SHASTA RIVER FISH PASSAGE AND LONGITUDINAL HABITAT CONNECTIVITY

1.0 Study Goals and Objectives

The goals of this study are to 1) identify potential structural and hydraulic barriers to anadromous fish passage in the Shasta River, and 2) identify streamflows that support passage of anadromous fish of multiple life stages at these potential barriers. The specific objectives of the study include:

1) Review existing information and conduct field surveys to identify potential fish passage barriers.
2) Classify potential fish migration barriers and select study sites (critical passage sites) for application of fish passage and habitat connectivity assessment methods.
3) Identify the appropriate data and methods for evaluating fish passage success as a function of high and/or low flow at the study sites.
4) Using physical and hydraulic data, apply appropriate fish passage methods and criteria (e.g., minimum passage depths, maximum water velocities) to evaluate potential fish passage success. (Longitudinal habitat connectivity as affected by high water temperatures or dry channels will be addressed by temperature modeling and hydrologic study plans, respectively.)
5) Identify protective flow regimes for passage of target species and lifestages, and apply hydrologic data to evaluate the frequency and duration of suitable passage flows under existing, unimpaired, and alternative flow scenarios to recover and/or enhance populations and restore watershed function.

2.0 Review Existing Information

The purpose of this task is to review and update available information on known or potential fish passage barriers in the Shasta River watershed to guide identification of key sites where additional information is needed to evaluate fish passage needs and identify actions to improve passage and connectivity of critical migration, spawning, and rearing areas. During the initial phase of study plan development, specific study reaches were identified where fish passage is a primary resource issue. Sources for relevant information on the location, status, and recommended or proposed actions at specific passage barriers within these reaches were also identified as part of this effort. A key source for updated information on fish passage barriers in these reaches is the CalFish Fish Passage Assessment Database (CalFish 2014). This database contains a GIS-based catalog of available fish passage information that can be queried using a number of search criteria, and includes the location, type, and status of known or potential barriers; passage assessment protocols; survey team and date; ownership information; and relevant citations. Additional information on hydrologic connectivity could be identified from available aerial or satellite photo sources (e.g. Google Earth) or previous investigations (Watershed Sciences 2004).

This task includes: 1) reviewing and updating information on all known or potential fish passage barriers within the study reaches identified below; 2) reviewing current information on the key species and life stages of concern in these reaches; 3) interviewing biologists and other technical specialists, stakeholders, and local experts currently engaged in monitoring, evaluation, planning, and implementation of fish passage and habitat restoration actions in the Shasta River watershed; and 4) identifying major gaps in information on specific barriers or barrier types within the study reaches (e.g., critical riffles).

This task also includes telephone and email correspondence with the management team to review the results and agree on major data gaps and the specific study reaches or sites where field surveys will be conducted.

3.0 Study Areas

The Shasta River watershed has a watershed area of approximately 795 square miles. Snowmelt from Mount Shasta contributes a relatively constant source of spring flow to the Shasta River and its eastern tributaries. During project scoping, the Shasta River was segmented into study reaches using criteria such as hydrology, length, geomorphology, and others (Normandeau Associates 2013; Figures 1 and 2). The proposed study reaches where fish passage and hydrologic connectivity have been identified as concerns are listed in Tables 1 and 2 (see Shasta River Potential Studies Matrix http://www.normandeau.com/scottshasta/project_materials.asp).

Table 1. Reaches of the Shasta River and tributaries where critical riffles are to be identified.

REACH DESCRIPTION	Reference(s)	Studies Status
Mainstem Shasta Studies	CDFG 1997	Needed
Tributary Studies	CDFG 1997	Needed

Table 2. Reaches of the Shasta River and tributaries where barriers are to be identified.

