Standard Operating Procedure for
Critical Riffle Analysis for Fish Passage in California

CDFW-IFP-001

September 2017

California Department of Fish and Wildlife
Instream Flow Program
Sacramento, California

Standard Operating Procedure for Critical Riffle Analysis

for Fish Passage in California

CDFW-IFP-001

Approved by:

Robert Holmes, CDFW Instream Flow Program Unit Supervisor, September 21, 2017

Beverly van Buuren, Quality Assurance Program Manager, September 21, 2017

Prepared by:

Diane Haas, CDFW Statewide Instream Flow Coordinator, August 2017

Original Version Prepared by:

Melinda E. Woodard, Quality Assurance Team, Marine Pollution Studies Laboratory, October 2012

Table of Contents

List of Figures

List of Tables

Acknowledgements

This standard operating procedure (SOP) represents the protocol for critical riffle analysis (CRA) of the California Department of Fish and Wildlife (Department; previously known as California Department of Fish and Game) Water Branch Instream Flow Program (IFP). It is intended to replace the original 2012 document, which received updates in 2013 and 2015. The process in this SOP draws from current methods used by the Oregon Department of Fish and Wildlife (ODFW). Modifications are made to ODFW methods in both procedural scope and in the application of regional information relevant to California. The overall concept of the procedure in this SOP is based on information in *Determining Stream Flows for Fish Life* presented by Ken Thompson at the *Instream Flow Requirements Workshop* on March 15-16, 1972 (Thompson 1972). This SOP was developed by the Marine Pollution Studies Laboratory Quality Assurance Team. The Department IFP provided Microsoft Excel® (Excel) spreadsheet technical assistance. Technical review of this document was provided by IFP staff, and members of the ODFW Water Quality and Quantity Program. This document has been reviewed by the Department Office of the General Counsel.

Suggested Citation

California Department of Fish and Wildlife. 2017. **Critical Riffle Analysis for Fish Passage in California.** California Department of Fish and Wildlife Instream Flow Program Standard Operating Procedure CDFW-IFP-001**,** 25 p.
Available at: https://www.wildlife.ca.gov/Conservation/Watersheds/Instream-Flow/SOP.

Abbreviations and Acronyms

CRA	Critical Riffle Analysis
Department	California Department of Fish and Wildlife
IFP	Instream Flow Program
ODFW	Oregon Department of Fish and Wildlife
SOP	Standard Operating Procedure

Introduction

This document serves as the SOP for CRA studies for the Department's IFP. It may be used in conjunction with other IFP SOPs. Instructions are provided for:

- Project planning considerations:
  - Project timing
  - Site selection
  - Fish passage criteria
- Field methods:
  - Transect preparation
  - Data collection
- Data analysis:
  - Tabular data entry
  - Consideration of fish passage criteria
  - Graphing of results
  - Comparison of results against fish passage criteria

Scope of Application

This SOP provides procedural reference for Department staff conducting CRA, when site conditions and research objectives indicate that CRA is an appropriate methodology. It is also intended as an informational resource for other state and federal agencies, nongovernmental organizations, private contractors, and other organizations throughout California. Fish passage criteria cited in this document are specific to California and should not be extrapolated beyond the state borders.

This SOP applies only to wadeable streams having low gradient riffles with less than 4% gradient and substrates dominated by gravel and cobble. This procedure is used to identify flows that support physical movement of salmonids through critical riffle sites. Other factors that may be important to evaluate overall migratory success include length of riffle, availability of rest areas, condition of fish, water temperature, and others.

This SOP is not applicable to high gradient riffles with greater than 4% gradient and boulder dominated substrates (Flosi et al. 1998). It does not apply to river or stream channels that do not have riffles, such as those dominated by silt and sand substrates with particle sizes less than 0.1 inches. Finally, this procedure is not applicable to culverts, weirs, bedrock ledges, or anticlines with associated drops.

Note: Safety should always be a primary concern when conducting CRA. Do not conduct sampling when field conditions are unsafe.

What is Critical Riffle Analysis?

