless the as-built installation does not reasonably conform to the design guidelines, or an obvious fish passage problem continues to exist. Over time, NOAA Fisheries anticipates that the second and third elements of these evaluations will be abbreviated as commonly used designs are evaluated and fine-tuned to assure optimal passage conditions..

Section 18. Experimental Fish Guidance Devices

Position Statement of the National Marine Fisheries Service
Northwest Region
November 1994

National Marine Fisheries Service Northwest Region Position Paper on Experimental Technology for Managing Downstream Salmonid Passage

SUMMARY

NOAA Fisheries believes that positive-exclusion barrier screens, as described below, are appropriate for utilization in the protection of downstream migrant salmon at all intakes. However, the process described herein delineates an approach whereby experimental behavioral guidance devices can be evaluated and (if comparable performance is confirmed to the satisfaction of NOAA Fisheries) installed in lieu of screens.

INTRODUCTION

Numerous stocks of salmon and steelhead trout in Pacific Northwest streams are at low levels and many stocks continue to decline. Idaho sockeye salmon and Snake River spring, summer, and fall chinook are listed as "endangered" under the Endangered Species Act. Petitions for additional listings are pending. It is essential to provide maximum protection for all salmonid juveniles to halt and reverse overall population declines.

The death and injury of juvenile fish at water diversion intakes have long been identified as a major source of fish mortality [Spencer1928, Hatton 1939, Hallock and Woert 1959, Hallock 1987]. Fish diverted into power turbines incur up to 40 percent immediate mortality, while also experiencing injury, disorientation and delay of migration that may increase predation related losses [Bell, 1991]. Fish entrained into agricultural and municipal water diversions experience 100 percent mortality. Diversion mortality is the major cause of decline in some fish populations. For the purposes of this document, diversion loses includes turbine, irrigation, municipal, and all other potential fish losses related to the use of water by man.

Positive-exclusion barrier screens which screen the entire diversion flow have long been used to prevent or reduce entrainment of juvenile fish for diversions of up to 3000 cfs. In recent decades, design improvements have been implemented to increase the biological effectiveness of positive-exclusion screen and bypass systems by taking advantage of known behavioral responses to hydraulic conditions. Recent evaluations have consistently demonstrated high success rates (typically greater than 98 percent) at moving juvenile salmonids past intakes with a minimum of delay, loss, or injury. (For diversion flows over 3000 cfs, such as at Columbia River main-stem turbine intakes, submerged traveling screens or bar screens are commonly used. These are not considered positive-exclusion screens in the context of this position statement.)

The past few decades have also seen considerable effort in developing "startle" systems to elicit a taxis (response) by fish, with an ultimate goal of reducing entrainment. This paper addresses research performed to avoid losses at intakes and presents a position statement for reviewing and implementing future fish protection measures.

JUVENILES AT INTAKES

Entrainment, impingement, and delay/predation are the primary contributors to the mortality of juvenile migrating salmonids. Entrainment occurs when fish are drawn into the diversion canal or turbine intake. Impingement occurs when a fish is not able to avoid contact with a screen surface, trashrack, or debris at the intake. This can cause bruising, descaling and other injuries. Impingement, if prolonged, repeated or occurring at high velocities also causes direct mortality. Predation (which is the leading cause of mortality at some diversion sites) occurs when fish are preyed upon by aquatic or avian animals. Delay at intakes increases predation by stressing or disorienting fish and/or by providing habitat for predators.

A. Positive-Exclusion Screen and Bypass Systems (PESBS)

Design criteria for PESBS have been developed, tested, and proven to minimize adverse impacts to fish at diversion sites. Screens with small openings and fish-tight seals are positioned at a slight angle to flow. This orientation allows fish to be guided to safety at the downstream end of the screen, while they resist being impinged on the screen face. These screens are very effective at preventing entrainment [Pearce and Lee 1991]. Carefully designed bypass systems minimize fish exposure to screens and provide hydraulic conditions that safely return fish to the river, thereby preventing impingement [Rainey 1985]. The PESBS are designed to minimize entrainment, impingement, and delay/predation from the point of diversion through the facility to the bypass outfall.

PESBS have been installed and evaluated at numerous facilities [Abernathy et al 1989, 1990, Rainey, 1990, Johnson, 1988]. A variety of screen types (e.g. fixed-vertical, drum, fixed-inclined) and screen materials (e.g. woven cloth [mesh], perforated plate, profile wire) have proven effective, when used in the context of a satisfactory design for the specific site. Facilities designed to previously referenced criteria consistently resulted in a guidance efficiencies of over 98 percent [Hosey, 1990, Neitzel, 1985, 1986,1990 a,b,c,d, Neitzel, 1991].

The main detriment of PESBS is cost. At diversions of several hundred cubic feet per second and greater, the low velocity requirement and structure complexity can drive the cost of fish passage to over $1 million. At the headworks, the need to clean thescreen, remove trash, control sediment, and provide regular maintenance (e.g. seasonal installation, replacing seals, etc.) also increases costs.

B. Behavioral Devices

Due to the high costs of PESBS, there has been considerable effort since 1960 to develop less expensive behavioral devices as a substitute for positive fish protection [EPRI, 1986]. A behavioral device, as opposed to a conventional screen, requires a volitional taxis on the part of the fish to avoid entrainment. Some devices were investigated with the hope of attracting fish to a desired area while others were designed to repel fish. Most studies focused on soliciting a behavior response, usually noticeable agitation, from the fish.

