Appendix C
Technical References

1. **Culvert Criteria for Fish Passage:** California Salmonid Stream Habitat Restoration Manual; Appendix IX-A. (California Department of Fish and Game; Flosi et al, 2002**)**
   http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp

2. **Guidelines for Salmonid Passage at Stream Crossings - NOAA Fisheries;** California Salmonid Stream Habitat Restoration Manual; Appendix IX-B. (California Department of Fish and Game; Flosi et al, 2002)
   http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp

3. **NOAA Fisheries Water Drafting Specifications:** Southwest Region, August 2001
   http://www.swr.nmfs.**noaa**.gov/hcd/**WaterDrafting-**02.htm

4. **CDFG Guidelines for Temporary Water Drafting:** California Department of Fish and Game Timber and Resources Program; DRAFT 2001

5. **Dust Palliative Application Guidelines:** San Francisco Regional Water Quality Control Board; Erosion and Sediment Control Manual 2002.

CALIFORNIA SALMONID STREAM HABITAT RESTORATION MANUAL

FISH PASSAGE EVALUATION IX-A-1 April 2003

APPENDIX IX-A

STATE OF CALIFORNIA RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME

CULVERT CRITERIA FOR FISH PASSAGE

> **"For habitat protection, ecological connectivity should be a goal of stream-road crossing designs. The narrowest scope of crossing design is to pass floods. The next level is requiring fish passage. The next level includes sizing the crossing for sediment and debris passage. For ecosystem health, "ecological connectivity" is necessary Ecological connectivity includes fish, sediment, debris, other organisms and channel/floodplain processes."**
>
> Ken Bates – WDFW

INTRODUCTION

The following criteria have been adopted by the California Department of Fish and Game (DFG) to provide for upstream fish passage at culverts. This is not a culvert design manual, rather it is supplemental criteria to be used by qualified professionals for the design of culverts that meet both hydraulic and fish passage objectives while minimizing impacts to the adjacent aquatic and riparian resources. The objective of these criteria is to provide unimpaired fish passage with a goal of providing ecological connectivity.

Previous versions of the DFG Culvert Criteria were based on hydraulic design of culverts to match the swimming performance of adult anadromous salmonids. This revision of the criteria has been expanded to include considerations for juvenile anadromous salmonids, nonanadromous salmonids, native non-salmonids, and non-native fish. While criteria are still included for the hydraulic design option, criteria have been added for two additional design options that are based on the principles of ecological connectivity. The two additional design methods are:

- Active Channel Option
- Stream Simulation Option

The criteria contained in this document are based on the works of several organizations including state and federal agencies, universities, private organizations and consulting professionals. These criteria are intended to be consistent with the National Oceanic and Atmospheric Administration Fisheries, Southwest Region (NOAA-SWR) *Guidelines for Salmonid Passage at Stream Crossings*, as well as being in general agreement with Oregon and Washington Departments of Fish and Wildlife culvert criteria for fish passage. This document is considered a "Work in Progress" and will be revised as new information warrants.

The Caltrans Highway Design Manual defines a culvert as "A closed conduit which allows water to pass under a highway," and in general, has a single span of less than 6.1 meters (20 feet) or multiple spans totaling less than 6.1 meters. 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.
The primary factors that determine the extent to which fish passage will be impacted by the construction of a crossing are:

- The degree of constriction the crossing has on the stream channel
- The degree to which the streambed is allowed to adjust to vertically
- The length of stream channel impacted by the crossing
- The degree to which the stream velocity has been increased by the crossing.

For unimpaired fish passage, it is desirable to have a crossing that is a large percentage of the channel bankfull width, allows for a natural variation in bed elevation, and provides bed and bank roughness similar to the upstream and downstream channel. In general, bridges are preferred over culverts because they typically do not constrict a stream channel to as great a degree as culverts and usually allow for vertical movement of the streambed. Bottomless culverts may provide a good alternative for fish passage where foundation conditions allow their construction and width criteria can be met. In all cases, the vertical and lateral stability of the stream channel should be taken into consideration when designing a crossing.

APPLICATION OF CRITERIA

These criteria are intended to apply to new and replacement culverts where fish passage is legally mandated or is otherwise important to the life histories of the fish and wildlife that utilize the stream and riparian corridor. Not all stream crossings may be required to provide upstream fish passage, and of those that do, some may only require passage for specific species and age classes of fish.

Where existing culverts are being modified or retrofitted to improve fish passage, the Hydraulic Design Option 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 Option criteria should be the goal for improvement and not the required design threshold.

To determine the biological considerations and applicable criteria for a particular culvert site, the project sponsors should contact the Department of Fish and Game, the National Oceanic and Atmospheric Administration Fisheries (for projects in marine and anadromous waters) and the US Fish and Wildlife Service (for projects in anadromous and fresh waters) for guidance.
It is the responsibility of the project sponsor to obtain the most current version of the culvert criteria for fish passage. Copies of the current criteria are available from the Department of Fish and Game through the appropriate Regional office, which should be the first point of contact for

any stream crossing project. Addresses and phone numbers for the California Department of Fish and Game Regional Offices are shown in Table IX A-1.

Table IX-A- 1. California Department of Fish and Game regional offices

Region	Address	Phone Number
Northern California – North Coast Region	601 Locust Street Redding, CA 96001	(530) 225-2300
Sacramento Valley – Central Sierra Region	1701 Nimbus Drive, Rancho Cordova, CA 95670	(916) 358-2900
Central Coast Region	7329 Silverado Trail, P.O. Box 47, Yountville, CA 94599	(707) 944-5500
San Joaquin Valley – Southern Sierra Region	1234 E. Shaw Avenue Fresno, CA 93710	(559) 243-4005 x151
South Coast Region	4649 Viewridge Avenue San Diego, CA 92123	(858) 467-4200
Eastern Sierra - Inland Deserts Region	4775 Bird Farm Road Chino Hills, CA 9709	(909) 597-9823

DESIGN OPTIONS

All culverts should be designed to meet appropriate hydraulic capacity and structural integrity criteria. In addition, where fish passage is required, the culvert shall be designed to meet the criteria of the Active Channel Design Option, Stream Simulation Design Option or the Hydraulic Design Option for Upstream Fish Passage. The suitability of each design option is shown in Table IX-A-2.

Table IX-A- 2. Suitability design options.

Allowable Design Options			
Fish Passage Requirement	**Active Channel Design Option or Stream Simulation Design Option**	**Hydraulic Design Option For Upstream Fish Passage**	**Hydraulic Capacity & Structural Integrity**
Adult Anadromous Salmonids	X	X	
Adult Non-Anadromous Salmonids	X	X	
Juvenile Salmonids	X	X	
Native Non-Salmonids	X	Conditional based on species swimming data	
Non-Native Species	X		
Fish Passage Not Required	X		X

Active Channel Design Option

The Active Channel Design Option (Figure IX-A-1) is a simplified design method that is intended to size a crossing 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 option since the stream hydraulic characteristics within the culvert are intended to mimic the stream conditions upstream and downstream of the crossing.

