Bishop Creek Progress Report 2:
APPENDIX E - INSTREAM FLOW INCREMENTAL METHODOLOGY MEMO

BISHOP CREEK HYDROELECTRIC PROJECT
FERC NO. 1934-CA

BISHOP CREEK FLOW NEEDS STUDY REPORT

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FERC NO. 1394

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GLOSSARY

CFS. *Cubic Feet per Second*. A volumetric flow rate passing a known point.

HABTAE. A sub-program with PHABSIM that calculates habitat suitability based on hydraulic model output for flow increments of interest.

HSC. *Habitat Suitability Criteria*. A quantitative index that rates the suitability of depth, velocity and substrate on a scale from 0.0 to 1.0 for application to the hydraulic output of a PHABSIM model. Used by the HABTAE sub program to generate WUA. HSC are usually species- and lifestage-specific.

IFIM. *Instream Flow Incremental Methodol*ogy. A method that quantitatively assesses changes in aquatic habitat suitability across a range of stream flows and project operating conditions that facilitates the analysis and negotiation of alternative flow recommendations.

PHABSIM. *Physical Habitat Simulation*. A family of hydraulic and habitat use computer programs that quantifies changes in aquatic habitat suitability across a range of flows in support of the IFIM.

STGQ, MANSQ, and WSP. Hydraulic simulation programs used to calibrate and simulate water surface elevations in PHABSIM.

VAF. *Velocity Adjustment Factor*. A hydraulic modeling output parameter used during model calibration in PHABSIM that indicates the extent to which the model had to adjust simulated velocities to conform to predicted WSL's.

WSL. *Water Surface Elevation*. A stream water elevation necessary for hydraulic modeling, surveyed at a point of interest such as a transect.

WUA. *Weighted Usable Area*. The quantitative index of habitat suitability that is the output from the PHABSIM model. WUA is based on the wetted stream area (square ft.) of the study area adjusted by the relative suitability of a given set of flow hydraulics (*i.e.*, depth and velocity) for a specific species and lifestage at a given flow.

1.0 INTRODUCTION

Southern California Edison Company (SCE) is the licensee, owner, and operator of the Bishop Creek Hydroelectric Project (Project) Federal Energy Regulatory Commission (FERC) Project No. 1394. The Project is located on Bishop Creek in Inyo County, California, approximately 5 miles southwest of the city of Bishop (Figure 1.1). The licensee operates the Project under a 30-year license issued by FERC on July 19, 1994. As the current license is due to expire June 30, 2024, SCE has initiated the formal relicensing process utilizing the Integrated Licensing Process (ILP) by filing the Notification of Intent (NOI) and Pre-Application Document (PAD) with FERC on May 1, 2019.

In advance of filing the NOI and PAD, SCE worked with stakeholders to identify necessary studies, with the goal of accelerating FERC's ability to issue a Study Plan Determination. Efforts began over a year before formal initiation of the process with FERC, through a series of Technical Working Group (TWG) meetings held in Bishop, California. During these TWG meetings, stakeholders identified the need for an Instream Flow Needs Study Plan (Study Plan) that focused on creeks located below Project plant diversions. Draft study plans were distributed with the PAD and revised after receiving comments pursuant to 18 CFR § 5.9. FERC approved the Revised Study Plan (RSP) with its Study Plan Determination on November 4, 2019. As required by the Integrated Licensing Procedures (ILP) described in 18 Code of Federal Regulations (CFR) section 5.15 (b), this memorandum will support a periodic progress report to stakeholders and will be incorporated by reference in the Initial Study Report (ISR) in November of 2020.

While the overall scope of this study is to quantify the effects of releases from South Lake, Sabrina Lake, and Project bypass reach flows on aquatic habitat suitability for the Bishop Creek drainage aquatic community and its managed fish resources, the intent of this technical memorandum is to review data collected in 2019 that will be used in conjunction with hydrologic, operational, and other models to evaluate the costs and benefits of providing alternate flows to the targeted reaches of Bishop Creek. Specifically, the data will be useful in determining the range of flows necessary to provide suitable habitat to support the brown trout population in Bishop Creek in the Middle and South forks of Bishop Creek, and in bypass reaches below Plants 2, 3, 4, 5 and 6, and below the South Fork Diversion, and potential native non-game species (Owens sucker and Owens speckled dace) below Plant 4.

1.1 METHODOLOGY AND STUDY AREA

The California Department of Fish and Wildlife (CDFW) recommended an Instream Flow Incremental Methodology (IFIM) study to develop key habitat-flow relationships in the study area and to provide a basis for negotiating instream flow recommendations for the Project. This was quantified by a Physical Habitat Simulation (PHABSIM) model used to simulate reach-specific habitat suitability for selected fish species at various flow increments. PHABSIM employs one-dimensional (1-D) transect-based hydraulic data to simulate channel hydraulics in various areas of interest (Study Sites).

Upstream and Downstream Boundaries

The study area includes Bishop Creek between the Plant 2 spillway and Plant 6, and the South and Middle forks of Bishop Creek (Figure 1.1). Only the two reaches below Plant 4 and Plant 5 are managed primarily for native non-game species.

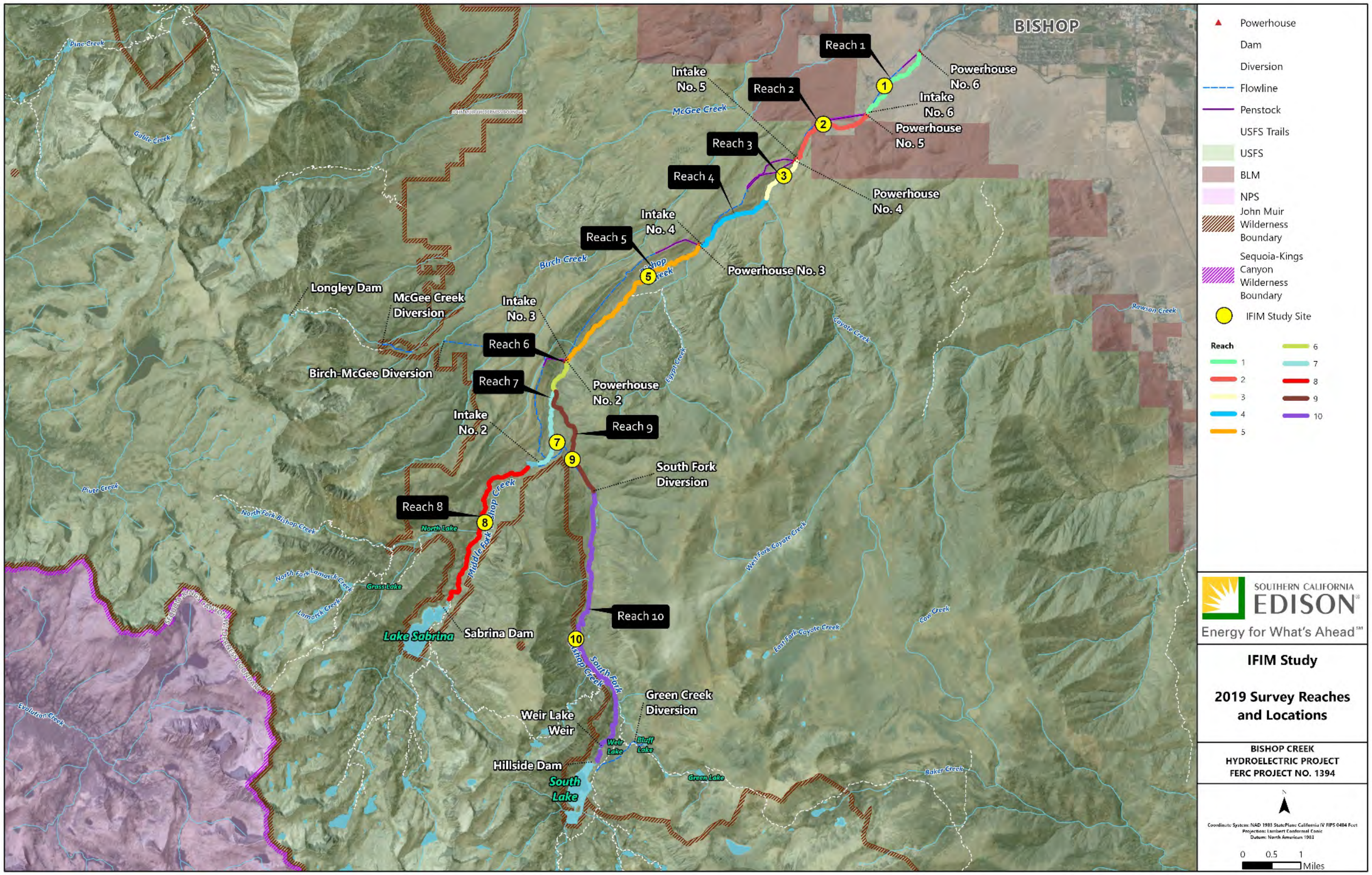


FIGURE 1.1 INSTREAM FLOW NEEDS ASSESSMENT STUDY AREA

Consistent with IFIM protocol, a study team comprised of agency and SCE biologists, along with aquatic TWG members, collaboratively made technical decisions regarding input parameters and review of study results. Specifically, the team provided input on:

- specific spatial and temporal habitat management goals,
- boundaries of the study area and reaches,
- locations of specific study sites, and study site transects,
- habitat suitability index (HSI) criteria for applicable species, lifestages, and
- calibration of flows and the range of flows to be assessed.