REACH DESCRIPTION	Reference(s)	Studies Status
Mainstem - Mouth to Yreka Creek (1)	CDFG 1997; SVRCD, M&T 2013	Partial
Mainstem - Little Shasta River to the GID Diversion (3)	CDFG 1997; SVRCD, M&T 2013	Partial
Mainstem - Parks Creek to Dwinnell Dam (6)	CDFG 1997; SVRCD, M&T 2013	Partial
Mainstem - Dwinnell Dam to Headwaters (7)	CDFG 1997; SVRCD, M&T 2013	Partial
Big Springs Creek (BS1)	CDFG 1997; SVRCD, M&T 2013	Partial
Little Springs Creek (BS1a)	CDFG 1997; SVRCD, M&T 2013	Partial
Little Shasta Confluence to Lower Shasta Rd (LS1)	CDFG 1997; SVRCD, M&T 2013	Partial
Little Shasta Lower Shasta Road to Cold Bottle Springs Creek (LS2)	CDFG 1997; SVRCD, M&T 2013	Partial
Little Shasta Cold Bottle Springs Creek to Headwaters (LS3)	CDFG 1997; SVRCD, M&T 2013	Partial
Parks Creek Shasta River to I-5 (P1)	CDFG 1997; SVRCD, M&T 2013	Partial
I-5 to the MWCD Diversion (P2)	CDFG 1997; SVRCD, M&T 2013	Partial
MWCD Diversion to East Fork confluence (P3)	CDFG 1997; SVRCD, M&T 2013	Partial
East Fork Confluence to Headwaters (P4)	CDFG 1997; SVRCD, M&T 2013	Partial

Table 3. Shasta River tributaries where tributary connectivity (within-tributary and to mainstem Shasta River) needs to be evaluated.

REACH DESCRIPTION	Reference	Life Stage Access	Studies Status
Little Shasta River (LS1, LS2, LS3)	CDFW (2015)	Spawning, juvenile	Needed
Yreka Creek (Y1, Y2, Y3)	CDFW (2015)	Spawning, juvenile	Needed
Parks Creek (P1, P2, P3)	CDFW (2015)	Spawning, juvenile	Needed
Big Springs Creek (BS1)	CDFW (2015)	Spawning, juvenile	Needed
Little Springs Creek (BS1a)	CDFW (2015)	Spawning, juvenile	Needed
Hole in the Ground Creek	CDFW (2015)	Spawning, juvenile	Needed
Kettle Springs	CDFW (2015)	Spawning, juvenile	Needed
Bridgefield Springs	CDFW (2015)	Juvenile	Needed
Black Meadow Springs	CDFW (2015)	Juvenile	Needed
Roggenbuck Springs	CDFW (2015)	Juvenile	Needed

4.0 Study Methods

The following methods are focused on evaluation of structural and hydraulic fish passage barriers only. Integration and coordination with other study plans that cover hydrology, groundwater, and water temperature will likely be required to address the full range of fish barriers that may affect passage. These other barriers may include dry channel and thermal blockages.

4.1. Field Surveys

Reconnaissance-level field surveys will be conducted to identify potential fish barriers, evaluate the current status of known barriers, and determine the need for additional data and/or analyses to evaluate the flow and/or structural requirements for successful fish passage at these barriers based on the species and life stages of concern. These surveys will focus on the reaches and sites identified through review of existing information and coordination with the management team. A fish passage inventory data sheet will be developed in coordination with California Department of Fish and Wildlife (CDFW) to classify potential passage barriers, collect preliminary field measurements, and prioritize barriers for subsequent fish passage evaluation based on a set of filtering criteria. An example of a fish passage inventory data sheet for stream crossings and a description of the filtering process (passage evaluation filter) can be found in Part IX of the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 2010).

General types of fish passage barriers include 1) critical riffles and other non-structural, low-flow passage barriers, including dewatered channels; 2) artificial structural barriers such as diversion dams, culverts, and road crossings, and 3) natural structural barriers such as falls, chutes, cascades, and beaver dams. Depending on barrier type and site characteristics, initial field measurements may include water depths, fall heights, water column velocity, and passage route profiles and distances. This task should be coordinated with habitat mapping surveys described in the *Shasta River Mesohabitat Delineation Study Plan*.