The Active Channel Design Option is suitable for the following conditions:

- New and replacement culvert installations
- Simple installations with channel slopes less than 3 percent
- Short culvert length (less than 100 feet)
- Passage required for all fish.

Culvert Setting & Dimensions

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

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

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

Embedment does not apply to bottomless culverts.

See section on Considerations, Conditions, and Restrictions for all design options.

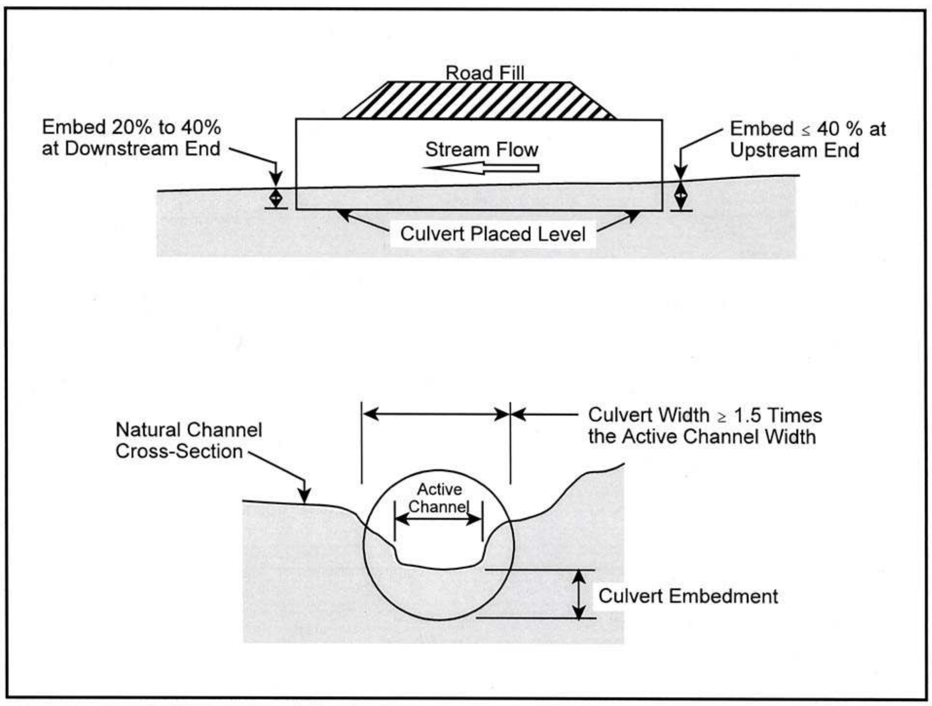

Figure IX-A-1. Active channel design option.

Stream Simulation Design Option

The Stream Simulation Design Option (Figure IX-A-2) is a design process that is intended to mimic the natural stream processes within a culvert. Fish passage, sediment transport, flood and debris conveyance within the crossing 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 options since the stream hydraulic characteristics within the culvert are designed to mimic the stream conditions upstream and downstream of the crossing.

Stream simulation crossings are sized as wide, or wider than, the bankfull channel and the bed inside the culvert is sloped at a gradient similar to that of the adjacent stream reach. These crossings are filled with a streambed mixture that is resistant to erosion and is unlikely to change grade, unless specifically designed to do so. Stream simulation crossings require a greater level of information on hydrology and topography and a higher level of engineering expertise than the Active Channel Design Option.

The Stream Simulation Design Option is suitable for the following conditions:

- New and replacement culvert installations
- Complex installations with channel slopes less than 6 percent
- Moderate to long culvert length (greater than 100 feet)
- Passage required for all fish
- Ecological connectivity required.

Culvert Setting & Dimensions

Culvert 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.
Culvert Slope - The culvert slope shall approximate the slope of the stream through the reach in which it is being placed. The maximum slope shall not exceed 6 percent.
Embedment - The bottom of the culvert shall be buried into the streambed not less than 30 percent and not more than 50 percent of the culvert height. Embedment does not apply to bottomless culverts.

Substrate Configuration and Stability

- Culverts with slopes greater than 3 percent shall have the bed inside the culvert arranged into a series of step-pools with the drop at each step not exceeding the limits shown in Table IX-A-7.
- Smooth walled culverts with slopes greater than 3 percent may require bed retention sills within the culvert to maintain the bed stability under elevated flows.
- The gradation of the native streambed material or engineered fill within the culvert shall address stability at high flows and shall be well graded to minimize interstitial flow through it.

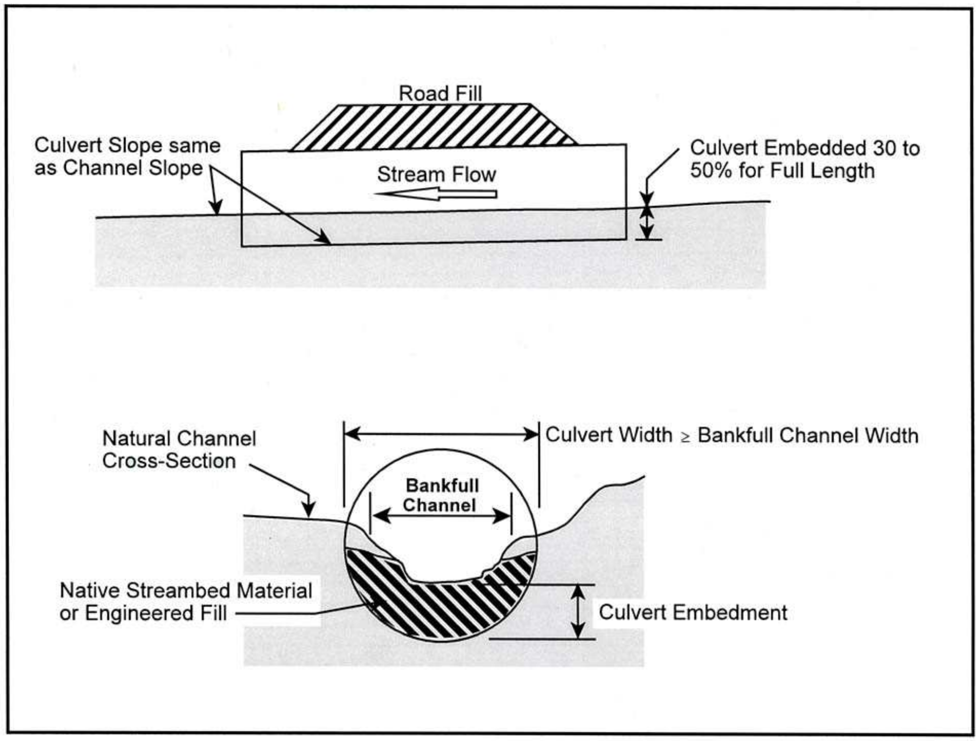

Figure IX-A- 2 Stream simulation design option.