Study Area, Reach and Study Site Selection

The proposed study methodology involved a phased approach beginning with mapping mesohabitat distribution in the study area. The study area spans approximately 22 miles of creek (Figure 1.1) including:

- Bishop Creek from Plant 6 upstream to the confluence of the Middle and South Forks.
- Middle Fork Bishop Creek upstream to the Sabrina Lake spillway channel.
- Bishop Creek upstream to the South Lake spillway channel.

Selection of Reaches, Study Sites and Transects

Study reach boundaries are typically placed at significant breaks in geomorphic, hydrologic, or habitat use in the study area (Bovee et al. 1998). The study team reviewed mesohabitat mapping and site reconnaissance data to define study reaches and to select applicable study sites within each reach and transect.

A total of 10 reaches (numbered from downstream to upstream) were identified in consultation with the Aquatics TWG (Figure 1.1).

Bishop Creek was divided into a total of six hydrologic reaches, numbered beginning from downstream to upstream. Flows in Reaches 1 and 2 are influenced by releases from the Intake 6 and Intake 5 spillways, respectively. Reach 3 flow is influenced by releases from Intake 4 and Coyote Creek discharge; Reach 4 is solely influenced by releases from Intake 4. Reach 5 is influenced by releases from Intake 3; Reach 6 receives flow from Intake 2 (on the Middle Fork) and a diversion from the South Fork of Bishop Creek.

Middle Fork Bishop Creek. Reach 7 is influenced by releases from Intake 2; Reach 8 is influenced by releases from Sabrina Lake.

South Fork Bishop Creek. Reach 9 is influenced by releases from the Intake 2 diversion; Reach 10 is influenced by releases from South Lake.

Presently, minimum flows have reach-specific targets ranging from 5 to 18 cubic feet per second (cfs) (Table 1-1).

TABLE 1-1 HABITAT-BASED MINIMUM FLOW REQUIREMENTS UNDER EXISTING LICENSE ARTICLE 105

Location	IFIM Reach	Flow	Notes
South Lake to S. Fork Diversion	Reach 10	13 cfs	
S. Fork Diversion to Middle Fork	Reach 9	10 cfs	April- October, otherwise 7 cfs
Sabrina to Intake 2	Reach 8	13 cfs	
Intake 2 to Plant 2	Reach 7	13 cfs*	Last weekend in April – Oct. 31*
Confluence of the forks to Intake 3	Reach 6	23 cfs**	
Intake 3 to Plant 3	Reach 5	13 cfs	
Intake 4 to Plant 4	Reaches 3 and 4	5 cfs	
Intake 5 to Plant 5	Reach 2	18 cfs	
Intake 6 to Plant 6	Reach 1	N/A	

*7 cfs November 1 through late April; at least 5 cfs on dry years
** not a compliance requirement; rather sum of flows from below South Fork Diversion and from below Intake 2

Mesohabitat Mapping

Mesohabitats are recurring types of aquatic habitat such as riffles, runs, pool, and glides (Bovee *et al*, 1998). Aquatic mesohabitat mapping quantified the extent, location and distribution of specific aquatic habitats to inform the secondary phase of study. Each mesohabitat type of interest was assigned specific attributes for field delineation. Delineation occurred at Project base flows, therefore mesohabitat boundaries, substrate, object cover, and hydraulics could be readily observed. The upstream and downstream boundaries of each mesohabitat within the study were geo-referenced, and the information transferred to a geographic information system (GIS) format to provide quantitative and spatial information on the abundance of each mesohabitat type. A technical memorandum was prepared and distributed to the TWG on

September 21, 2019 (Appendix A). TWG representatives participated in a conference call on October 25, 2019 to review these data, high resolution drone movies and photographs, and make preliminary recommendations for study sites and transects.

Data Collection and Modeling

The second phase used standard PHABSIM data collection and flow modeling procedures (Bovee 1982; Bovee *et al*. 1998). The PHABSIM modeling approach is based on hydraulic data developed from cross-sectional depth, velocity, and substrate measurements taken at a series of calibration flows following Milhouse *et al*. (1989) and USGS (2001). PHABSIM for Windows (V 1.5.1), developed by the United States Fish and Wildlife Service (FWS) and distributed by the U.S. Geological Survey (USGS) Fort Collins Science Center, Colorado was used for modeling.

Reaches 4, 6 and a portion of 8 were deemed unsuitable for PHABSIM. Reaches 4 and 6 are extremely steep gradient and composed of small pocket pools and cascades which are difficult to accurately model with PHABSIM; a portion of Reach 8 is composed of a complex of split channels that would also be difficult to simulate across a range of flows. The U.S. Forest Service (USFS) recommended the Habitat Criteria Mapping approach (https://www.hydroreform.org/hydroguide/science/414-habitat-criteria-mapping) which relies on empirical measurements of depth, velocity, and substrate at a series of flows and mapping of preferred habitat. Resulting polygons are transferred into a GIS framework to calculate available habitat area for each measured flow and extrapolated to similar mesohabitat units in the study area.

Flow Range

Based on TWG input, SCE targeted modeling habitat suitability-discharge relationships for flows ranging from approximately 4 cfs to 100 cfs.

Habitat Suitability Index Criteria

SCE evaluated habitat suitability criteria (HSC) for brown trout, Owens sucker and speckled dace based on consultation with the TWG (Table 1-2), and collaborated with CDFW and USFS biologists to identify HSC index curves adapted from other applicable PHABSIM models and CDFW speckled dace habitat survey data.

TABLE 1-2 SPECIES AND LIFESTAGE CRITERIA TO ASSESS BISHOP CREEK INSTREAM FLOW HABITAT NEEDS

Brown trout	Juvenile
	Adult
	Young-of-year
Owens sucker	Spawning
	Incubation (if different than spawning)
	Juvenile
	Adult
Speckled dace	Adult

Transect Data Collection

The location of each transect was field blazed with flagging or other appropriate means. Each study site and upstream and downstream cell boundaries were mapped to quantify the area represented by each transect. The transect headpin and tailpins were located at or above the top-of-bank elevation and secured by steel rebar or other similar means. A measuring tape accurate to 0.1 foot was secured at each transect to enable repeat field measurements at specific stream locations. Stream bed and water elevations linked to local datum were surveyed to the nearest 0.1 foot using standard optical surveying instrumentation and methods.

Depth, velocity, and substrate data were gathered at intervals (verticals) along each transect (Photo 1.1) at three calibration flows that allowed model extrapolation between 4 and 100 cfs. Each vertical was located to the nearest 0.1 foot wherever an observed shift in depth or substrate/cover occurred. At least 20 verticals per transect were established as necessary on each transect and arrayed so that no more than 10 percent of the discharge passed between any pair to enhance hydraulic model calibration. A study site staff gage was monitored at the beginning and end of each set of hydraulic measurements to verify stable flow. If flow was determined to be unstable, the related data were discarded and re-measured once stable flow was established.

PHOTO 1.1 TYPICAL TRANSECT DATA COLLECTION

Mean column velocity was measured to the nearest 0.1 foot per second with a calibrated Marsh-McBirney Flowmate 2000 electronic velocity meter mounted on a top-setting wading rod. In water less than 2.5 feet in depth, measurements were made at 0.6 of total depth (measured from the water surface); at greater depths, paired measurements were made at 0.2 and 0.8 of total depth and averaged. A series of three 15-second-averaged readings were taken at each vertical.

Coyote Creek provides significant tributary inflow into Reach 4; during the study, flow there was manually gauged, and a staff gauge was placed there to verify that inflow remained stable during the survey.

The hydraulic model was built from measurements gathered at three calibration flows to facilitate extrapolation of hydraulic data across the range of interest. Each study site calibration flow was provided by scheduled releases from applicable Project spillways or gates; study-site field flow was obtained from real-time gaging data from the SCE Bishop operations center. A full set of depth, velocity and water surface elevation (WSEL) data were gathered at the low and intermediate flow, and WSEL was measured at each transect for the high flow calibration. Table 1-3 summarizes calibration flows achieved in the field.