The CRA methodology is used to identify stream flow rates necessary for the passage of salmon and trout through critical riffles. Riffles are habitat units in streams and rivers with relatively shallow depth and swiftly flowing turbulent water. They serve multiple functions in the ecological processes of cold water streams and rivers, and are an integral link in the life histories of salmon and trout. Many species of aquatic macroinvertebrates develop and grow in riffles, which provide a food source for salmonids. Riffles also provide salmonids with well-mixed oxygenated water and escape shelter from predators.

Critical riffles are particularly shallow and sensitive to changes in stream flow. Changes in stream flow and associated water depth may limit the hydrologic connectivity of river habitats and impede critical life history tactics of salmon and trout. In such cases, the critical riffle may become a potential barrier to upstream and downstream salmonid passage. Critical riffles may prevent adults from moving to and from spawning areas, prevent smolts from migrating downstream to staging areas in brackish waters of lagoons and estuaries before entering the ocean, and prevent rearing juvenile salmonids (e.g., steelhead) from being able to move between adequate summer freshwater rearing habitats.

Method Overview

Stream flow rates for salmon and trout passage are determined by locating a critical riffle, identifying a transect along the riffle's shallowest course from bank to bank, measuring water depth at a set interval across the transect, and visiting the site over a range of flow. Adequate water depths over a sufficient width of the transect are necessary to identify flows for passage of adult and juvenile salmonids through critical riffle sites. Field measurements are compared to target species and lifestage water depth criteria (see *Section 3* for more information). After a minimum of three to six field sampling events have been completed along the transect over a wide range of flows, a graph of stream flow rates versus the corresponding percent of transect meeting the minimum depth criteria for the species and lifestages can be used to determine flow rates necessary for passage.

Section 1: Considerations for Project Planning

Before collecting data for CRA, it is important to identify both the appropriate timing of the sampling events and the appropriate site. The timing of the sampling events should be linked to the target species and lifestage.

CRA is conducted by establishing a transect across the critical riffle and collecting depth measurements along that transect. This SOP uses depth criteria for a target species and lifestage to determine flow rates necessary for passage of that species through critical riffles. The project manager may decide to collect stream velocity measurements along the critical riffle transect and assess results in relation to a target species' maximum velocity tolerances. Please consult the Department IFP for more information about these procedures before planning such a project.

Crew safety is of paramount importance; ensure that the river can be safely sampled during the highest flow point. Contact the Department IFP for project planning assistance, as needed.

1.1 Project Timing

Data for CRA are collected during three to six field sampling events, typically during the receding limb of the hydrograph. The sampling events should be timed to capture the full range of discharges for the passage of the target species and lifestages. Ideally, the first sampling event would be at the highest wadeable flow, with subsequent sampling events taken as flow decreases.

Development of a flow exceedance probability chart based upon unimpaired flow conditions for the period of record may be useful to identify flows for field sampling. The exceedance probability chart will indicate the percentage of time that a stream flow rate is likely to equal or exceed a value of interest. A good project planning starting point is to identify the 20%, 50%, and 80% exceedance flows for field sampling. To develop a robust relationship between salmon and trout passable criteria and flows, additional sampling events are needed. These additional sampling events for data collection will most likely be at flows between the 20% to 80%

exceedance probability range, depending on site-specific conditions such as channel morphology, substrate, and flow relationships.

When identifying flows for field sampling, Department staff should consider that each field event must have at least one depth measurement along the CRA transect that meets or exceeds the target species and lifestage depth criteria (see Section 3.2) in order for that sampling event to be used in the analysis.

It may be useful to create a lifestage periodicity table indicating when target species migration occurs in the river of interest. This table may be used to determine what exceedance flows likely occur during migration as well as help to plan the timing of field work so that sampling events encapsulate the appropriate range of flows for the species and lifestage of interest. Contact the Department IFP for assistance developing a flow exceedance probability chart or lifestage periodicity table, as needed. The Department SOP CDFW-IFP-005 (CDFW 2013a) on how to develop flow exceedance probability charts is available on the Department’s IFP web site.

1.2 Site Selection: Locating the Critical Riffle

The identification of sampling sites for CRA should be made collaboratively by Department staff familiar with the study area. In some cases, it may be difficult to identify or agree collaboratively on the most critical riffle (i.e., most water depth-sensitive riffle) in a stream reach by visual observation alone. In these instances, it may be necessary to collect depth measurements at multiple critical riffle sites, including the maximum thalweg depth along the shallowest course of each riffle, in order to identify the most depth-sensitive critical riffles and their respective flows for salmonid passage.