Hydraulic Design Option

The Hydraulic Design Option 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, therefore it does not account for ecosystem requirements of non-target species. There can be significant errors associated with estimation of hydrology and fish swimming speeds that are mitigated 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 Option 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 option can be applied to the design of new and replacement culverts and can be used to evaluate the effectiveness of retrofits for existing culverts.

The Hydraulic Design Option is suitable for the following conditions:

- New, replacement, and retrofit culvert installations
- Low to moderate channel slopes (less than 3 percent)
- Active Channel Design or Stream Simulation Options is not physically feasible
- Swimming ability and behavior of target species of fish is known
- Ecological connectivity not required
- Evaluation of proposed improvements to existing culverts.

High Design Flow for Fish Passage

The high design flow for fish passage is used to determine the maximum water velocity within the culvert. Where flow duration data is available or can be synthesized, use the values for Percent Annual Exceedance Flow shown in Table IX-A-3. If flow duration data is not available the values shown for Percentage of 2-year Recurrence Interval Flow may be used as an alternative.

Table IX-A- 3. High design flow for fish passage.

High Design Flow for Fish Passage		
Species/Life Stage	**Percent Annual Exceedance Flow**	**Percentage of 2-year Recurrence Interval Flow**
Adult Anadromous Salmonids	1%	50%
Adult Non-Anadromous Salmonids	5%	30%
Juvenile Salmonids	10%	10%
Native Non-Salmonids	5%	30%
Non-Native Species	10%	10%

Low Design Flow for Fish Passage

The low design flow for fish passage is used to determine the minimum depth of water within a culvert. Where flow duration data is available or can be synthesized, use the values for Percent Annual Exceedance Flow shown in Table IX-A-4. If the Percent Annual Exceedance Flow is determined to be less than the Alternate Minimum Flow, use the Alternate Minimum Flow. If flow duration data is not available, the values shown for Alternate Minimum Flow may be used.

Table IX-A- 4. Low design flow for fish passage.

Low Design Flow for Fish Passage		
Species/Lifestage	**Percent Annual Exceedance Flow**	**Alternate Minimum Flow (cfs)**
Adult Anadromous Salmonids	50%	3
Adult Non-Anadromous Salmonids	90%	2
Juvenile Salmonids	95%	1
Native Non-Salmonids	90%	1
Non-Native Species	90%	1

Hydraulics

Maximum Average Water Velocity in Culvert (At high design flow) - Where fish passage is required, the maximum average water velocity within the culvert shall not exceed the values shown in Tables IX-A-5 and IX-A-6.

Minimum Water Depth in Culvert (At low design flow) - Where fish passage is required, the minimum water depth within the culvert shall not be less than the values shown in Table IX-A-5.

Table IX-A- 5. Maximum average water velocity and minimum depth of flow.

Species/Lifestage	Maximum Average Water Velocity(fps)	Minimum Flow Depth(ft)
Adult Anadromous Salmonids	See Table 6	1.0
Adult Non-Anadromous Salmonids	See Table 6	0.67
Juvenile Salmonids	1	0.5
Native Non-Salmonids	Species specific swimming performance data is required for the use of the hydraulic design option for non-salmonids. Hydraulic design is not allowed for these species without this data.	
Non-Native Species		

Table IX-A- 6. Culvert length vs. maximum average water velocity for adult salmonids.

Culvert Length (ft)	Adult Non-Anadromous Salmonids (fps)	Adult Anadromous Salmonids (fps)
<60	4	6
60-100	4	5
100-200	3	4
200-300	2	3
>300	2	2

Maximum Outlet Drop - Hydraulic drops between the water surface in the culvert to the pool below the culvert should be avoided for all cases. Where fish passage is required and a hydraulic drop is unavoidable, its magnitude should be evaluated for both high design flow and low design flow and shall not exceed the values shown in Table IX-A-7. If a hydraulic drop occurs at the culvert outlet, a jump pool of at least 2 feet in depth shall be provided.

Table IX-A- 7. Maximum drop at culvert outlet.

Species/Lifestage	Maximum Drop (ft)
Adult Anadromous Salmonids	1
Adult Non-Anadromous Salmonids	1
Juvenile Salmonids	0.5
Native Non-Salmonids	Where fish passage is required for native non-salmonids, no hydraulic drop shall be allowed at the culvert outlet unless data is presented which will establish the leaping ability and leaping behavior of the target species of fish.
Non-Native Species	

Hydraulic Controls - Hydraulic controls in the channel upstream and/or downstream of a crossing can be used to provide a continuous low flow path through the crossing and stream reach. They can be used to facilitate fish passage by establishing the following desirable conditions:

- Control depth and water velocity within the crossing
- Concentrate low flows
- Provide resting pools upstream and downstream of the crossing
- Control erosion of the streambed and banks.

Baffles - Baffles shall not be used in the design of new or replacement culverts in order to meet the hydraulic design criteria.

Adverse Hydraulic Conditions - The following hydraulic conditions are generally considered to be detrimental to efficient fish passage and should be avoided. The degree to which they impede fish passage depends upon the magnitude of the condition. Crossings designed by the Hydraulic Design Option should be evaluated for the following conditions at high design flow for fish passage:

- Super critical flow
- Hydraulic jumps
- Highly turbulence conditions
- Abrupt changes in water surface elevation at inlet and outlet.

Culvert Setting & Dimensions
Culvert Width - The minimum culvert width shall be 3 feet.
Culvert Slope - The culvert slope shall not exceed the slope of the stream through the reach in which the crossing is being placed. If embedment of the culvert is not possible, the maximum slope shall not exceed 0.5 percent.
Embedment - Where physically possible, the bottom of the culvert shall be buried into the streambed a minimum of 20 percent of the height of the culvert below the elevation of the tailwater control point downstream of the culvert. The minimum embedment should 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.

CONSIDERATIONS, CONDITIONS, AND RESTRICTIONS FOR ALL DESIGN OPTIONS

Anadromous Salmonid Spawning Areas
The hydraulic design method shall not be used for new or replacement culverts in anadromous salmonid spawning areas.

High Design Flow for Structural Integrity
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.

Headwater Depth
The upstream water surface elevation shall not exceed the top of the culvert inlet for the 10-year peak flood and shall not be greater than 50 percent of the culvert height or diameter above the top of the culvert inlet for the 100-year peak flood.