TABLE 1-3 BISHOP CREEK IFIM STUDY CALIBRATION FLOWS FOR EACH PHABSIM STUDY SITE

Study Site	Low Flow	Mid Flow	High Flow
1	1.5 cfs	20 cfs	37 cfs
2	8 cfs	20 cfs	107 cfs
*3	9 cfs	23 cfs	43 cfs
5	14.5 cfs	22 cfs	39 cfs
7	7 cfs	**23 cfs	36 cfs
8	8 cfs	20 cfs	40 cfs
9	8 cfs	20 cfs	40 cfs
10	8 cfs	20 cfs	40 cfs

* includes 3 cfs inflow from Coyote Creek
** transect 7.3 was measured at a flow of 18 cfs

Habitat Criteria Mapping

The Reach 8 braided channel survey site was selected in the field in consultation with the USFS and CDFW on November 4, 2019[1]. The wetted width, water depth, and velocity of each braided channel was measured at approximately 1 to 2-foot intervals across each of the three channel braids during each calibration flow release required for the PHABSIM study site located elsewhere in Reach 8. These data were then spatially depicted in ArcGIS Pro and plotted as points using the *Generate Points Along a Line* tool. Polygons were developed according to channel widths at each of the three flows by using the points generated in the previous step as a guide. Polygons were extended 25-feet upstream and 25-feet downstream to be representative each of the three braided channels. Polygons were assigned adult and juvenile brown trout suitability values at each of the three flows based on the depth and velocity measurement at a given location and suitability criteria of each respective life stage (Appendix A). Suitability from 0.0 to 1.0 foot for depth substrate and velocity were spatially binned as quartile values for each life stage and flow; the *Calculate Geometry* tool was then used to calculate the wetted habitat area of each quartile. These wetted areas were then multiplied by the upper limit of their

[1] It was not possible to survey Reaches 4 and 6 in 2019. These reaches will be surveyed and analyzed in 2020.

respective quartile suitability index value and summed to produce a weighted usable area (WUA) analogous to PHABSIM output for both life stages at each of the three flows.

Hydraulic Modeling

A stage-discharge curve was initially developed for each transect to simulate water elevations at various flow increments. The three water surface modeling options available in PHABSIM, include STGQ, MANSQ, and WSP[1] (USGS 2001). Each modeling option can be used to calibrate the model, and the one yielding the best results was chosen; the MANSQ model was determined to be the most appropriate for this Project. MANSQ calibration parameters include WSEL calibration sets and a "roughness modifier" at each transect. Both parameters were adjusted to raise or lower the simulated water surface elevation to match observed calibration flow elevations as closely as possible, by calculating a coefficient, *K*, that represents the channel slope and roughness at each transect. This coefficient is modified using the roughness modifier at each flow. This is done iteratively until the observed and simulated water surface elevations match reasonably well at each transect.

The stage-discharge curve is used to simulate velocities through mass balance. The first step determines the range of simulation flows for which each calibration flow is optimal. The lower calibration flows are typically used at the low end of the simulation range and mid or high calibration flows at the high end. The velocity adjustment factor (VAF) output provides guidance along with professional judgement to determine the reasonable range of simulation for each calibration flow (USGS 2001).

Habitat Suitability

Habitat suitability is indexed as units of WUA by combining the hydraulic and HSC components (USGS 2001). The HSC were developed in consultation with the TWG (Appendix A). Each

[1] STGQ and MANSQ are used to develop the stage *vs.* flow relationship at each transect independently of other transects. The WSP method is a step-backwater process, in which the predicted stage is a sequential computation starting at the downstream end of the study reach. The results at each linked transect are controlled by the combined effects of the downstream transects and the conveyance properties at the given transect. Each option includes additional input parameters that can be adjusted to improve the model's calibration. The values of these parameters have a range of typical values that can be found in modeling references, but the site-specific values of the parameters are determined by the calibration processes.

wetted segment, or “cell” of each transect has a known area based on survey data. The number of such cells that are wetted will rise and fall as flow levels change. Each of these areal cells is weighted per how the resulting hydraulics and substrate type provide a given mix of depth, velocity and substrate suitability on the HSC. These weighted cell areas are then summed to generate a suitability score (WUA standardized per 1,000-feet of stream length) for each flow. The habitat model produces the study area-level WUA score for each flow increment by summing these values across all transects, weighting each transect based on the percentage of the overall study site that it represents. Study area output is then extrapolated to the study reach based on the linear distance (represented by the study area mesohabitat from Phase 1 mesohabitat mapping). Habitat modeling was performed using the standard HABTAE component of PHABSIM, in which all three suitability criteria variables (depth, velocity, and substrate/cover) are equally weighted. Model output was exported to MS Excel® to develop curves and tables that depict the relationship between flow and WUA across the range of modeled flows.

2.0 RESULTS

2.1 HYDRAULIC DATA

Calibration flows were targeted as approximately 8, 20 and 40 cfs, although specific calibration flows varied slightly among reaches depending on operational requirements and tributary inflows (Table 1-1). Representative photos of study sites at calibration flows are presented in Appendix C; transect bed profile and calibration flow water elevation charts are presented in Appendix B.

2.2 HABITAT SUITABILITY

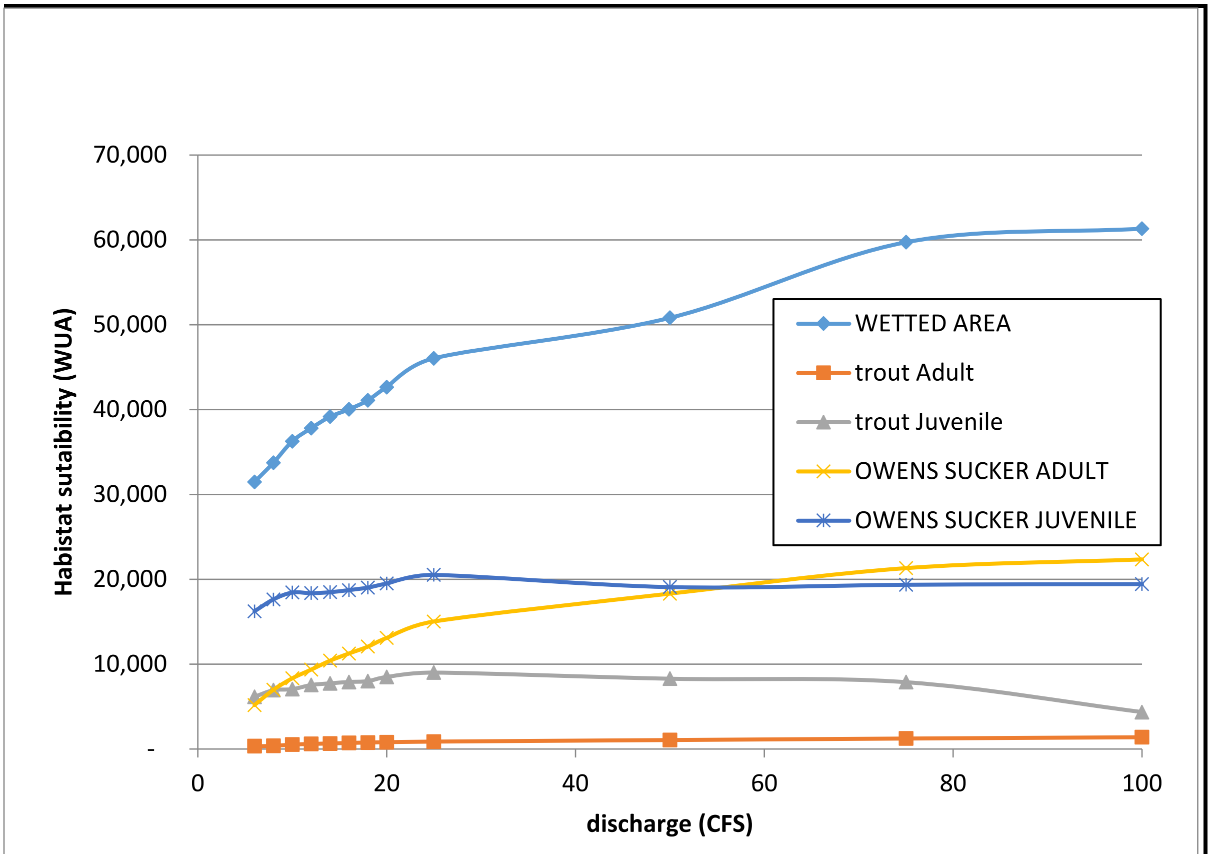
2.2.1 REACH 1

Reach 1 extends from Plant 6 upstream to the Intake 6 forebay pool spillway and is generally 15 to 40-feet-wide; substrate is dominated by small and large boulder and patches of cobble substrate, with a narrow band of riparian vegetation comprised of bushes and some small tree canopy (Photo 2.1). Riffle and pockets of pool/riffle complex mesohabitat types dominate this reach.

PHOTO 2.1 REPRESENTATIVE RIFFLE RUN HABITAT IN REACH 1

The hydraulic model did not perform well at 4 cfs, therefore the low flow end of habitat simulation began at 6 cfs. Wetted area increases at a relatively steady rate between 6 and 25 cfs after which the rate of increase is much more gradual at higher flows (Figure 2.1 and Table 2-1). Twenty-five cfs reflects the point in which the channel is essentially fully wetted, with gradual increases occurring at higher flows as the stream margin gradually becomes wetted.

FIGURE 2.1 REACH 1 HABITAT SUITABILITY BETWEEN 4 AND 100 CFS



Adult brown trout habitat suitability is relatively low and unchanging across the flow range (Figure 2.1)1; adult suitability response primarily reflects a lack of suitable depths for adults at any flow. There is greater suitability in this reach for juvenile brown trout as the HSC for that life stage show more tolerance of shallow depths. A flow of 8 cfs provides 77 percent of optimal habitat suitability for juvenile brown trout, and flow must be approximately tripled to gain an additional 15 percent suitability to reach optimal suitability at 25 cfs (Table 2-1).