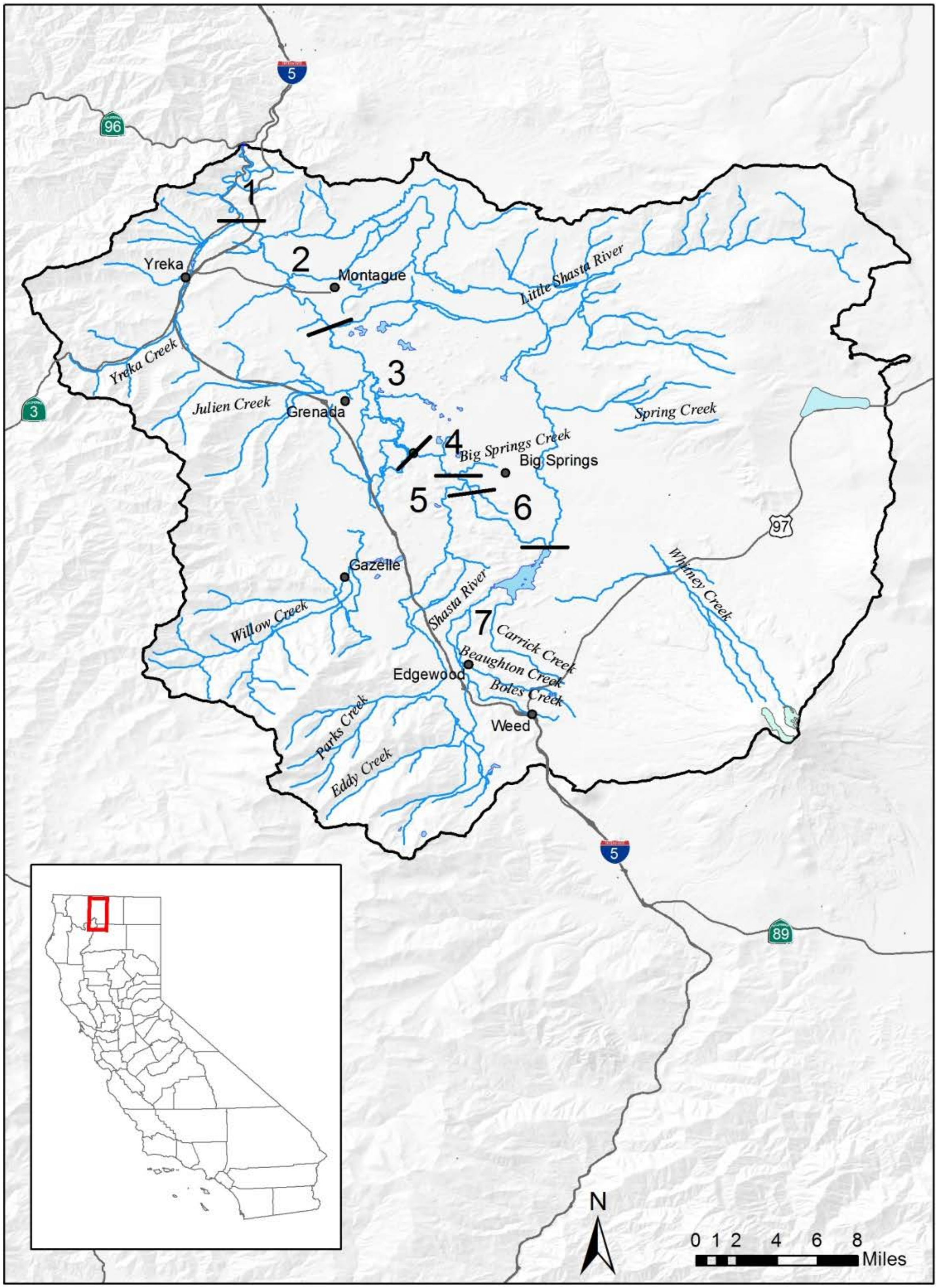

Figure 1. Shasta River Mainstem Reaches.