Oversizing for Debris
In some cases, it may be necessary to increase the size of a culvert beyond that calculated for flood flows or fish passage in order to pass flood-borne debris. Where there is significant risk of inlet plugging by flood borne debris, culverts should be designed to pass the 100-year peak flood without exceeding the top of the culvert inlet. Oversizing for flood-borne debris may not be necessary if a culvert maintenance agreement has been effected and the culvert inlet can be safely accessed for debris removal under flood flow conditions.

Inlet Transitions
A smooth hydraulic transition should be made between the upstream channel and the culvert inlet to facilitate passage of flood borne debris.

Interior Illumination
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.

Adverse Conditions to be Avoided:

- Excessive skew with stream alignment
- Changes in alignment within culvert
- Trash racks and livestock fences
- Realignment of the natural stream channel.

Multiple Culverts
Multiple culverts are discouraged where the design criteria can be met with a single culvert. If multiple culverts are necessary, a multi-barreled box culvert is preferred over multiple individual culverts. Site-specific criteria may apply to multiple culvert installations.

Bottomless Culverts
Bottomless culverts are generally considered to be a good solution where fish passage is required, so long as culvert width criteria are met and the culvert footings are deep enough to avoid scour exposure. Site-specific criteria may apply to bottomless culverts installations.

CULVERT RETROFITS FOR FISH PASSAGE

Culverts that have fish passage problems were generally designed with out regard for fish passage. While these culverts may convey stream flow, they are often undersized for the watershed hydrology, stream fluvial processes, have been placed at a slope that is too steep for fish passage, or have had the outlet raised above the channel bed in order to control the water velocity in the culvert. Most of these problems arise from the culvert being undersized. For undersized culverts it is difficult, if not impossible, to meet the objective of unimpaired fish passage without replacing the culvert. However, in many cases, fish passage can be significantly improved for some species and their life stages without fully meeting the hydraulic criteria for new culverts. In some cases a modest improvement in hydraulic conditions can result in a significant improvement in fish passage.

Where existing culverts are being modified or retrofitted to improve fish passage, the Hydraulic Design Option criteria should be the design objective for 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 Option criteria should be the goal for improvement and not the required design threshold.

A protocol for fish passage evaluation at existing culverts is included in the Department of Fish and Game's *California Salmonid Stream Habitat Restoration Manual*. This manual also includes information methods for improving fish passage at road crossings.
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 substitute for good fish passage design for new or replacement culverts.

Gradient Control Weirs

- Downstream Channel - Control weirs can be used in downstream channel to backwater through culvert or reduce an excessive hydraulic drop at a culvert outlet. The maximum drop at the culvert outlet shall not exceed the values in Table IX-A-7.
- Upstream Channel - Control weirs can be used in the channel upstream of the culvert inlet to re-grade the bed slope and improve exit conditions.
- Hydraulic Drop - The individual hydraulic drop across a single control weir shall not exceed the values in Table IX-A-7, except that boulder weirs may drop 1 foot per weir for all salmonids, including juveniles.

Baffles

Baffles may provide incremental fish passage improvement in culverts with excess hydraulic capacity that cannot be made passable by other means. Baffles may increase clogging and debris accumulation within the culvert and require special design considerations specific to the baffle type.

Fishways

Fishways are generally not recommended, but may be useful for some situations where excessive drops occur at the culvert outlet. Fishways require specialized site-specific design for each installation.

SELECT REFERENCES AND INTERNET WEB SITES

Baker, C.O. and F.E. Votapka. 1990. *Fish Passage Through Culverts*. Federal Highways Administration & USDA Forest Service. FHWA-FL-90-006. (Available from USDA Forest Service publications, San Dimas Laboratory, CA)

Behlke, C.E., D.L. Kane, R.F. McLean, and M.D. Travis. 1991. *Fundamentals of Culvert Design for Passage of Weak-Swimming Fish, Final Report*. Alaska DOT&PF and USDT, Federal Highway

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FishXing software and learning systems for the analysis of fish passage through culverts. USDA. Forest Service. 1999. *Fish Xing. Version 2.2*. Six Rivers National Forest Watershed Interactions Team, Eureka, CA. www.stream.fs.fed.us/fishxing/

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Washington Department of Fish and Wildlife, 1999. *Fish Passage Design at Road Culverts*. www.wa.gov/wdfw/hab/engineer/cm/toc.htm

APPENDIX IX-B

National Oceanic and Atmospheric Administration Fisheries
Southwest Region

GUIDELINES FOR SALMONID PASSAGE AT STREAM CROSSINGS

INTRODUCTION

This document provides guidelines for design of stream crossings to aid upstream and downstream passage of migrating salmonids. It is intended to facilitate the design of a new generation of stream crossings, and assist the recovery of threatened and endangered salmon species. These guidelines are offered by the National Oceanic and Atmospheric Administration Fisheries, Southwest Region (NOAA-SWR), as a result of its responsibility to prescribe fishways under the Endangered Species Act, the Magnuson-Stevens Act, the Federal Power Act, and the Fish and Wildlife Coordination Act. The guidelines apply to all public and private roads, trails, and railroads within the range of anadromous salmonids in California.

Stream crossing design specifications are based on the previous works of other resource agencies along the US West Coast. They embody the best information on this subject at the time of distribution. Meanwhile, there is mounting evidence that impassable road crossings are taking a more significant toll on endangered and threatened fish than previously thought. New studies are revealing evidence of the pervasive nature of the problem, as well as potential solutions. Therefore, this document is appropriate for use until revised, based on additional scientific information, as it becomes available.

The guidelines are general in nature. There may be cases where site constraints or unusual circumstances dictate a modification or waiver of one or more of these design elements. Conversely, where there is an opportunity to protect salmonids, additional site-specific criteria may be appropriate. Variances will be considered by the NOAA on a project-by-project basis. When variances from the technical guidelines are proposed, the applicant must state the specific nature of the proposed variance, along with sufficient biological and/or hydrologic rationale to support appropriate alternatives. Understanding the spatial significance of a stream crossing in relation to salmonid habitat within a watershed will be an important consideration in variance decisions.

Protocols for fish-barrier assessment and site prioritization are under development by the California Department of Fish and Game (DFG). These will be available in updated versions of the *California Salmonid Stream Habitat Restoration Manual*. Most streams in California also support important populations of non-salmonid fishes, amphibians, reptiles, macroinvertebrates, insects, and other organisms important to the aquatic food web. Some of these may also be threatened or endangered species and require "ecological connectivity" that dictate other design criteria not covered in this document. Therefore, the project applicant should check with the local Fish and Game office, the US Fish and Wildlife Service (USFWS), and/or tribal biologists to ensure other species are fully considered.