[1] WUA is reported in units of suitability per 1,000 ft of stream reach

Reach 1 provides generally greater habitat suitability for Owens sucker at all flows relative to brown trout (Figure 2.1and Table 2-1). A flow of 8 cfs provides 86 percent of optimal habitat suitability for juvenile sucker; doubling this flow provides an additional 5 percent of suitability. Habitat suitability gradually declines at flow greater than 25 cfs. Most habitat suitability increases for adult Owens sucker occur between 6 and 14 cfs; habitat suitability gains at higher flows are very gradual.

TABLE 2-1 SUMMARY OF WETTED AREA AND WUA IN REACH 1 BETWEEN 6 AND 100 CFS

DISCHARGE (CFS)	WETTED AREA	TROUT ADULT	% OPTIMAL	TROUT JUVENILE	% OPTIMAL	OWENS SUCKER ADULT	% OPTIMAL	OWENS SUCKER JUVENILE	% OPTIMAL
6	31,468	326	24	6,163	68	5,184	23	16,237	79
8	33,731	374	27	6,927	77	6,977	31	17,630	86
10	36,267	521	38	7,052	78	8,329	37	18,441	90
12	37,808	598	43	7,541	84	9,356	42	18,365	90
14	39,157	655	47	7,741	86	10,407	47	18,480	90
16	40,032	716	52	7,901	88	11,256	50	18,730	91
18	41,089	764	55	7,998	89	12,061	54	19,022	93
20	42,658	805	58	8,490	94	13,090	59	19,502	95
25	46,045	875	63	9,008	100	15,031	67	20,517	100
50	50,812	1,057	76	8,284	92	18,313	82	19,080	93
75	59,722	1,235	89	7,877	87	21,319	95	19,357	94
100	61,323	1,387	100	4,356	48	22,345	100	19,436	95

2.2.2 REACH 2

Reach 2 extends from the inflow to the Plant 6 forebay, upstream to the Intake 5 spillway and is similar to Reach 1; generally 15 to 30-feet-wide; substrate is dominated by small boulder and patches of cobble, with a narrow band of riparian vegetation comprised of bushes and some small tree canopy (Photo 2.2). However, this reach is incrementally steeper and thus riffle mesohabitat dominates this reach. The overall study site is the same used in the previous IFIM study (EA Science and Engineering 1986), however the present study transects did not exactly duplicate the prior study.

Trends in Reach 2 are similar to Reach 1. Wetted area increases at a relatively steady rate between 4 and 25 cfs, after which the rate of increase is much more gradual at higher flows (Figure 2.2 and Table 2-1). Twenty-five cfs reflects the point in which the channel is essentially fully wetted, with gradual increases occurring at higher flows as the stream margin gradually becomes wetted.

PHOTO 2.2 REACH 2 STUDY SITE

Juvenile and adult brown trout habitat suitability is low across the flow range relative to the amount of wetted area and habitat suitability for Owens sucker (Figure 2.2). The existing minimum flow of 18 cfs provides 92 percent of optimal habitat suitability for juvenile brown trout; habitat suitability remains essentially flat at flow greater than 25 cfs (Table 2-2). Adult suitability remains low overall, due to a lack of suitable depths at any flow but rises gradually throughout the flow range.

Reach 2 generally provides greater habitat suitability for Owens sucker relative to brown trout (Figure 2.2 and Table 2-2). There is an inflection point for juvenile Owens sucker suitability at 10 cfs, where 83 percent of optimal habitat suitability occurs; the existing minimum flow of 18 cfs provides 94 percent of optimal habitat suitability for juvenile sucker; habitat suitability remains essentially flat or declines gradually at flows greater than 25 cfs. Most habitat suitability increases for adult Owens sucker occur between 6 and 25 cfs; habitat suitability gains at higher flows are relatively gradual.

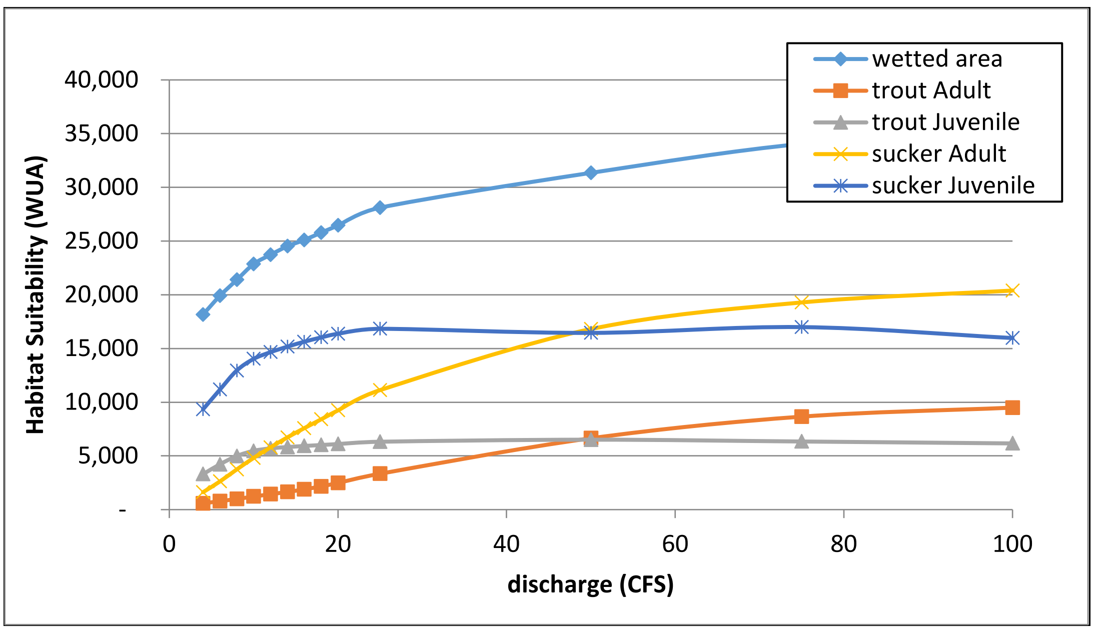


FIGURE 2.2 REACH 2 HABITAT SUITABILITY BETWEEN 4 AND 100 CFS

TABLE 2-2 SUMMARY OF WETTED AREA AND WUA IN REACH 2 BETWEEN 4 AND 100 CFS.

DISCHARGE	WETTED AREA	TROUT ADULT	PERCENT OPTIMAL	TROUT JUVENILE	PERCENT OPTIMAL	SUCKER ADULT	PERCENT OPTIMAL	SUCKER JUVENILE	PERCENT OPTIMAL
4	18,163	581	6	3299	51	1620	8	9335	55
6	19,902	785	8	4218	65	2619	13	11168	66
8	21,386	988	10	4992	77	3739	18	12948	76
10	22,859	1216	13	5470	84	4810	24	14030	83
12	23,724	1434	15	5702	88	5792	28	14656	86
14	24,516	1645	17	5822	89	6722	33	15169	89
16	25,100	1885	20	5924	91	7578	37	15628	92
18	25,783	2163	23	6012	92	8401	41	16026	94
20	26,449	2479	26	6103	94	9233	45	16370	96
25	28,109	3340	35	6319	97	11126	55	16831	99
50	31,349	6643	70	6509	100	16809	82	16451	97
75	34,051	8655	91	6340	97	19285	95	16990	100
100	35,214	9493	100	6162	95	20395	100	15973	94

2.2.3 REACH 3

Reach 3 is a higher gradient riffle complex extending from the Plant 5 forebay upstream to the confluence with Coyote Creek and is generally 10 to 20-feet-wide with steep embankments; substrate is dominated by boulder, with a wider band of riparian vegetation comprised of bushes and some taller tree canopy than found in Reaches 1 and 2 (Photo 2.3).

PHOTO 2.3 REACH 3 STUDY SITE

Wetted area increases at a relatively steady rate between 4 and 25 cfs, after which the rate of increase is much more gradual at higher flows (Figure 5 and Table 2-3). Increasing discharge tends to accelerate velocities at a greater rate than depth; 25 cfs reflects the point in which the channel is essentially fully wetted, with small increases occurring at higher flows as the stream margin becomes wetted at a gradual rate.

This reach is affected by releases from Intake 4 and inflow from Coyote Creek, which was measured as 3 cfs during the study; the results reflect net flow through the site rather than solely releases from Intake 4. Juvenile and adult brown trout habitat suitability remains relatively low across the flow range relative to the amount of wetted area (Figure 2.3). Juvenile habitat suitability is essentially optimal between 4 and 10 cfs and gradually declines at higher flows that create increased areas of suboptimal (high) velocities. The existing minimum flow of 5 cfs (released at Intake 4) combined with the 3 cfs from Coyote Creek provides near optimal habitat suitability for juvenile brown trout (Table 2-3) (optimal would be 2 cfs or less). This same flow provides 66 percent of optimal habitat suitability for adults, although adult suitability remains low overall, due to a lack of suitable depths at any flow. Flows between 10 and 50 cfs provide suitability of 75 percent optimal suitability or greater for adults.