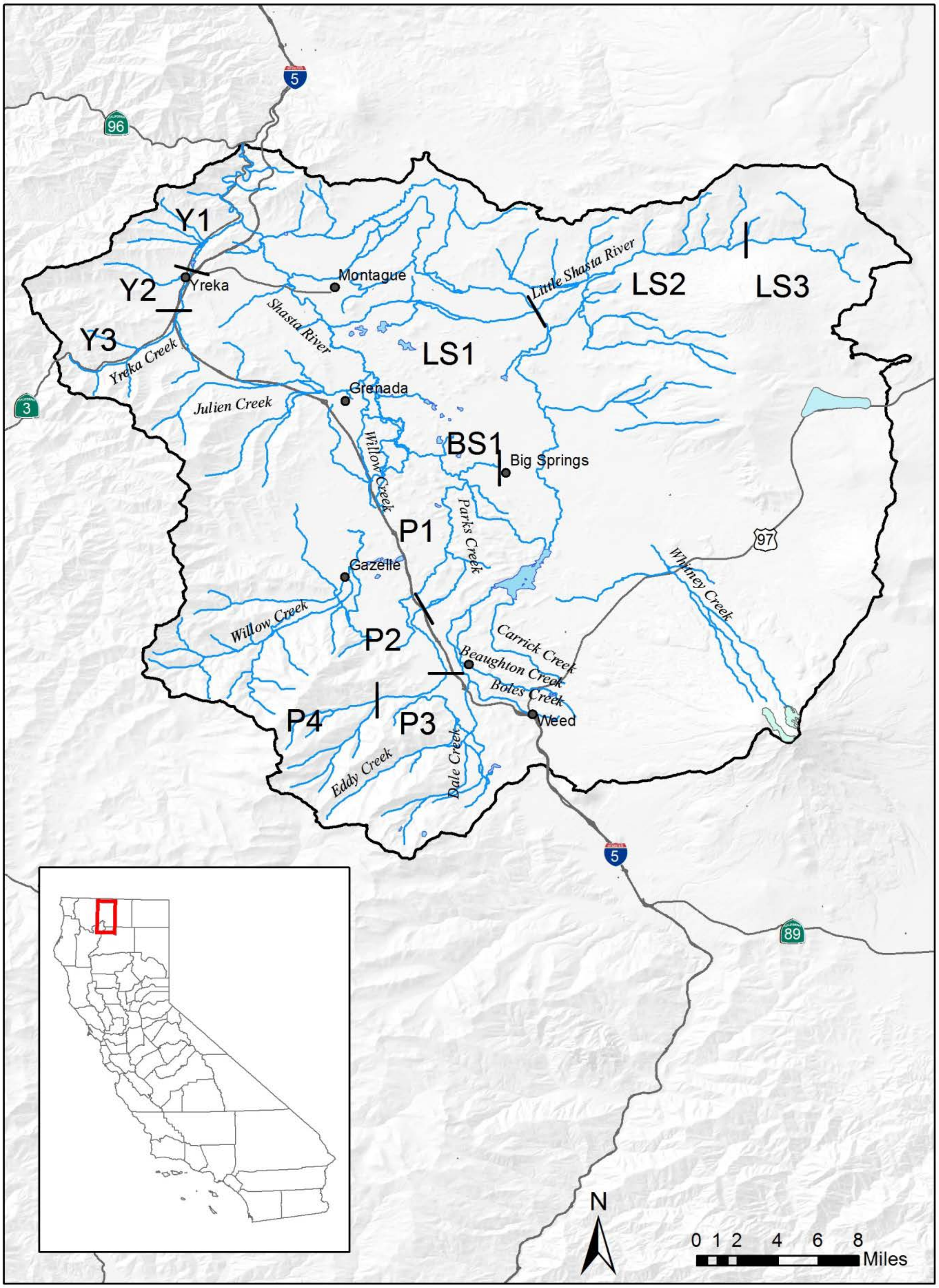

Figure 2. Shasta River Tributary Reaches. Little Springs Creek (Reach BS1a) is a tributary to Big Springs Creek and is not depicted due to its short relative length (1.2 miles).

4.2. Fish Passage Implementation Strategy

Once potential fish passage barriers have been identified through review of existing information and field surveys, the contractor will coordinate with CDFW to finalize the selection of study site and fish passage assessment methods for each study site or reach. The implementation strategy will include summary descriptions of each study site, including barrier type, target species/life stages, and key physical and hydraulic attributes potentially limiting fish passage. A draft implementation strategy report will be prepared and submitted to CDFW for review and comment before finalizing and submitting the strategy to CDFW for approval.

4.3. Fish Passage Assessment Methods

The selection of an appropriate fish passage assessment method depends on barrier type, site conditions, evaluation flow range, and species and life stage of concern. The following methods are generally recommended by CDFW to identify streamflows that support passage of anadromous fish based on existing channel or structural conditions. However, an engineered approach may be identified as the most practical or effective solution to restoring passage at certain sites or structures following review of site-specific information.

The methods described below should be guided by consideration of the timing of the passage needs for the species and life stages of concern (see *Shasta River Hydraulic Habitat Modeling Study Plan*) and an analysis of hydrologic conditions within the study reaches to define the range of flows during which these species and life stages typically migrate (see *Shasta River Hydrologic and Water Balance Modeling Study Plan*). As a starting point, CDFG (2013a) recommends targeting flows between 20% and 80% exceedance flows as determined from a flow exceedance probability curve based on unimpaired flow conditions.