The California Department of Transportation Highway Design Manual defines a culvert as “A closed conduit which allows water to pass under a highway,” and in general, has a single span of less than 20 feet or multiple spans totaling less than 20 feet. 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.

PREFERRED ALTERNATIVES AND CROSSINGS

The following alternatives and structure types should be considered in order of preference:

- Nothing - Road realignment to avoid crossing the stream
- Bridge - spanning the stream to allow for long term dynamic channel stability
- Streambed simulation strategies - bottomless arch, embedded culvert design, or ford
- Non-embedded culvert - this is often referred to as a hydraulic design, associated with more traditional culvert design approaches limited to low slopes for fish passage
- Baffled culvert, or structure designed with a fishway - for steeper slopes.

If a segment of stream channel where a crossing is proposed is in an active salmonid spawning area then only full span bridges or streambed simulations are acceptable.

DESIGNING NEW AND REPLACEMENT CULVERTS

The guidelines below are adapted from culvert design criteria published by many federal and state organizations including the California Department of Fish and Game (DFG 2002). It is intended to apply to new and replacement culverts where fish passage is legally mandated or important.

Active Channel Design Method

The Active Channel Design 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 percent in natural slope or for culvert lengths greater than 100 feet. Structures for this design method are typically round, oval, or squashed pipes made of metal or reinforced concrete.

- Culvert Width - The minimum culvert width shall be equal to, or greater than,
- 1.5 times the active channel width.
- Culvert Slope - The culvert shall be placed level (0 percent slope).

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

Stream Simulation Design Method
The Stream Simulation Design method is a design process that is intended to mimic the natural stream processes within a culvert. 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 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. These culverts contain a streambed mixture that is similar to the adjacent stream channel. Stream simulation culverts require 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.

- Culvert 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.
- Culvert Slope - The culvert slope shall approximate the slope of the stream through the reach in which it is being placed. The maximum slope shall not exceed 6 percent.
- Embedment - The bottom of the culvert shall be buried into the streambed not less than 30 percent and not more than 50 percent of the culvert height. For bottomless culverts the footings or foundation should be designed for the largest anticipated scour depth.

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.

- Culvert Width - The minimum culvert width shall be 3 feet.
- Culvert Slope - The culvert slope shall not exceed the slope of the stream through the reach in which it is being placed. If embedment of the culvert is not possible, the maximum slope shall not exceed 0.5 percent.
- Embedment - Where physically possible, the bottom of the culvert shall be buried into the streambed a minimum of 20 percent of the height of the culvert below the elevation of the tailwater control point downstream of the culvert. The minimum embedment should

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.

Hydrology for Fish Passage under the Hydraulic Design Method

High Flow Design For Fish Passage - The high flow design for adult fish passage is used to determine the maximum water velocity within the culvert. Where flow duration data is available or can be synthesized the high fish passage design flow for adult salmonids should be the 1 percent annual exceedance. If flow duration data or methods necessary to compute them are not available then 50 percent of the 2 year flood recurrence interval flow may be used as an alternative. Another alternative is to use the discharge occupied by the cross-sectional area of the active stream channel. This requires detailed cross-section information for the stream reach and hydraulic modeling. For upstream juvenile salmonid passage the high design flow should be the 10 percent annual exceedance flow.

Low Flow Design For Fish Passage - The low flow design for fish passage is used to determine the minimum depth of water within a culvert. Where flow duration data is available or can be synthesized the 50 percent annual exceedance flow or 3 cfs, whichever is greater, should be used for adults and the 95 percent annual exceedance flow or 1 cfs, whichever is greater, should be used for juveniles.

Maximum Average Water Velocities in the Culvert at the High Fish Passage Design Flow

Average velocity refers to the calculated average of velocity within the barrel of the culvert. Juveniles require 1 fps or less for upstream passage for any length culvert at their High Fish Passage Design Flow. For adult salmonids use the following table to determine the maximum velocity allowed.

Table IX-B- 1. Water velocity for culvert length.

Culvert Length (ft)	Velocity (fps) - Adult Salmonids
<60	6
60-100	5
100-200	4
200-300	3
>300	2

Minimum Water Depth at the Low Fish Passage Design Flow

For non-embedded culverts, minimum water depth shall be twelve inches for adult steelhead trout and salmon, and six inches for juvenile salmon.

Juvenile Upstream Passage

Hydraulic design for juvenile upstream passage should be based on representative flows in which juveniles typically migrate. Recent research (NOAA 2001, in progress) indicates that providing for juvenile salmon up to the 10 percent annual exceedance flow will cover the majority of flows in which juveniles have been observed moving upstream. The maximum average water velocity at this flow should not exceed 1 fps. In some cases, over short distances, 2 fps may be allowed.

Maximum Hydraulic Drop
Hydraulic drops between the water surface in the culvert and the water surface in the adjacent channel should be avoided for all cases. This includes the culvert inlet and outlet. Where a hydraulic drop is unavoidable, its magnitude should be evaluated for both high design flow and low design flow and shall not exceed 1 foot for adults or 6 inches for juveniles. If a hydraulic drop occurs at the culvert outlet, a jump pool of at least 2 feet in depth should be provided.

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.

Other Hydraulic Considerations
Besides the upper and lower flow limit, other hydraulic effects need to be considered, particularlywhen installing a culvert:

- Water surface elevations in the stream reach must exhibit gradual flow transitions, both upstream and downstream.
- Abrupt changes in water surface and velocities must be avoided, with no hydraulic jumps, turbulence, or drawdown at the entrance.
- 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 streambed or banks, and allow passage of bedload material.

Culverts and other structures should 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.

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 “improvement” 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 or DFG 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 substitute for good fish passage design for new or replacement culverts. The following guidelines should be used:

- 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. A change in water surface elevation of up to one foot is acceptable for adult passage conditions, provided water depth and velocity in the culvert meet other hydraulic guidelines. A jump pool must be provided that is *at least* 1.5 times the jump height, or a minimum of two feet deep, whichever is deeper.
- Baffles - Baffles may provide incremental fish passage improvement in culverts with excess hydraulic capacity that cannot be made passable by other means. Baffles may increase 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.

- Fishways - Fishways are generally not recommended, but may be useful for some situations where excessive drops occur at the culvert outlet. Fishways require specialized site-specific design for each installation. A NOAA or DFG fish passage specialist should be consulted.
- 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.

OTHER GENERAL RECOMMENDATIONS

Trash racks and livestock fences should not be used near the culvert inlet. Accumulated debris may lead to severely restricted fish passage, and potential injuries to fish. Where fencing cannot be avoided, it should be removed during adult salmon upstream migration periods. Otherwise, a minimum of 9 inches clear spacing should 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.