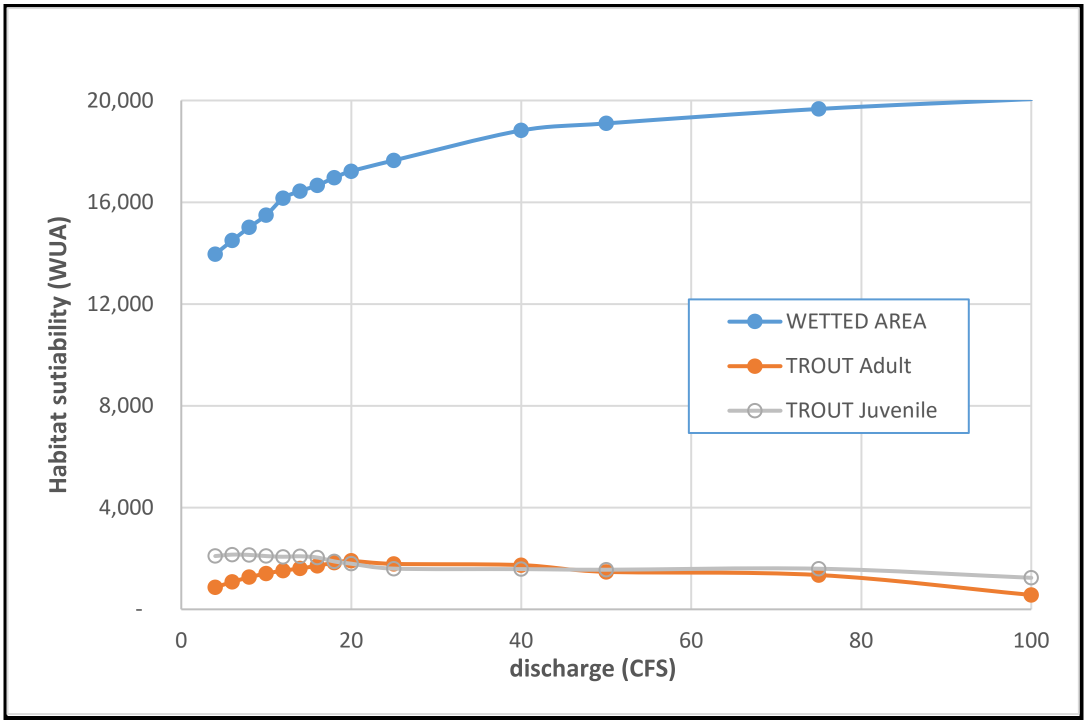


FIGURE 2.3 REACH 3 HABITAT SUITABILITY

TABLE 2-3 SUMMARY OF WETTED AREA AND WUA IN REACH 3 BETWEEN 4 AND 100 CFS

DISCHARGE (CFS)	WETTED AREA	TROUT ADULT	PERCENT OPTIMAL	TROUT JUVENILE	PERCENT OPTIMAL
4	13,962	864	45	2,094	97
6	14,498	1,078	57	2,151	100
8	15,015	1,263	66	2,139	99
10	15,500	1,411	74	2,093	97
12	16,157	1,522	80	2,067	96
14	16,443	1,608	84	2,085	97
16	16,660	1,714	90	2,037	95
18	16,968	1,829	96	1,883	88
20	17,222	1,904	100	1,794	83
25	17,643	1,786	94	1,600	74
40	18,821	1,739	91	1,581	73
50	19,099	1,474	77	1,557	72
75	19,667	1,348	71	1,596	74
100	20,054	566	30	1,240	58

2.2.4 REACH 5

Reach 5 is a moderate gradient riffle/run complex extending from the Plant 4 forebay upstream to Plant 3 Intake and is generally 30-feet- wide with shallow embankments and dense riparian and forest vegetation; substrate is dominated by cobble and small boulder (Photo 2.4).

PHOTO 2.4 REACH 5 STUDY SITE

Wetted area increases at a relatively rapid rate between 4 and 12 cfs, indicating inundation of the channel after which the rate of increase is much more gradual at higher flows (Figure 2.4 and Table 2-4). Increasing discharge tends to accelerate velocities at a similar rate to depth.

Juvenile brown trout habitat suitability increases between 4 and approximately 20 cfs and remains relatively constant at higher flows with increases in suitable depth being offset by increases in suboptimal high velocity. The existing minimum flow of 13 cfs provides approximately 80 percent of optimal suitability for juvenile brown trout (Table 2-4). Adult suitability remains low due to a lack of suitable depths but rises gradually between 4 and 100 cfs.

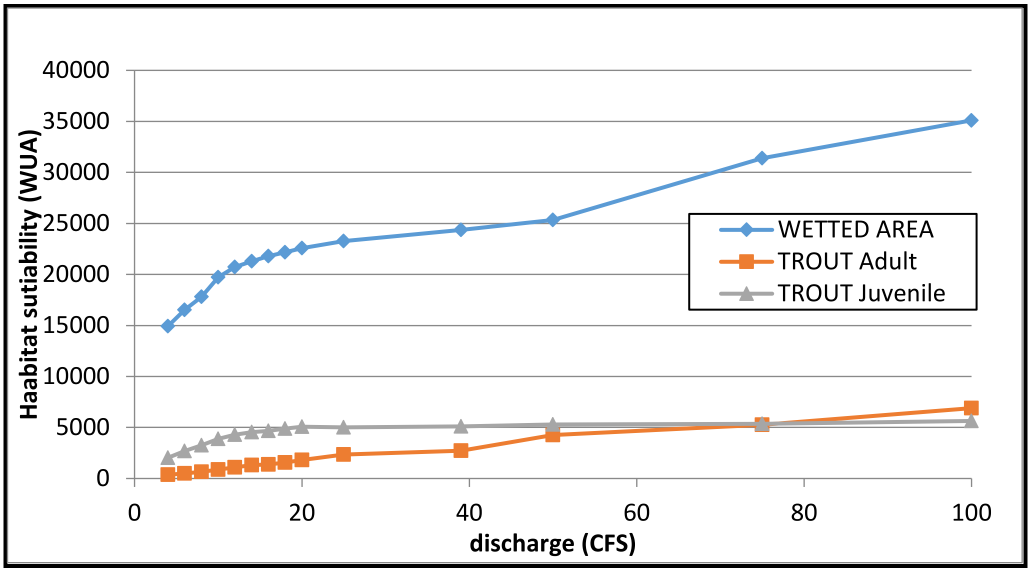


FIGURE 2.4 HABITAT SUITABILITY REACH 5

TABLE 2-4 SUMMARY OF WETTED AREA AND WUA IN REACH 5 BETWEEN 4 AND 100 CFS

DISCHARGE (CFS)	WETTED AREA	TROUT ADULT	PERCENT OPTIMAL	TROUT JUVENILE	PERCENT OPTIMAL
4	14934	366	5	2,032	36
6	16526	511	7	2,692	48
8	17804	667	10	3,269	58
10	19730	880	13	3,868	69
12	20722	1,101	16	4,298	76
14	21302	1,319	19	4,529	80
16	21777	1,369	20	4,653	83
18	22183	1,572	23	4,877	86
20	22574	1,807	26	5,072	90
25	23269	2,335	34	4,997	89
39	24374	2,732	40	5,104	91
50	25340	4,273	62	5,282	94
75	31397	5,252	76	5,342	95
100	35101	6,895	100	5,639	100

2.2.5 REACH 7

Reach 7 is a high gradient riffle complex on the Middle Fork Bishop Creek extending from the confluence with the South Fork upstream to Intake 2 and is generally 30 to 40-feet-wide with generally steep banks and dense riparian and old growth tree vegetation; substrate is dominated by boulder (Photo **2.5**).

PHOTO 2.5 REACH 7 STUDY SITE

Wetted area increases at a relatively rapid rate between 4 and 14 cfs, indicating inundation of the channel, after which the rate of increase is much more gradual at higher flows (Figure 2.5 and Table 2-5). Increasing discharge tends to accelerate velocities at a similar rate to depth.

Juvenile brown trout habitat suitability increases between 4 and approximately 20 cfs and remains relatively constant at higher flows with increases in suitable depth being offset by increases in sub optimally high velocity. Flows between 25 and 100 cfs only increase suitability by 5 percent. The existing minimum flow of 13 cfs provides approximately 80 percent of optimal suitability for juvenile brown trout (Table 2-5). Adult suitability remains limited due to a lack of suitable depths at any flow but rises gradually between 4 and 75 cfs.