4.3.1. Fish Passage at Critical Riffles

CDFW developed a critical riffle analysis (CRA) procedure (CDFW 2013a) to evaluate and identify stream flows needed to protect anadromous salmonid passage and overall riverine habitat connectivity in California streams and rivers. The evaluation procedure draws from the Thompson (1972) methodology in procedural scope with the application of regional species- and lifestage-specific criteria relevant to California salmonids. The Thompson (1972) method is based on over a decade of extensive field observations spanning all 18 drainages of Oregon by ODFW, including several hundred of the most important salmonid streams in the state. Critical riffle analysis is used to identify protective flows for physical movement (passage) of salmon and trout through natural critical riffles (CDFW 2013a) and may be applicable to other sites where shallow depths may impede upstream or downstream passage (e.g., tributary mouths). CDFW's standard operating procedure for critical riffle analysis includes the following overview and general criteria for application of the method:

Salmon and trout passage flows are determined by locating a critical riffle, identifying a transect along the riffle's shallowest course from bank to bank, and measuring water depth (and average water column velocity) at multiple locations across the transect. Adequate water depths of sufficient width are necessary to identify passage flows and promote passage of adult and juvenile salmonids at critical riffle sites. Field data are compared to species- and lifestage-specific water depth criteria meeting the percent total and percent contiguous proportion (see Section 3 for more information) of the critical riffle width available for fish passage. After a minimum of three to six field events have been completed over a wide range of discharges, stream discharge rates and percent of transect meeting the minimum depth criteria for the *species and lifestages are plotted to determine flow rates necessary for passable flows. Both the criteria (percent total and the percent contiguous) must be met and then the higher flow rate among the two criteria that are found to meet the minimum depth for the target species and lifestage may be used to identify the passage flows for the target salmon and trout at the critical riffle site.*

The IFP has established two criteria for development of passage flows for salmon and trout:

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

The minimum water depth criteria recommended for adequate adult and juvenile salmonid passage through a critical riffle is established in Table 6. Passage depths include addition of 0.1 ft to maximum fish body depth for species and lifestages to provide for protective conditions and avoid abrasion with the stream bottom (SWRCB 2014).

Table 4. Minimum depth criteria for adult and juvenile salmonid passage to be used in critical riffle analysis.

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

This SOP applies only to wadeable streams having low gradient riffles with less than 4% gradient and substrates dominated by gravel and cobble. This SOP is not applicable to high gradient riffles greater than 4% gradient and boulder dominated substrates (Flosi et al. 2010). This SOP 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. This procedure is also not applicable to culverts, weirs, bedrock ledges, or anticlines with associated drops.

CDFW recommends including an evaluation of velocity conditions across the passage transect and comparison with fish swimming threshold values for the target species and lifestage. This Critical Riffle SOP is best suited for riffles with relatively simple geometry where fish passage conditions can be evaluated at single transects, and where water depths and velocities can be measured safely and effectively at three to six flows bracketing the range of target flows. CDFW also recommends evaluation of length of riffle, water temperature, existence of rest areas and other factors which could limit or impair fish passage at natural critical riffle sites. However, where sufficient field measurements are not possible or practical, hydraulic modeling may be required to assess fish passage beyond the measured range of flows. 2D hydraulic modeling may be required for sites with complex physical and hydraulic characteristics that require relatively high-resolution modeling to accurately characterize fish passage conditions over the full range of target flows (see *Hydraulic Modeling* below).

4.3.2. Fish Passage Analysis at Artificial and Natural Structural Barriers

The following methods are applicable to artificial and natural structural barriers that may pose partial or complete barriers to passage of adult and juvenile salmonids. Potential structural barriers in the Shasta River watershed include permanent and seasonal dams or weirs and natural features (e.g., falls, chutes, cascades, beaver dams) where vertical drops or steep, swift and/or turbulent passage conditions may impede or block upstream passage of adults or juveniles.

The procedure described by Powers and Orsborn (1985) will be used to analyze fish passage conditions for adult salmonids and guide design of proposed modifications at structural barriers. This procedure considers the swimming and leaping capabilities of the target species and life stages in relation to the physical and hydraulic characteristics of culverts, waterfalls, and other jump barrier. The general components of this procedure are described below.