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

The NOAA and the DFG set instream work windows in each watershed. Work in the active stream channel should be avoided during the times of year salmonids are present. Temporary crossings, placed in salmonid streams for water diversion during construction activities, should 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.

Culverts shall only be installed in a de-watered site, with a sediment control and flow routing plan acceptable to NOAA or DFG. 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.
Construction disturbance to the area should be minimized and the activity should not adversely impact fish migration or spawning. If salmon are likely to be present, fish clearing or salvage operations should 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 and DFG biologists to gain authorization for these activities. Care should 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.

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 or DFG hydraulic engineering staff for appropriate fish screen specifications. Unacceptable wastewater associated with project activities shall be disposed of off-site in a location that will not drain directly into any stream channel.

POST-CONSTRUCTION EVALUATION AND LONG TERM MAINTENANCE AND ASSESSMENT

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:

- Verify the culvert is installed in accordance with proper design and construction procedures
- Measure hydraulic conditions to assure that the stream meets these guidelines
- Perform biological assessment to confirm the hydraulic conditions are resulting n successful passage.

NOAA and/or DFG technical staff may assist in developing an evaluation plan to fit site-specific conditions and species. The goal is to generate feedback about which techniques are working ell, and which require modification in the future. 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, the NOAA anticipates that the second and third elements of these evaluations will be abbreviated as clear trends in the data emerge.

Any physical structure will continue to serve its intended use only if it is properly maintained. During the storm season, timely inspection and removal of debris is necessary for culverts to continue to move water, fish, sediment, and debris. In addition, all culverts should be inspected at least once annually to assure proper functioning. Summary reports should be completed annually for each crossing evaluated. An annual report should be compiled for all stream crossings and submitted to the resource agencies. A less frequent reporting schedule may be agreed upon for proven stream crossings. Any stream crossing failures or deficiencies discovered should be reported in the annual cycle and corrected promptly.

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INTERNET RESOURCES

California Department of Fish and Game
http://www.dfg.ca.gov

National Oceanic and Atmospheric Administration Fisheries Southwest Region
http://swr.nmfs.noaa.gov

Washington Department of Fish and Wildlife Fish Passage Technical Assistance
http://www.wa.gov/wdfw/hab/engineer/habeng.htm

Oregon Road/Stream Crossing Restoration Guide, Spring 1999 (with ODFW criteria)
http://www.nwr.noaa.gov/1salmon/salmesa/4ddocs/orfishps.htm

FishXing software and learning systems for the analysis of fish migration through culverts
http://www.stream.fs.fed.us/fishIXing/

USDA Forest Service Water-Road Interaction Technology Series Documents
http://www.stream.fs.fed.us/water-road/indeIX.html

British Columbia Forest Practices Code Stream Crossing Guidebook for Fish Streams
http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/stream/str-toc.htm

Please direct questions regarding this material to:
National Oceanic and Atmospheric Administration Fisheries Phone: (707) 575-6050
Hydraulic Engineering Staff Fax: (707) 578-3425
777 Sonoma Avenue, Suite 325
Santa Rosa, CA 95404
Email: nmfs.swr.fishpassage@noaa.gov

WATER DRAFTING SPECIFICATIONS

National Marine Fish Service
Southwest Region
August 2001

"Water-drafting" is a short-duration, small-pump operation that withdraws water from streams or impoundments to fill conventional tank trucks or trailers. Usually, this water is used to control road dust, or for wildfire management.(1) Short term water drafting is also used to temporarily de-water a construction site, or to temporarily divert water around a construction site.
The specifications below are given primarily for the protection of juvenile anadromous salmonids, in waters where they are known to exist; but they also may be applied to protect a host of other aquatic organisms as well. The issue of sufficient in-stream flow for life support of the aquatic ecosystem should be addressed by a local Fish & Game biologist. Temporal and cumulative effects should be considered on a watershed scale. While we give some guidelines in that area, the actual impact of water drafting on stream ecology should be assessed and monitored at the local level by qualified personnel.

The main focus of this guidance is the construction, operation, and maintenance of a fish screen module(s) that must be installed at the in-stream end of the drafting hose to protect small salmon and steelhead fry from being entrained in the hose, or impinged on the surface of the screen. The specifications are based on the critical "approach velocity" at the screen surface(2), and a recognition that many temporary screens will not be outfitted with automatic cleaning devices to remove debris buildup. Since it is difficult to measure water velocities in the field, only the construction, pumping capacities, and operations are specified. Variances from these specifications may be considered on a case-by-case basis.

Operating Guidelines

1. Operations are restricted to one hour after sunrise to one hour before sunset.(3)
2. Pumping rate shall not exceed 350 gallons per minute.
3. The pumping rate shall not exceed ten percent of the stream flow.(4)
4. Seek streams and pools where water is deep and flowing, as opposed to streams with low flow and small isolated pools.
5. Pumping shall be terminated when the tank is full. The effect of single pumping operations, or multiple pumping operations at the same location, shall not result in obvious draw-down of either upstream or downstream pools.
6. Each pumping operation shall use a fish screen. The screen face should be oriented parallel toflow for best screening performance. The screen shall be designed and used such that it can be submerged with at least one-screen-height-clearance above and below the screen.
7. Operators shall keep a log on the truck containing the following information: *Operator's Name, Date,Time, Pump Rate, Filling Time, Screen Cleaned (Y or N), Screen Condition, Comments.* These guidelines should be included as instructions in a logbook with serially numbered pages. This assures each truck operator easy access to this information.

Screen Construction Criteria

1. Surface Area

The total (unobstructed) surface area of the screen shall be at least 2.5 square feet, based on the upper limit of pumping of 350 gpm(5). Larger surface areas are recommended where debris buildup is anticipated, and where stream depth is adequate to keep the screen submerged at approximately mid-depth.

2. Screen Mesh

Screen Mesh must be in good repair and present a sealed, positive barrier- effectively preventing entry of the "design fish" into the intake. The design fish in this case is a immature (20-30mm) salmon or steelhead fry.