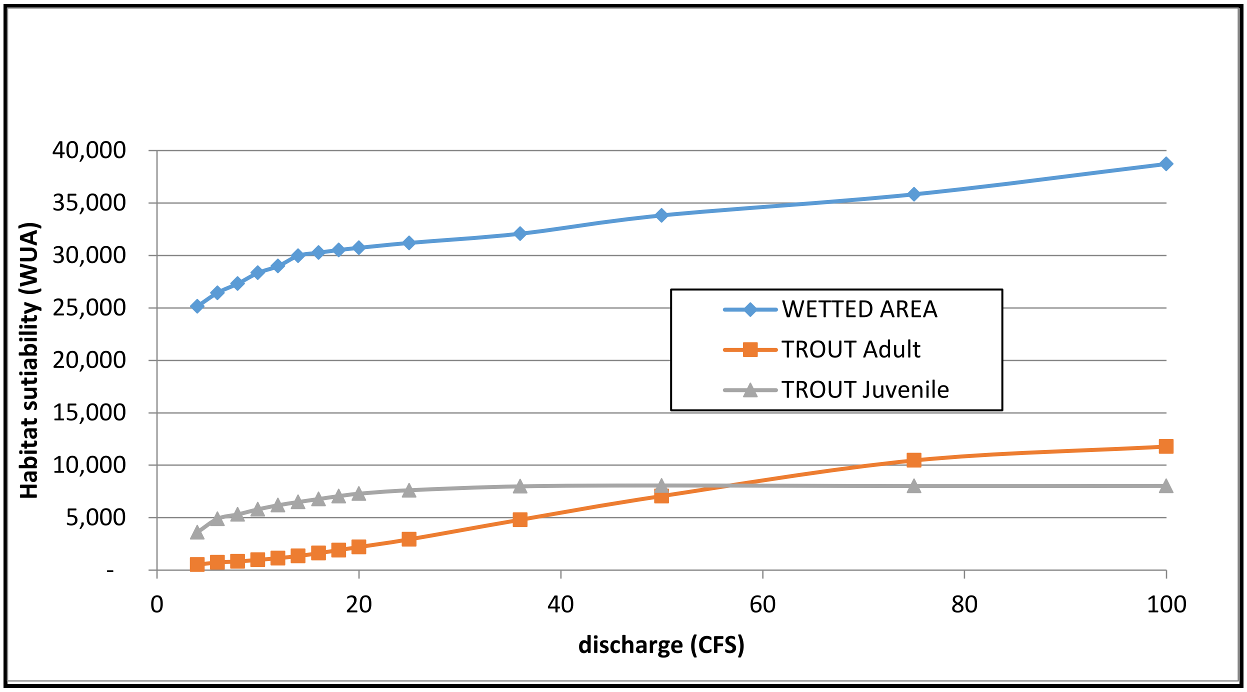


FIGURE 2.5 REACH 7 HABITAT SUITABILITY

TABLE 2-5 SUMMARY OF WETTED AREA AND WUA IN REACH 7 BETWEEN 4 AND 100 CFS

DISCHARGE CFS	WETTED AREA	TROUT ADULT	PERCENT OPTIMAL	TROUT JUVENILE	PERCENT OPTIMAL
4	25,150	513	4	3,611	45
6	26,439	738	6	4,895	61
8	27,309	829	7	5,313	66
10	28,334	980	8	5,794	72
12	28,978	1,144	10	6,186	77
14	29,970	1,349	11	6,494	80
16	30,259	1,616	14	6,776	84
18	30,512	1,913	16	7,054	87
20	30,725	2,203	19	7,286	90
25	31,192	2,938	25	7,617	94
36	32,074	4,803	41	7,989	99
50	33,813	7,061	60	8,068	100
75	35,826	10,457	89	8,017	99
100	38,720	11,782	100	8,029	100

2.2.6 REACH 8

The Reach 8 study site includes both a medium gradient riffle and a low gradient braided channel run complex on the Middle Fork Bishop Creek between the Intake 2 reservoir upstream to

Sabrina Lake. This stream reach has generally low, forested banks in the riffle area, and an open alluvial flood plain with riparian vegetation in the braided channel section; substrate is dominated by cobble and boulder in the riffle, and gravel and small cobble in the braided section (Photo 2.6 and Photo 2.7).

PHOTO 2.6 REACH 8 RIFFLE PHABSIM STUDY SITE

PHOTO 2.7 REACH 8 BRADED CHANNEL HCM STUDY SITE

Riffle Habitat *(modeled with PHABSIM)*

Wetted area increases at a relatively rapid rate between 4 and 20 cfs, indicating inundation of the channel, after which the rate of increase is much more gradual at higher flows (Figure 2.6 and Table 2-6). Increasing discharge above 20 cfs tends to accelerate velocities at a greater rate than depth.

Juvenile brown trout habitat suitability increases between 4 and approximately 10 cfs and remains relatively constant at higher flows with increases in suitable depth being offset by increases in sub optimally high velocity. A flow of 10 cfs provides 93 percent of optimal suitability, the existing minimum flow of 13 cfs provides approximately 95 percent of optimal habitat suitability for juvenile brown trout (Table 2-6). Flows between 20 and 50 cfs only increase suitability by 3 percent. Juvenile brown trout suitability declines at flows greater than 50 cfs. Adult suitability remains limited due to a lack of suitable depths at most flows but rises gradually throughout the flow range.

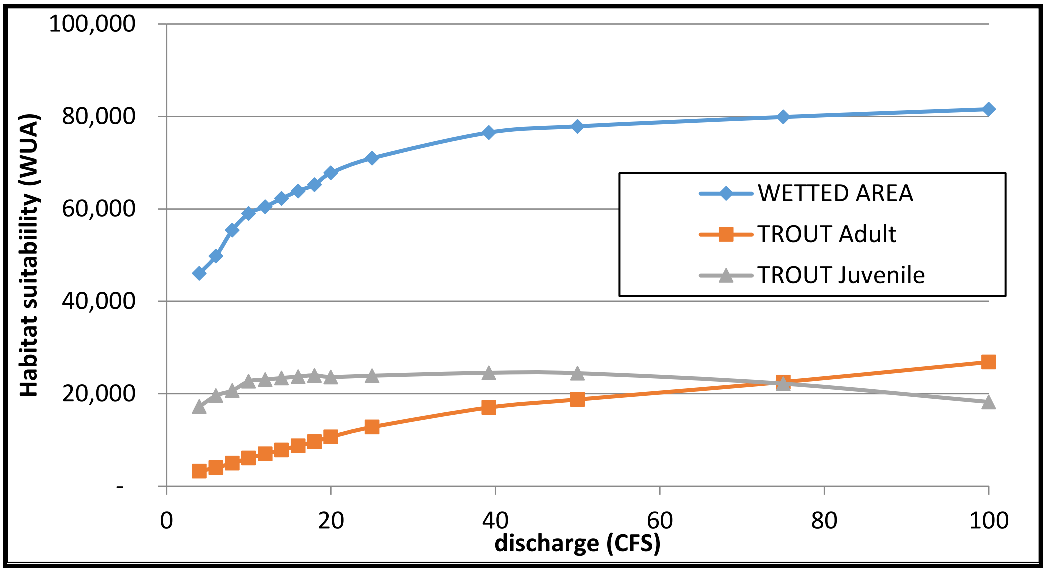


FIGURE 2.6 HABITAT SUITABILITY IN REACH 8 RIFFLE

TABLE 2-6 SUMMARY OF WETTED AREA AND WUA IN REACH 8 BETWEEN 4 AND 100 CFS

DISCHARGE (CFS)	WETTED AREA	TROUT ADULT	PERCENTAGE OPTIMAL	TROUT JUVENILE	PERCENTAGE OPTIMAL
4	46,042	3,268	12	17,249	70
6	49,786	4,029	15	19,607	80
8	55,427	4,972	19	20,712	84
10	59,001	6,085	23	22,715	93
12	60,478	6,987	26	23,070	94
14	62,248	7,869	29	23,413	95
16	63,871	8,749	33	23,724	97
18	65,245	9,639	36	24,005	98
20	67,795	10,687	40	23,629	96
25	70,975	12,808	48	23,914	97
50	77,866	18,768	70	24,451	100
75	79,879	22,550	84	22,195	90
100	81,561	26,864	100	18,235	74

***Braided Channel Ru**n (assessed with HCM method).*

Habitat suitability of the three calibration flows (8, 18 and 39 cfs) were empirically measured (Figure 2.7 and Table 2-7)[2]. HCM habitat suitability heatmaps showing the spatial distribution of suitability quartiles are provided in Figure 2.7 and Table 2-7. Overall, the relative trend in gross suitability was consistent between this site and the PHABSIM site in that there is greater stability for juveniles than for adults at flows across a comparable flow range (8 to 39 cfs). A flow of 18 cfs provides 92 percent of maximum juvenile habitat suitability; interpolation suggests that the existing minimum flow provides approximately 85 percent of maximum suitability; this flow would provide approximately 50 percent of adult suitability.