Section 2: Field Procedures

Once a critical riffle has been identified for CRA, the transect is established, marked, and photographed. During the initial CRA sampling event, the critical riffle transect is located and marked with head- and tailpins and flagged with site information. CRA also requires a discharge measurement, which may be obtained either from an appropriate stream gage, or by measuring discharge as outlined in the Department discharge SOP CDFW-IFP-002 (CDFW 2013b).

The field data sheet can be found online at the Department IFP documents page: https://www.wildlife.ca.gov/Conservation/Watersheds/Instream-Flow/SOP.

2.1 Equipment List

Field crews should pack the following equipment for sampling:

- Stadia rod (engineering grade rod capable of measuring 1/10 ft and 1/100 ft)
- Fiberglass measuring tape (100-300 ft)
- Staff gage
- 0.5 in x 2.5 - 4 ft rebar (2-10 pieces depending on site)
- Hammer or mallet
- GPS unit
- Field data sheets (available at https://www.wildlife.ca.gov/Conservation/Watersheds/Instream-Flow/SOP)
- Pencils
- Flagging and permanent marker
- Camera
- Calculator
- Small carabiners or spring clamps (5-10; optional)

Note: If discharge will be measured in the field, crews should also pack equipment as listed in the Department discharge SOP CDFW-IFP-002.

2.2 Establishing the Transect

Establish a transect running along the shallowest course of the riffle from bank to bank using rebar and a measuring tape. This transect will rarely be linear, but should instead follow the contours of the riffle along its shallowest course from bank to bank (*Figures 1-3*). The critical riffle transect is established during the first sampling event, and is then used repeatedly for each subsequent sampling event. Once the transect is identified, markers are placed at the wetted edge on each bank marking the headpin and tailpin, and along the course of the shallowest contour. During subsequent sampling events, the course of the shallowest contour across the riffle should be re-identified and verified with depth measurements to confirm transect location.

Step 1: Set the headpin for the transect on the left bank of the river looking upstream. The headpin serves as the starting point for each critical riffle measurement, starting from zero feet.

Step 2: Attach a flag to the headpin. This flag is marked with project and site identification information.

Step 3: Set the tailpin adjacent to the edge of the critical riffle on the right bank of the river when facing upstream.

Step 4: Attach a wind-up, light weight measuring tape to the base of the headpin. The tape should be of sufficient length for the site (e.g., 100-ft, 200-ft, 300-ft). The tape should display 1/10-ft measurements.

Step 5: Work across the riffle, following the contour of shallowest course (*Figure 2* and *3*). Use a stadia rod to locate the shallowest depths. Hammer in rebar while working across the riffle. Secure the measuring tape along the riffle contour by wrapping tape around rebar, or by using small carabiners or spring clamps to hold the tape in place.

Step 6: Continue to work across the riffle until the tailpin is reached. Attach the other end of the measuring tape to the base of the tailpin.