The screen mesh size shall be: Round openings - maximum 3/32 inch diameter (.09 inch)
Square openings - maximum 3/32 inch diagonal (.09 inch)
Slotted openings - maximum 1/16 inch width (.07 inch)

3. Screen Design

Water drafting screens may be off-the-shelf products, but they are often custom-made devices appropriate to the scale and duration of pumping operation. To keep the screen supported and correctly positioned in the water column, adjustable support legs are advised. Screen geometry can be configured either as rectangular or cylindrical, i.e.- as a shallow "box-shape" or tubular. The intake structure shall be designed to promote uniform velocity distribution at all external mesh surfaces. This can be accomplished with a simple internal baffle device that distributes the flow evenly across the entire surface of the screen. In order to accomplish this, the designer needs to understand the hydraulic characteristics of these devices. There is a tendency for most of the intake water to enter the screen near the hose end, so a typical internal baffle would consist of a pipe (or a manifolded set of pipes) which have variable porosity holes at predetermined spacing. We recommend starting near the hose end with approximately 5-10% average open area, and gradually increasing the porosity toward the length of the screen. At a point where screen length exceeds three times the diameter of the suction hose, the baffling effect tends to diminish rapidly. At this point the baffle porosity may approach 100%. A successful baffle system will functionally distribute flow to all areas of the screen. A poorly designed screen may result in high-velocity "hot spots," which could lead to fish impingement on the screen face. Hydraulic testing of prototype screen designs is recommended where the application is on-going and extensive.

4. Screen Structure

The screen frame must be strong enough to withstand the hydraulic forces it will experience. However, structural frames, braces, and other elements that block the flow, change flow direction, or otherwise decrease the screen surface area should be minimized.

5. Screen Cleaning

The screen shall be cleaned as often as necessary to prevent approach velocity from exceeding 0.33 feet per second. Operators should withdraw the screen and clean it after each use, or as necessary to keep screen face free of debris. Pumping should stop for screen cleaning when approximately fifteen percent or more of the screen area is occluded by debris. A suitable brush shall be on board the truck for this cleaning operation.

If the operator notes (a) impingement of any juvenile fish on the screen face or (b) entrainment of any fish through the screen mesh, he/she should stop operations and notify the Department of Fish & Game and/or NMFS hydraulic engineering staff:

National Marine Fisheries Service
Engineering Section
777 Sonoma Avenue, Suite 325
Santa Rosa, CA. 95404
(707) 575-6050

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Rebecca Lent, Ph.D.
Regional Administrator

1. In case of emergency wildfire, where human life is in danger, the operator may disregard the screening requirement if a suitable screen is not immediately accessible.
2. Approach velocity is the horizontal velocity vector component, typically measured at a distance of 3 inches from the screen face.
3. Restricting operations to daylight-only prevents the use of lights that will attract fish to the drafting pool
4. Restricting drafting to ten percent of the stream flow provides adequate downstream flow to support fish, aquatic insects, amphibians, and other biota. Ten percent of flow may be estimated by pump operators.
5. If larger pumping volumes are needed, or if the pumping application is continuous, refer to http://swr.nmfs.noaa.gov/habitat.htm and review addendum for small pump intakes.

<u>DRAFT</u>

Guidelines for Temporary Water Drafting from Watersheds Supporting Anadromous Salmonids;

Special Application for Timber Harvest Activities

<u>Preliminary Draft - Subject to Revision</u>

by Richard Macedo
STATE OF CALIFORNIA, Resources Agency, Department of Fish and Game

Timberland Resources Program
Central Coast Region
November 16, 2001

The purpose of this paper is to provide concise and updated criteria for protecting anadromous salmonids from impacts associated with water drafting. Criteria in this report are directed at anyone responsible for operating, permitting or overseeing small, temporary water diversion projects associated with timber harvest activities in coastal timberlands supporting salmon, steelhead or other important aquatic resources. Information in this report may not be applicable to water diversion projects in other locations. Criteria in this paper may change as a result of improved biological knowledge and/or changes associated with state or federal regulation.

Laws and policies governing the Department of Fish and Game (Department) in this matter include Section 1600 et seq. and Section 6100 of the Fish and Game Code, Section 703 of the Fish and Game Code (specifically the policies identified as “Salmon”, “Steelhead Rainbow Trout”, “Endangered and Threatened Species”, “Water”, and the “Joint Policy Statement on Coho Salmon” between the California State Board of Forestry and the California Fish and Game Commission). Fish and Game Code Section 1600 et seq. requires that the Department enter into an agreement with a person proposing to, among other actions, substantially divert or obstruct the natural flow of a river, stream, or lake. This includes water drafting. Applications can be obtained from a Department office.

Streams and rivers are used as water sources for timber harvest operations in coastal California. Water is used by itself or in combination with additives to minimize dust and improve running conditions on unpaved roads. Watering roads for dust abatement is often an enforceable condition for approved timber harvest plans. In addition to roads, water may be used in conjunction with controlled burns, wildfire suppression and watering for revegetation projects.

The typical water drafting system for a timber harvest operation involves a truck outfitted with a three to four thousand gallon storage tank, a truck-mounted centrifugal pump and an extendable intake hose. Pools are often targeted for diversion sites because they have sufficient volume to permit high diversion rates. Operators often pump at or near maximum rates to limit down time, thereby maximizing the amount of road surface that can be watered in a given period. To prevent damage to the pump, operators avoid entraining rocks or air during pumping. Typically, an operator will back next to or pull alongside a pool, position a hose with the intake end near the bottom of a pool and commence pumping. Depending on the size and condition of the pump, an operator may fill a four thousand gallon water truck in 10 to 20 minutes. For most systems, the drafting rate can be adjusted.

The following three variables should be considered when designing a small, portable water drafting operation; 1) screen size, 2) approach velocity and 3) diversion rate. The following criteria for screen size, approach velocity and diversion rate are designed to protect fry-size salmonids from water diversion activities in California's timberlands. Use of these criteria may protect other species which occupy the same streams and lakes.

Screen Mesh Size:

Openings in perforated plate and woven wire screens shall not exceed 3/32 inches (2.38 millimeters). Slot opening in wedge wire screens shall not exceed 1.75 mm.

To prevent entrainment of fish during water diversion, the pump intake shall be fitted with screen made of woven mesh, perforated plate, wedge wire, or other durable fabric. The screen medium shall be able to withstand forces related to pumping and be of sufficient size to prevent small fish from entering the intake and being pumped along with diverted water.

Approach Velocity:

The velocity of water across the screen surface shall not exceed 0.33 feet/second at any point on the screen surface. To achieve this standard, the screen shall be kept clean and free of accumulated algae, leaves or other debris which could block portions of the screen surface and increase approach velocities at any point on the screen. The screen shall be supported above the bed of the streams so that no part of the screen surface is obstructed. Water truck operators shall move drafting hoses with attached screens in and out of the water after each drafting operation. The screen should be brushed clean and inspected each time it is placed into the water. This practice will usually prevent screens from accumulating significant amounts of debris and essentially replicate the function of a self-cleaning screen. Where a stationary pump is used, the screen should be checked frequently to ensure it is kept clean and free of debris. For screens where regular cleaning cannot be guaranteed, the approach velocity across the screen surface shall not exceed 0.0825 feet/second at any point on the screen.