Investigations of prototype startle-response devices document that fish guidance efficiencies are consistently much lower than for conventional screens. Experiments show that there may be a large behavioral variation between individual fish of the same size and species to startle responses. Therefore, it cannot be predicted that a fish will always move toward or away from that stimuli. Until shown conclusively in laboratory studies, it should not be assumed that fish can discern where a signal is coming from and what constitutes the clear path to safety.

If juvenile fish respond to a behavioral device, limited size and swimming ability may preclude small fish from avoiding entrainment (even if they have the understanding of where to go and have the desire to get there). Another concern is repeated exposure; fish may no longer react to a signal after an acclimation period. In addition to vagaries in the response of an individual fish, behavior variations due to species, life stage, and water quality conditions can be expected.

Another observation is that past field tests of behavioral devices have been deployed without consideration of how controlled ambient hydraulic conditions (i.e. the use of a training wall to create uniform flow conditions, while minimizing stagnant zones or eddies that can increase exposure to predation) can optimize fish guidance and safe passage away from the intake. Failure to consider that hydraulic conditions can play a big role in guiding fish away from the intake is either the result of the desire to minimize costs or the assumption that behavioral devices can overcome the tendency for poor guidance associated with marginal hydraulic conditions. The provision of satisfactory hydraulic conditions is a key element of PESBS designs.

The primary motivation for selection of behavioral devices relates to cost. However, much of the cost in PESBS is related to construction of physical structures to provide hydraulic conditions which are known to optimize fish guidance. Paradoxically, complementing the behavioral device with hydraulic control structures needed to optimize juvenile passage will compromise much of the cost advantage relative to PESBS.

Skepticism about behavioral devices, at this stage of their development, is supported by the fact that few are currently being used in the field and those that have been installed and evaluated seldom show consistent guidance efficiencies over 60 percent [Vogel, 1988, EPRI, 1986]. The louver system is an example of a behavioral device with a poor record. Entrainment rates were high, even with favorable hydraulic conditions, due to the presence of smaller fish [Vogel, 1988, Cramer, 1973, Bates, 1961]. Due to their poor performance, most of these systems were eventually replaced by PESBS.

EXPERIMENTATION PROCESS

However, there is potential for future development of new and acceptable screening and behavioral guidance devices that will safely pass fish at a rate comparable with PESBS. These new concepts are considered "experimental" until they have been through the process described herein and have been proven in a prototype evaluation validated by NOAA Fisheries. These prototype evaluations should occur over the foreseeable range of adverse hydraulic and water quality conditions (i.e. temperature, dissolved oxygen). NOAA Fisheries will not discourage research and development on experimental fish protection devices, but the following elements should be addressed during the process of developing experimental juvenile passage protection concepts:

(1)Consider earlier research. A thorough review of similar methods used in the past should be performed. Reasons for substandard performances should be clearly identified.

(2)Study plan. A study plan should be developed and presented to NOAA Fisheries for review and concurrence. It is essential that tests occur over a full range of possible hydraulic, biological, and ecological conditions that the device is expected to experience. Failure to receive study plan endorsement from NOAA Fisheries may result in disputable results and conclusions.

(3)Laboratory research. Laboratory experiments under controlled conditions should be developed using species, size, and life stages intended to be protected. For behavioral devices, special attention must be directed at providing favorable hydraulic conditions and demonstrating that the device clearly induces the planned behavioral response. Studies should be repeated with the same test fish to examine any acclimation to the guidance device.

(4)Prototype units. Once laboratory tests show high potential to equal or exceed success rates of state-of-the-art screening, it is appropriate to further examine the new device as a prototype under real field conditions. Field sites must be appropriate to (a) demonstrate performance at all expected operational and natural variables, (b) evaluate the species, or an acceptable surrogate, that would be exposed to the device under full operation, and (c) avoid unacceptable risk to depressed or listed stocks at the prototype locations.

(5)Study results. Results of both laboratory tests and field prototype evaluations must demonstrate a level of performance equal to or exceeding that of PESBS before NOAA Fisheries will support permanent installations.

Conclusions

During the course of the past few decades, we have seen an increase in the number of unscreened stream diversions, and this trend is likely to continue unless corrective measures are implemented. Concurrently, anadromous fish numbers have dwindled. Proven fish passage and protection facilities, which have demonstrated high guidance rates at other sites, can provide successful passage at most diversion intakes.

Periodically, major initiatives have been advanced to examine the feasibility of experimental guidance systems. Results were generally poor or inconclusive, with low guidance efficiencies attributable to the particular device used. Often results were based on a small sample size, or varied with operational conditions. In addition, unforeseen operational and maintenance problems (and safety hazards) were sometimes a byproduct. Nevertheless, some of these experiments show potential. To further advance fish protection technology, NOAA Fisheries will not oppose tests that proceed in accordance with the tiered process outlined above. To ensure no further detriment to any fish resource, including delays in implementation of acceptable passage facilities, experimental field testing should occur simultaneous to design and development of a PESBS for that site. This conventional system should be scheduled for installation in a reasonable time frame, independent of the experimental efforts. In this manner, if the experimental guidance system once again does not prove to be as effective as a PESBS, a proven screen and bypass system can be implemented without additional delay and detriment to the resource.

Adopted

Original signed by Will Stelle 1/6/95
William Stelle, Jr., Date_______
Regional Director

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