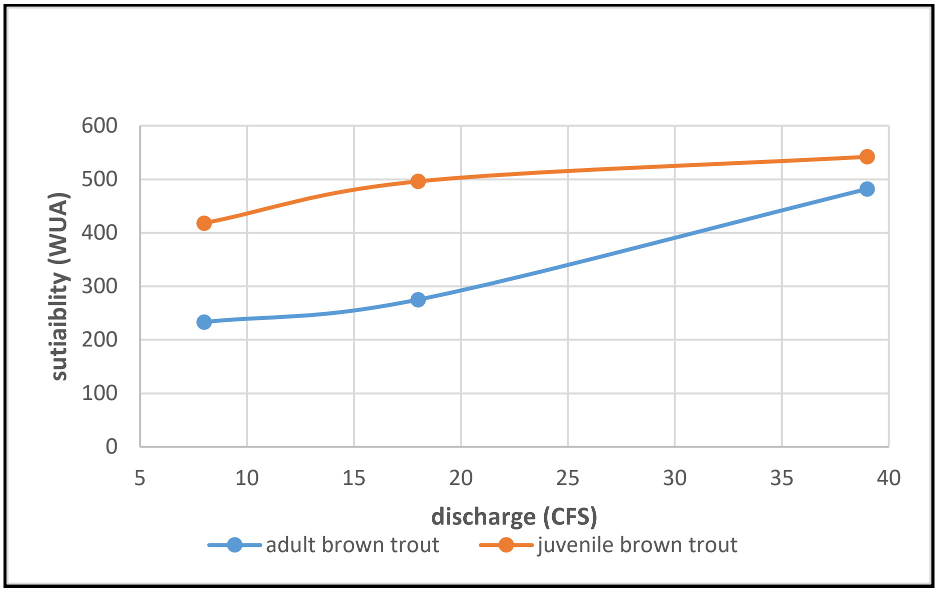


FIGURE 2.7 REACH 8 HABITAT SUITABILITY IN BRAIDED CHANNEL

TABLE 2-7 SUMMARY OF WETTED AREA AND WUA IN THE REACH 8 BRAIDED CHANNEL SITE AT 8, 18 AND 39 CFS

DISCHARGE (CFS)	ADULT BROWN TROUT	PERCENT OF MAXIMUM	JUVENILE BROWN TROUT	PERCENT OF MAXIMUM
8	233	48	418	77
18	275	57	496	92
39	482	100	542	100

[2] Data are reported in units of WUA per 50 foot stream length

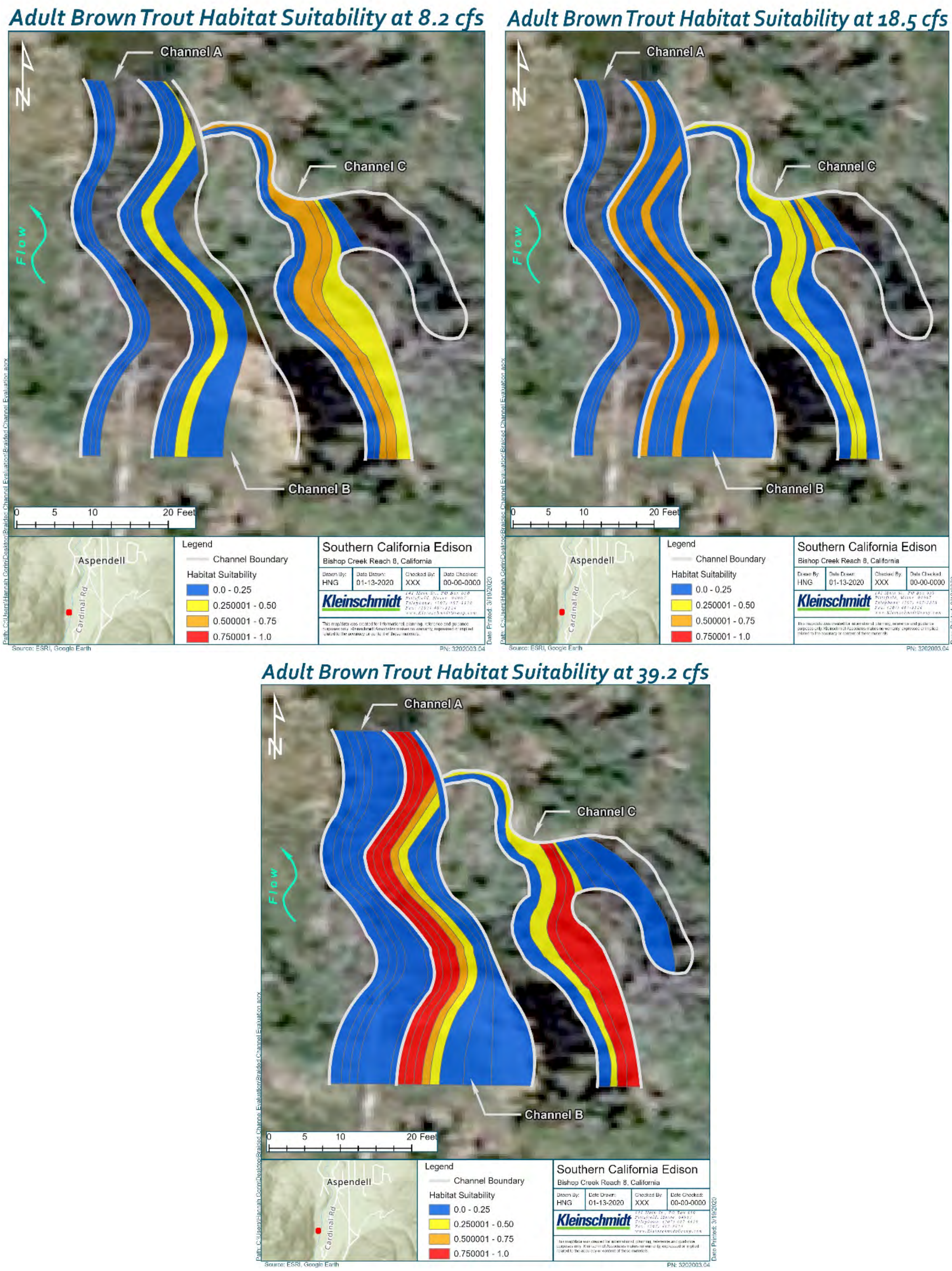


FIGURE 2.8 PLAN VIEW OF ADULT BROWN TROUT HABITAT SUITABLITY IN BRAIDED CHANNEL AREA OF REACH 8 AT 8, 18 AND 39 CFS

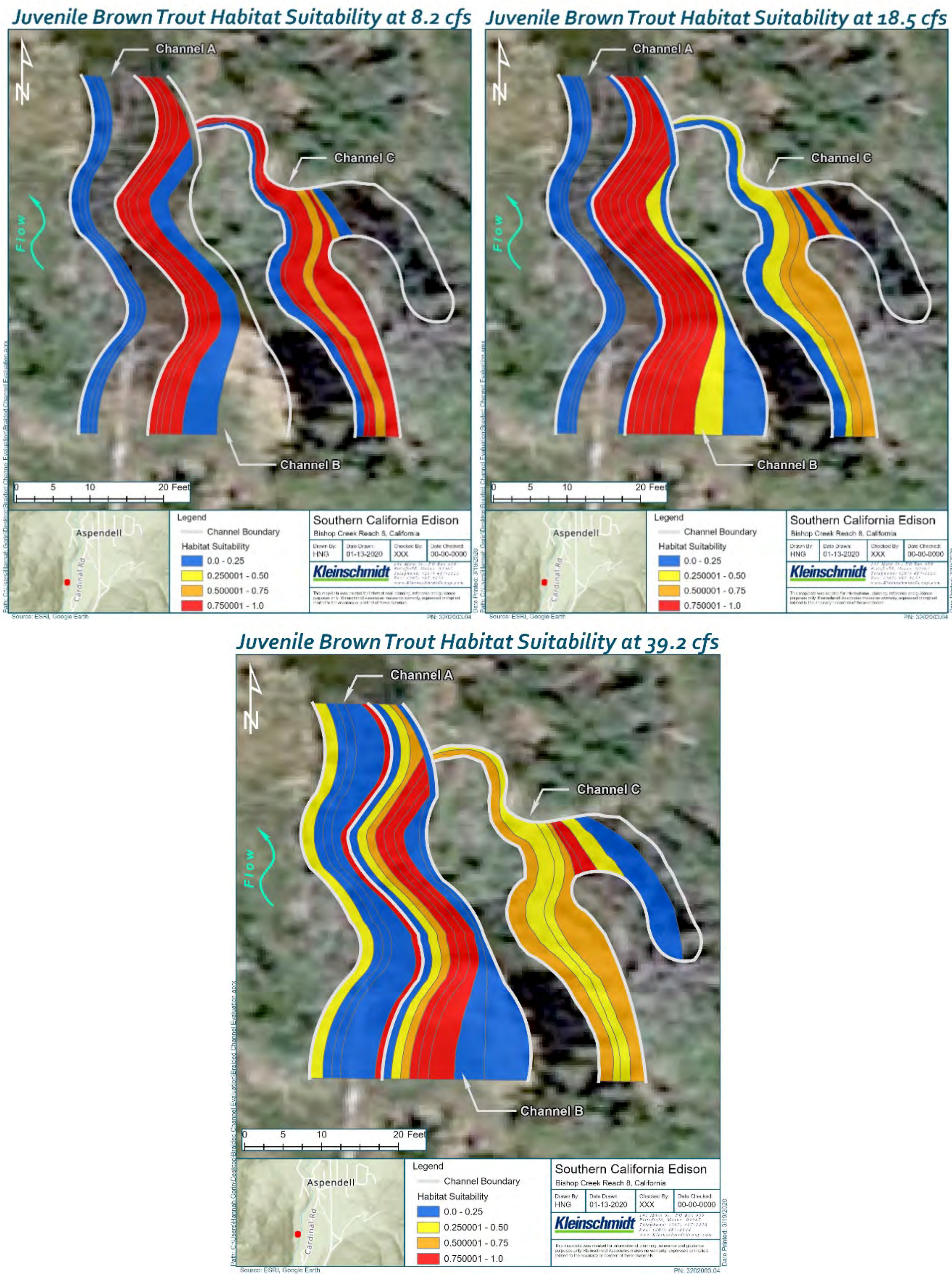


FIGURE 2.9 PLAN VIEW OF JUVENILE BROWN TROUT HABITAT SUITABLITY IN BRAIDED CHANNEL AREA OF REACH 8 AT 8, 18 AND 39

2.2.7 REACH 9

Reach 9 is on the South Fork of Bishop Creek extending from the confluence with the Middle Fork upstream to the Intake 2 diversion. Critical habitat in the reach captured by the study site is moderate gradient riffle typically approximately 25-feet-wide with substrate dominated by cobble and small boulder (Photo **2.8**).