Diversion Rate:

Water drafting may cause adverse impacts to juvenile salmonids if flow in source streams is reduced to insufficient levels. For these cases, a specific water drafting plan shall be developed. Concerns over impacts caused by reduced flows and the subsequent need for a water drafting plan may not be necessary if the proposed water diversion conforms to all of the following standards:

a. Flow in the source stream during water drafting will remain at 2.0 $feet^3$/second or greater, and

b. If diverting from a pool, reduction in pool volume will not exceed 10 percent, and

c. Diversion rate will not exceed 10 percent of the surface flow from the source stream, and

d. Instantaneous diversion rate is less than 350 gallons per minute (0.78 $feet^3$/second)

For water diversion projects that will not meet criteria a through d above, a water drafting plan shall be prepared and approved by the Department through an Agreement pursuant to Section 1600 et seq. of the Fish and Game Code. This plan shall include the following:

1. Determine the instantaneous flow reduction and duration of reduction from the source stream.

2. Disclose potential impacts associated with both the instantaneous flow reduction and cumulative flow reduction and total volume removed from the source stream.

3. Identify proposed recommendations for minimizing adverse impacts such as a reduced hose diameter, decrease in pumping rates, use of alternative sites and/or restrict number of water withdraws from one location.

4. Require operators to maintain a water diversion log which records the date, time, pump rate, filling time, screen cleaning and inspection, and bypass flow from the source stream.

5. Conduct a pre-operations briefing with personnel who will be operating water drafting equipment and charged with compliance of the water diversion plan.

Additional Considerations:

While outside the scope of this report, standards for protecting anadromous salmonids may also be sufficient for protecting other species of fish, amphibians, reptiles and invertebrates. These considerations should be made on a case-by-case and species-by-species bases.

In certain situations and at specific sites, the requirement for screen and approach velocity criteria may be disregarded if an approved watering hole or sump is constructed adjacent to a stream or river. Large gravel bars adjacent to streams may be appropriate sites for constructing temporary water drafting holes. Unaltered sections of the gravel bar which lie between the watering hole and the flowing stream may provide the functional equivalent of a screen. In addition, approach velocities along the gravel bar must meet Department standards (e.g. < 0.33

feet/second for fry-size fish). Construction and use of these watering holes will be restricted to summer periods when storms and increasing stream flows are uncommon. Pursuant to Section 1600 et seq. of the Fish and Game Code, construction and use of watering holes will likely require a Lake and Streambed Alteration Agreement.

Example for Calculating Surface Area for Intake Screens:

The purpose of this example is to outline steps for calculating the appropriate screen surface area necessary to meet Department guidelines for approach velocities.

Scenario:

A water drafting operation will use a 4,000 gallon truck to divert water from a small stream which supports fry-size salmon and steelhead. At the maximum rate, the truck can be filled in 15 minutes. Calculate the surface area of screen necessary to comply with Department guidelines for approach velocities not to exceed 0.33 feet/second.

Step 1:

Calculate diversion rate in gallons per minute (gpm) with the pump running at full capacity.

$$\frac{\text{4,000 gallons}}{\text{15 minutes}} = 266.7 \text{ gpm}$$

Step 2:

Convert diversion rate from gpm to feet^3/second (cfs). Note, to covert gpm to cfs, multiple the gpm figure by 0.00223.

$$266.7 \text{ gpm} \times 0.00223 = 0.59 \text{ cfs}$$

Step 3:

Using the maximum acceptable approach velocity of 0.33 feet/second, calculate how much surface area of screen is needed for a diversion rate of 0.59 cfs.

$$\frac{0.59 \text{ feet}^3\text{/second}}{0.33 \text{ feet/second}} = 1.79 \text{ feet}^2 \text{ (square feet)}$$

Answer: For this example, a screen surface area of 1.79 square feet or larger will satisfy the Department's standard for approach velocity.

Dust Palliative Application Guidelines

Source, with minor adaptations: SFRWQCB. (2002) Erosion and Sediment Control Field Manual, Table 1, p. 46.

Method	**Selection**	**Site Preparation**	**Recommended Application Rate**
Chemicals – Inorganic			
Water	- Most commonly used practice - Evaporates quickly - Lasts less than 1 day - Approved dust control agents are preferred over water drafting and application	For all liquid agents: 1. Blade a smooth surface. 2. Crown or slope to avoid ponding. 3. Compact soils if needed. 4. Uniformly pre-wet at 0.14-1.4 L/m^2 (0.03-0.3 gal/yd^2). 5. Apply solution under pressure. Overlap solution 100-300 mm (6-12 in). 6. Allow treated area to cure 0-4 hours. 7. Compact area after curing. 8. Apply 2nd treatment before 1st treatment becomes ineffective, using 50% application rate. 9. In low humidities, reactivate chemicals by rewetting at 0.5-0.9 L/m^2 (0.1-0.2	0.6 L/m^2 (0.125 gal/yd^2) every 20 to 30 minutes.
Salts:			
• Calcium Chloride (CaCl)	- Restricts evaporation - Lasts 6-12 months - Can be corrosive - Less effective in low humidity - Can build up in soils and leach by rain		Apply 38% solution at 1.21 L/m^2 (0.27 gal/yd^2) or as loose, dry granules per manufacturer.
• Magnesium Chloride (MgCl)	- Restricts evaporation - Works at higher temps. and lower humidity than CaCl - May be more costly than CaCl		Apply 26-32% solution at 2.3 L/m^2 (0.5 gal/yd^2)
• Sodium Chloride (NaCl)	- Effective over smaller range of conditions - Less expensive - Can be corrosive - Less effective in low humidity		Per manufacturer.
Silicates	- Generally expensive - Available in small quantities - Require second application		

Method	Selection	Site Preparation	Recommended Application Rate
Surfactants	- High evaporation rates - Effective for short periods - Must apply frequently		
Chemicals – Organic			
Copolymers	- Form semipermeable transparent crust - Resist ultraviolet radiation and moisture-induced breakdown - Last 1-2 years	Same as above (**Chemicals – Inorganic**)	750-940 L/ha (80-100 gal//ac)
Petroleum Products	- Bind soil particles - May hinder foliage growth - Environmental and aesthetic concerns - Higher cost		Use 57-63% resins as base. Apply at 750-940 L/ha (80-100 gal/ac).
Lignin Sulfonate	- Paper industry waste product - Acts as dispersing agent - Best in dry climates - Can be slippery		Loosen surface 25-50 mm (1-2 in). Need 4-8% fines.
Vegetable Oils	- Coat grains of soil, so limited binding ability - May become brittle - Limited availability		Per manufacturer.
Spray-on Adhesives	- Available as organic or synthetic - Effective on dry, hard soils - Form a crust - Can last 3-4 years		Per manufacturer.