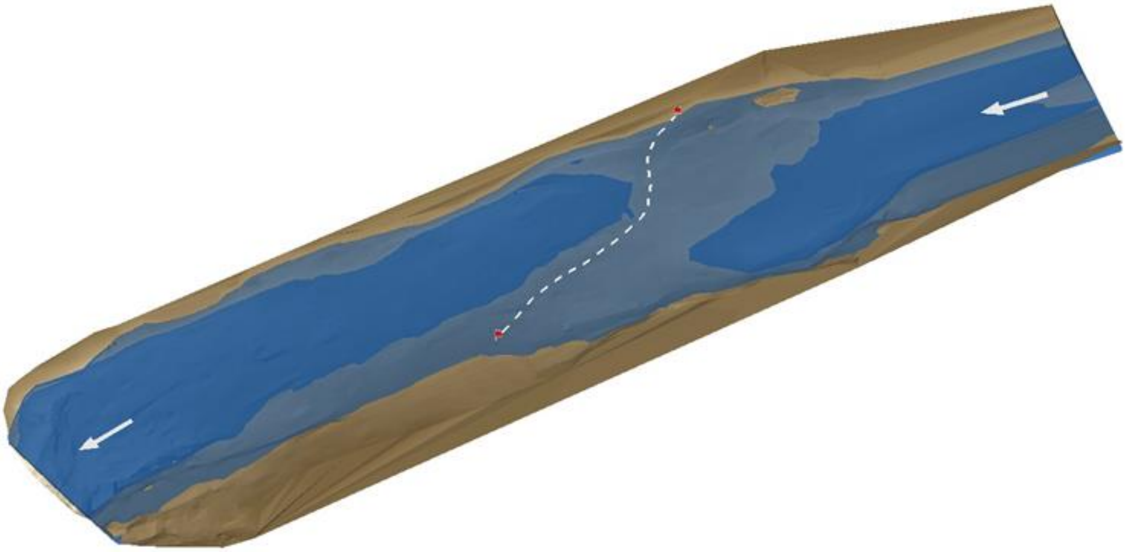

Figure 1. Example of passage transect delineation across a critical riffle

Figure 2. Example of a critical riffle transect that follows the shallowest course from bank to bank

Figure 3. Additional example of a critical riffle transect following the shallowest course from bank to bank

2.3 Data Collection

Once the CRA transect has been set up, data are collected.

Step 1: If not already in place, set up the measuring tape along the contour of the riffle's shallowest course, as described in *Section 2.2*.

Step 2: During each sampling event, document the transect with multiple photographs, taken while facing upstream and downstream.

Step 3: Populate the CRA field data sheet with the following:

- Stream name (e.g., Candice River)
- Reach (e.g., Lower Reach)
- Riffle name (e.g., CR5)
- Site description (e.g., Wide transverse riffle near pump #34)
- GPS coordinates or waypoint (e.g., N38° 53.331, W121° 17.092; or wpt. 22)
- Total length of the transect from headpin to tailpin (HP to TP; i.e., total transect length following the shallowest course from bank to bank)

- Left bank wetted edge (LBWE; i.e., the distance on the tape measure where the wetted edge exists on the left bank)
- Right bank wetted edge (RBWE; i.e., the distance on the tape measure where the wetted edge exists on the right bank)
- Sampling date
- Evaluator (i.e., initials of staff conducting CRA)
- Recorder (i.e., initials of staff recording data)
- Photo file range
- Time start (i.e., the time when sampling starts)
- Staff gage start (i.e., the stage height from a nearby staff gage when sampling starts). Staff gage may be a temporary gage that is installed just for purposes of doing the CRA, or it may be a nearby permanent gage if one exists. The staff gage stage height is used to assess whether fluctuations in flow occurred during the sampling event.

Step 4: Determine the interval size at which to measure depth along the transect by considering the total transect length. Depth should be measured a minimum of 20 times at regularly spaced intervals along the transect. The increment of the interval should be small enough to accurately represent changes in bed profile elevation. A minimum sampling interval of one foot is recommended for CRA sites with critical riffles of greater than 20 ft from bank to bank. The sampling interval for CRA sites that are less than 20 ft from bank to bank should be adjusted so as to meet the 20 minimum depth measurements. A more robust depth to flow relationship is achieved with approximately 50 depth measurements on the critical riffle (Tim Hardin, ODFW, personal communication, July 2, 2012).

Step 5: Using a stadia rod, measure water depth to the nearest 0.01 ft along the transect at the interval distance determined in Step 4 (*Figures 4* and *5*). Record station distance and depth in feet on the CRA field data sheet. There must be at least one depth measurement that meets or exceeds the target species and lifestage depth criteria (see *Section 3.2*) in order for the sampling event to be used in the analysis.

Note: Careful attention should be taken to record water depths at individual locations as the fish would encounter and use them. For example, the stadia rod should not be placed between two rocks to measure depth unless it appears that a fish could swim between them freely. Using the *same example, if the stadia rod fits between two rocks (without being on top of the rocks), but the upstream passage is blocked by other rocks immediately upstream or downstream within the measurement cell of the longitudinal profile of the critical riffle, then the measurement should be taken on top of, instead of between the rocks. In these cases the shallowest points (on top) of the wetted substrate should be selected if the fish could not use the depths between rocks due to passage obstructions either immediately upstream or downstream of the transect. Add any such notes to the comments section on the CRA field data sheet.*

Step 6: Populate closing data fields on the CRA field data sheet (i.e., end time and staff gage end depth).