1) Define the swimming capabilities of the target species. Powers and Orsborn (1985) summarize the swimming capabilities a number of species in terms of the upper limits of swimming speeds, leaping capabilities, and swimming performance based on published literature and information on fish size, condition, water temperatures, and other factors that may limit or impair fish passage success.
2) Classify fish passage barriers. Powers and Orsborn (1985) developed a classification system for fish passage barriers based on key characteristics that affect passage success. This classification system consists of four components: class, type, magnitude, and discharge. *Classes* are defined as falls, chutes, and cascades and further subdivided according to their degree of difficulty based on the number of passage routes, variation in bed slope, hydraulic diversity (e.g. presence of resting areas), and turbulence. *Type* is used to further rank passage conditions based on site geometry, bed slopes, and water depths encountered by fish during passage of the site. *Magnitude* and *discharge* include measurements of elevation differences, water velocities, slope lengths, and discharges at the time of observation or migration season.
3) Evaluate factors affecting fish passage. Powers and Orsborn (1985) describe field and analytical procedures for evaluating specific physical, hydraulic, and biological conditions that can affect fish passage success at structural barriers based on the passage requirements of the species and life stage of concern. These methods can be used in conjunction with site-specific hydrologic analyses to evaluate the flows supporting fish passage under existing conditions or identify structural modifications to improve fish passage conditions within the range of evaluation flows.

The same general procedure can be used to evaluate upstream passage conditions for juvenile salmonids based on current CDFW guidelines for juvenile passage at stream crossings (Flosi et al. 2010). In the Shasta River, juvenile passage is an important consideration at artificial and natural structures that may impede or block upstream movement of juveniles into critical over-summer rearing habitat (e.g. non-natal spring streams) where adequate temperatures or other habitat conditions would promote rearing success. Potential downstream passage impediments created by low flows or artificial structures (e.g. diversion dams) should also be considered as part of this assessment.

Similar to the procedures described above for adult passage, evaluation of juvenile passage will requires information on the swimming speeds, leaping capabilities, and behavior of juvenile salmonids, field measurements or modeling of the physical and hydraulic conditions potentially affecting passage success (e.g. hydraulic drops, water depths, velocities), and hydrologic analysis to identify the range of flows under which juveniles typically migrate. Current CDFW upstream passage guidelines for juvenile salmonids at culverts include maximum average water velocities of 1 foot per second, minimum flow depths of 0.5 feet, and maximum hydraulic drops of 0.5 foot (Flosi et al. 2010).[1] The recommended flow range for evaluation of juvenile fish passage are flows between the 10% and 95% exceedance flows as determined from a flow exceedance probability curve (Flosi et al. 2010).

At locations where significant barriers exist to both adult and juvenile passage, comparative analyses may be needed to identify appropriate flow or structural solutions that address the passage requirements for both life stages. This may include consideration of potential differences in passage requirements as a function of migration timing, fish size, swimming ability, and other behavioral attributes.

4.3.3. Hydraulic Modeling

The review of existing information and field survey results will be used to identify potential passage barriers that require hydraulic modeling. 2D hydraulic models are recommended by CDFW in such applications.

2-D hydraulic modeling may be warranted for some sites because of their physical extent and complexity and associated hydraulic complexity over the range of target flows. For example, because 2-D models consider the river as a spatial continuum rather than a number of independent cross sections (Leclerc et al. 1995), 2-D modeling may be particularly applicable to braided channels or long, boulder-dominated riffles where rapidly varying hydraulic conditions require finer resolution modeling of depths and velocities along potential fish passage routes within the site.

The procedures for application for 2-D modeling using River2D are described by USFWS (2011). The identification of protective flows supporting fish passage will be similar to that described above for CRA, although the 2-D modeling results will permit a more detailed spatial analysis of the suitability of potential passage and habitat connectivity pathways based on consideration of the CRA minimum depth criteria, swimming ability of the target species, and the distances between resting areas or cover. ArcGIS may be a useful tool for analysis of potential fish passage routes based on the 2-D modeling results.

4.4. Fish Passage Duration Analysis

Following identification of flows supporting fish passage within specific study reaches or at specific sites, potential fish passage success will be evaluated using a habitat duration or time series analysis (see S*hasta River Hydraulic Habitat Modeling Study Plan*) to evaluate the frequency and duration of protective passage flows under existing, unimpaired, and alternative flow scenarios.

5.0 Deliverables

The fish passage study products will include:

1) Fish passage inventory data sheets, including flow/depth/velocity profiles, maps, and photographs of potential fish passage barriers.

[1] Ongoing CDFW studies in the Shasta River (CDFW 2013b) using PIT-tagged juveniles may also provide insight into juvenile coho passage requirements in the Scott and Shasta Rivers.

2) An implementation strategy report describing selected study sites/reach, barrier types, and fish passage assessment methods.
3) Draft and final fish passage evaluation reports, including study sites, fish passage assessment methods and results (e.g., graphic and/or tabular displays of relationships between river discharge and fish passage metrics), and the results of fish passage duration analysis.

6.0 Literature Cited

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