Step 7: Ensure the staff gage remained constant during the sampling event, then remove the measuring tape from headpin and tailpin and clean up other equipment as necessary.

Step 8: Obtain and record discharge data on the CRA field data sheet either from an appropriate stream gage, or by conducting a site-specific discharge measurement in accordance with *CDFW-IFP-002*.

Step 9: Ensure that all data fields have been populated on the CRA field data sheet before leaving the site.

Figure 4. Example using stadia rod to measure depth along a critical riffle transect

Figure 5. Detail of stadia rod used to measure depth along a critical riffle transect

Section 3: Data Entry and Analysis

After each sampling event, data are entered and stored in Excel for data analysis. Depth data are compared with the target species and lifestage depth criteria for fish passage. This section discusses data entry and the criteria for fish passage, details how to determine stream flow rates for salmonid passage, and provides important considerations when applying the method.

3.1 Data Entry

After each sampling event, transfer data from the field data sheet to the corresponding spreadsheet in the Excel *Workbook for Critical Riffle Analysis for Fish Passage in California* (available online at the Department IFP SOP and QA/QC documents page: https://www.wildlife.ca.gov/Conservation/Watersheds/Instream-Flow/SOP).

Disclaimer: Due to variability in field data (e.g., station distances, transect lengths), adjustments in data entry fields may be needed to correctly populate the spreadsheet. Please contact the Department IFP for assistance. The Department is not responsible for inappropriate application of the Excel workbook or spreadsheets.

The Excel workbook contains spreadsheets to calculate the number of cells that meet the minimum depth criteria for fish passage (as outlined in *Section 3.2*) for each sampling event. See below for specific data entry instructions for transferring field data into the Excel workbook.

There are six tabs named for each of six sampling events (e.g., “CRA Passage Form 1” for sampling event one) in the online Excel workbook. The Excel workbook also contains:

1. The “Read Me” tab, which provides condensed instructions on data entry and analysis
2. The “Example Passage Form”, which is a filled-out example data form
3. The “CRA Cumulative Calculations” tab, which includes cumulative calculation data tables for the percent contiguous passable width and percent total passable width data; this is used to summarize the results from each sampling event for subsequent data analysis
4. The “Minimum Depth Criteria” tab, which includes the salmon and trout species or lifestage codes and their minimum depth criteria for passage

Using a “CRA Passage Form” tab, fill out all relevant information for the sampling event (e.g., stream name, site description, date). Specify the target species and lifestage for the CRA and enter the respective criteria into the form field. The target species and lifestage criteria (see *Section 3.2*) are selected from the “Minimum Depth Criteria” tab in the Excel workbook. For example, enter “St” in the Species/Lifestage Code and “0.7” ft depth in the Target Species Depth Criteria sections of the spreadsheet if interested in assessing flows for adult steelhead passage.

Continue entering field data into the “Distance” and “Depth” categories. The “Distance” entry is typically the position of the tape measure where the depth data were recorded. The “Width” column will be populated by the spreadsheet based upon the distance or locations of depth measurements taken. The spreadsheet will calculate the percent contiguous passable flows and percent total passable flows for each sampling event. In order for the “Percent Contiguous” calculation to be correctly summarized, the user will have to “Sum” the longest range of contiguous cells meeting the depth criteria and enter this value in the contiguous width cell on the bottom of the spreadsheet (highlighted in red).

It is important to note that the maximum transect length (i.e., maximum wetted width) must be entered in each of the (three to six) CRA Passage Forms for the percent contiguous and percent total calculations to be accurate. The maximum transect length is generally associated with the highest flow following the shallowest course from bank to bank. Maximum transect lengths should typically reach but not exceed beyond the toe of bank – the point where the streambed and bank join. The streambed is defined as that part of the channel usually not occupied by perennial terrestrial plants, but including gravel bars, and lying between the toe of each bank.

After all of the sampling events have been conducted, and data entered for all events in their individual CRA Passage Form tabs, select the “CRA Cumulative Calculations” tab. Manually enter the flows of each sampling event along with the percent of maximum transect length meeting passage depth criteria for the target species or lifestage as outlined above.

3.2 Criteria for Fish Passage

Stream width and depth criteria are used to derive flows for salmonid passage. The Department IFP has adopted two width criteria for development of flows for salmon and trout passage from Thompson (1972):

1. At least 10% of the maximum wetted transect length must be contiguous for the minimum depth criterion established for the target fish; *and*
2. A total of at least 25% of the maximum wetted transect length must be at least the minimum depth criterion established for the target fish.

The minimum water depth criteria for salmonids are outlined in *Table 1*. These criteria are based upon a literature review conducted by R2 Resources (2008) and are intended to provide protective conditions for passage. Ideally, there should be sufficient clearance underneath a fish so that contact with the streambed and abrasion are minimized, which R2 Resources (2008) considered to be 0.1 ft. When selecting the appropriate depth criteria, use the minimum depth for the adult fish if both adult and juvenile fish are known to be in the system at the same time. The Department may update the minimum depths in *Table 1* as new information is developed.

Table 1: Minimum depth criteria for adult and juvenile salmonid passage to be used in critical riffle analysis

Species	Minimum Depth (ft)
Chinook Salmon (adult)	0.9
Steelhead (adult)	0.7
Coho Salmon (adult)	0.7
Trout (adult, including 1-2+ juvenile steelhead)	0.4
Salmonid (young of year juvenile)	0.3

3.3 Graphing Results and Data Analysis

After data have been entered in the "CRA Cumulative Calculations" tab of the Excel workbook, stream flow rates for salmonid passage are determined by graphing and examining the relationship between flow and the stream width and depth criteria.

For each target species, generate two graphs:

- Flow versus percent contiguous passable width
- Flow versus percent total passable width

To determine the flows for target fish passage through the critical riffle, generate a best-fit regression line on each graph. First, find the point on the Y-axis that meets each criterion (e.g., 10% contiguous passable width), and then find where this point hits the line of best fit and its corresponding point on the X-axis. This point on the X-axis is the discharge for fish passage through this critical riffle.

Note: If there is more than one target species (as listed in Table 1) involved in the study, generate one set of graphs per target species.

3.4 Example of Data Analysis Results

A critical riffle measuring 100 ft (maximum transect length) from bank to bank along its shallowest course is being analyzed for passage of adult steelhead (minimum depth = 0.7 ft). To meet Department IFP criteria for adult steelhead passage, this riffle would need to have:

- A *contiguous* portion of at least 10 ft in length measuring at least 0.7 ft deep; *and*
- A *total* of at least 25 ft in length with a depth of at least 0.7 ft.

Below are examples of the results from six sampling events at a critical riffle site for both the percent contiguous passable width (*Figure 6*) and percent total passable width (*Figure 7*). In these examples, the flow rate (126 cfs) associated with Criterion 1 (Percent Contiguous; *Figure 6*) is the same as Criterion 2 (Percent Total; *Figure 7*), and is therefore identified as the stream flow rate for passage of adult steelhead through the critical riffle site.

Note: If the stream flow rates differ between the two criteria, the higher of the two stream flow rates shall be identified as the stream flow rate for passage through the critical riffle.

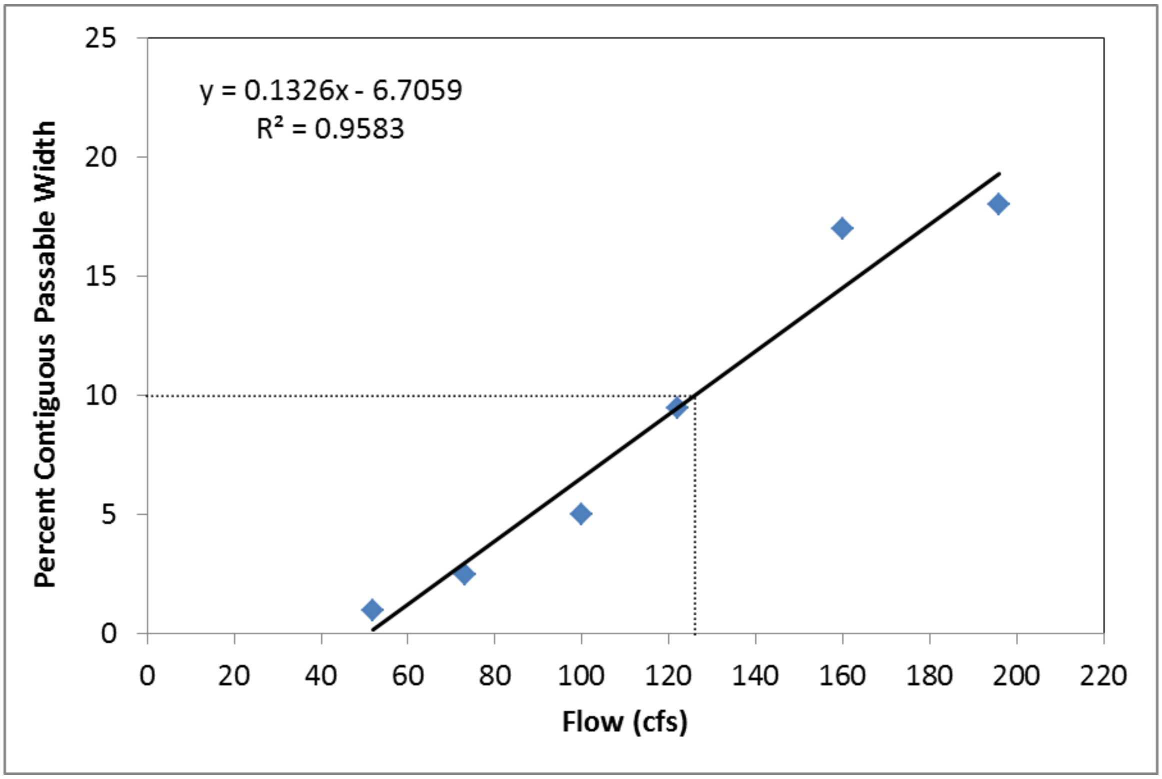

Figure 6. An example of the relationship between river flow (cfs) and percent contiguous passable width for adult steelhead passage. The dashed line represents the flow meeting the 10 percent contiguous passable criteria.

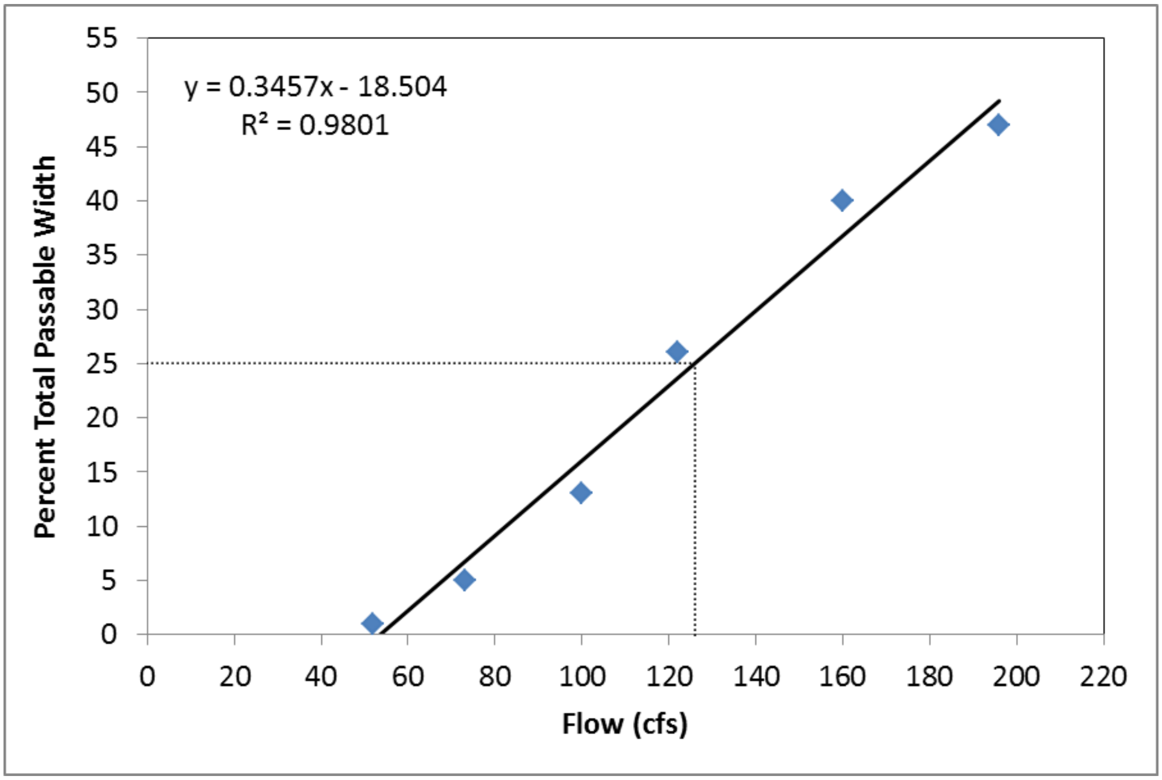

Figure 7. An example of the relationship between river flow (cfs) and percent total passable width for adult steelhead passage. The dashed line represents the flow meeting the 25 percent total passable criteria.

3.5 Considerations for Application of Flows for Salmonid Passage

Several important factors should be taken into consideration during the development and application of flows for passage of salmon and trout. Consider the target species and their life history tactics, with careful attention to approximate time frames for migration and emigration (movement).

Adult salmonids are dependent upon their ability to migrate to spawning habitats at appropriate times that coincide with their life history traits. If adult salmonids are delayed or are unable to reach spawning habitats, the spawning population could be impacted, leading to reduced egg and fry production. Juvenile salmonids are dependent upon their ability to migrate from freshwater riverine habitats (including lagoons) to the ocean. Juvenile salmonids that may rear in freshwater riverine and lagoon habitats (i.e., steelhead) for 1-3 years are dependent upon their ability to access successful rearing habitats in the low-flow summer months. This rearing habitat must have adequate flow (depth and velocity), food, water quality (temperature), and escape cover from predators.

Glossary

Channel Morphology	The dimension (e.g., width, depth), shape and pattern (e.g., sinuous, meandering, straight) of a stream channel.
Critical Riffles	Riffle habitats that may be particularly sensitive to changes in stream flow due to shallow water depth. Critical riffles may prevent adult salmon and steelhead passage to and from spawning areas and/or may prevent movement of rearing juvenile salmonids between adequate summer rearing habitats.
Discharge	The volume rate of water flow transported through a given cross-sectional area. The units that are typically used to express discharge include ft^3/s (cubic feet per second) and m^3/s (cubic meters per second).
Exceedance Probability	The probability that a certain flow value is going to be exceeded.
Thalweg	The lowest line of elevation along the length of a streambed, defining its deepest channel.
Toe of bank	The break in slope at the foot of a streambank where the bank meets the streambed.

References

California Department of Fish and Wildlife (CDFW). 2013a, Standard Operating Procedure for Flow Duration Analysis in California. Department of Fish and Wildlife Instream Flow Program Standard Operating Procedure CDFW-IFP-005, 16 pp. Available at: https://www.wildlife.ca.gov/Conservation/Watersheds/Instream-Flow/SOP

California Department of Fish and Wildlife (CDFW). 2013b. Standard Operating Procedure for Discharge Measurements in Wadeable Streams in California. California Department of Fish and Wildlife Instream Flow Program Standard Operating Procedure CDFW-IFP-002, 24 pp. Available at: https://www.wildlife.ca.gov/Conservation/Watersheds/Instream-Flow/SOP

Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 2010. California Salmonid Stream Habitat Restoration Manual, 4th ed. California Department of Fish and Game. Available at: http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp

Hardin, T. 2012. Personal communication with Tim Hardin, Instream Flow Specialist, Oregon Department of Fish and Wildlife. July 2, 2012.

R2 Resource Consultants, 2008. Appendix G: Approach for Assessing Effects of Policy Element Alternatives on Upstream Passage and Spawning Habitat Availability. Administrative Draft prepared for the California State Water Resources Control Board, Division of Water Rights as part of the North Coast Instream Flow Policy: Scientific Basis and Development of Alternatives Protecting Anadromous Salmonids. March 14, 2008. Accessed from: http://www.swrcb.ca.gov/waterrights/water_issues/programs/instream_flows.

Thompson, K.E. 1972. Determining Streamflows for Fish Life. pp. 31-50 in Proceedings of the Instream Flow Requirement Workshop. Pacific N.W. River Basins Commission. Portland, OR.