PHOTO 2.8 **REACH 9 RIFFLE PHABSIM STUDY SITE**

Wetted area increases at a relatively rapid rate between 4 and 12 cfs, indicating inundation of the channel, then remained unchanged up to 25 cfs. Between 25 to 50 cfs, wetted area again increases after which the rate of increase is much more gradual at higher flows (Figure 2.10 and Table 2-8). Increasing discharge above 12 cfs tends to accelerate velocities at a greater rate than depth.

Juvenile brown trout habitat suitability is essentially optimal between 4 and 8 cfs and decreases rapidly between 10 and 18 cfs (Figure 2.10 and Table 2-8). Adult suitability remains limited primarily due to limited suitable depths at most flows but has the greatest increase between 4 cfs up to 18 cfs.

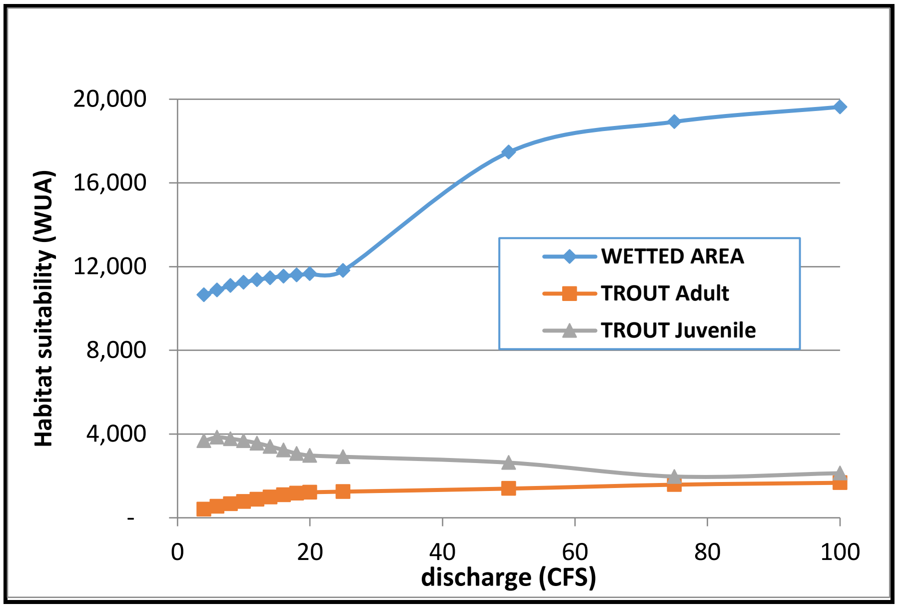


FIGURE 2.10 REACH 9 HABITAT SUITABILITY

TABLE 2-8 SUMMARY OF WETTED AREA AND WUA IN REACH 9 BETWEEN 4 AND 100 CFS

DISCHARGE (CFS)	WETTED AREA	TROUT ADULT	PERCENT OPTIMAL	TROUT JUVENILE	PERCENT OPTIMAL
4	10,649	408	24	3,675	96
6	10,887	548	33	3,845	100
8	11,089	659	39	3,777	98
10	11,253	769	46	3,686	96
12	11,369	882	53	3,564	93
14	11,468	990	59	3,409	89
16	11,542	1,088	65	3,237	84
18	11,601	1,173	70	3,067	80
20	11,655	1,217	73	2,975	77
25	11,810	1,248	75	2,914	76
50	17,468	1,393	83	2,634	69
75	18,922	1,581	95	1,972	51
100	19,632	1,671	10	2,131	55

2.2.8 REACH 10

Reach 10 is on the South Fork of Bishop Creek extending from the Intake 2 diversion upstream to the South Fork spillway flume. Critical habitat in the reach captured by the study site is the low gradient run with substrate dominated by gravel and cobble and scattered boulder

(Photo 2.9). Transects were arranged to capture both the riffle transition into the upstream end of this run, and within the run itself.

PHOTO 2.9 REACH 10 PHABSIM STUDY SITE *(RUN ON LEFT, RIFFLE TRANSITION ON RIGHT)*

Wetted area increases at a relatively rapid rate between 4 and 8 cfs, indicating inundation of the channel, then increases more gradually at higher flows (Figure 2.11 and Table 2-9) where increasing discharge tends to accelerate velocities at a greater rate than depth.

Juvenile brown trout habitat suitability is optimal at 6 to 8 cfs and decreases between at higher flows; as flows increase, velocity becomes progressively less suitable for this lifestage. The existing base flow in this reach of 13 cfs provides approximately 88 percent of optimal habitat (Figure 2.11 and Table 2-9). Adult suitability increases linearly between 4 and 37 cfs and declines at higher flows.

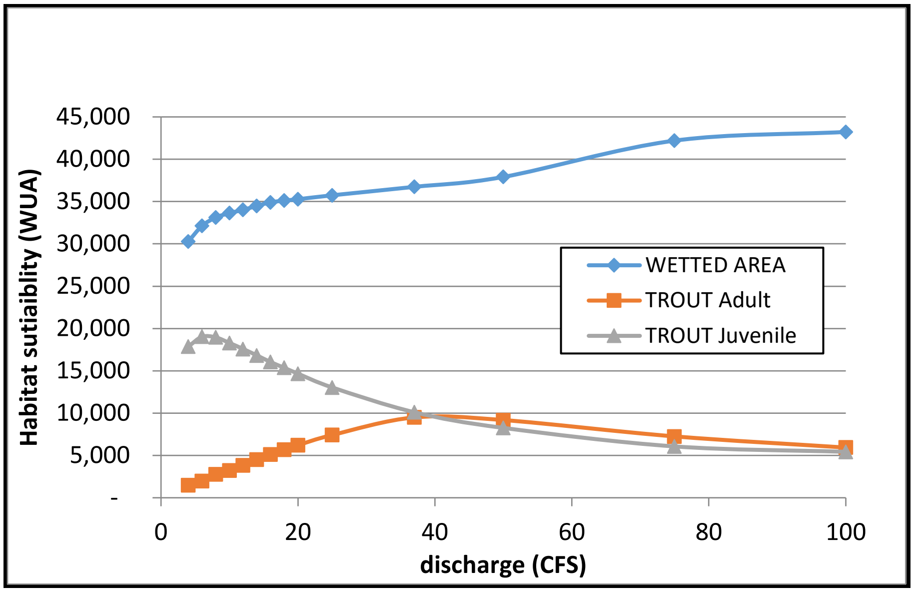


FIGURE 2.11 HABITAT SUITABILITY REACH 10

TABLE 2-9 SUMMARY OF WETTED AREA AND WUA IN REACH 10 BETWEEN 4 AND 100 CFS

DISCHARGE (CFS)	WETTED AREA	TROUT ADULT	PERCENTAGE OPTIMAL	TROUT JUVENILE	PERCENTAGE OPTIMAL
4	30,293	1,492	16	17,877	94
6	32,128	1,972	21	19,025	100
8	33,115	2,768	29	18,947	100
10	33,633	3,226	34	18,289	96
12	34,022	3,841	40	17,577	92
14	34,490	4,510	48	16,822	88
16	34,907	5,125	54	16,036	84
18	35,113	5,691	60	15,355	81
20	35,273	6,210	65	14,663	77
25	35,740	7,415	78	13,036	69
37	36,736	9,495	100	10,106	53
50	37,908	9,183	97	8,255	43
75	42,198	7,251	76	6,067	32
100	43,224	5,931	62	5,430	29

3.0 DISCUSSION

The purpose of this discussion is to highlight considerations that should contribute to determining flow requirements in the project bypass reaches.

During study consultation, the Aquatics TWG drew an *a priori* conclusion that the brown trout population in this watershed was not spawning-limited (*N. Buckmaster, personal communication*). The implication of this is that the incubation, fry, and young-of-year (YOY) lifestages were not analyzed in this model, and that an older lifestage was deemed to be the limiting factor for brown trout populations in Bishop Creek.

Data from a 2019 fish survey effort that was conducted at four locations throughout the Bishop Creek watershed, including IFIM reaches 2, 4 8 and 10 (Stillwater Sciences in press) generally support this conclusion, as it documents good spawning recruitment from young-of-year (YOY) up through early adult lifestages, along with a few larger, older adults. For example, most fish ranged from YOY up to age 3+ with a few older fish observed (*Data from Stillwater Sciences (in press*, Figure 2.11)[3]. According to Stillwater Sciences,

> *"...brown trout less than 100 mm FL are expected to fall within the YOY age-class based on the length frequency distribution and scale age data reported in Walsh and Williams (1991). Brown trout within the age 1+ and age 2+ age-classes were also common but in lower numbers. A few brown trout longer than 220 mm FL were captured and likely fall within the age 2+ through age 4+ range*".

[3] More details about this and other study sites, and discussion can be found in Stillwater Sciences (*in press*).

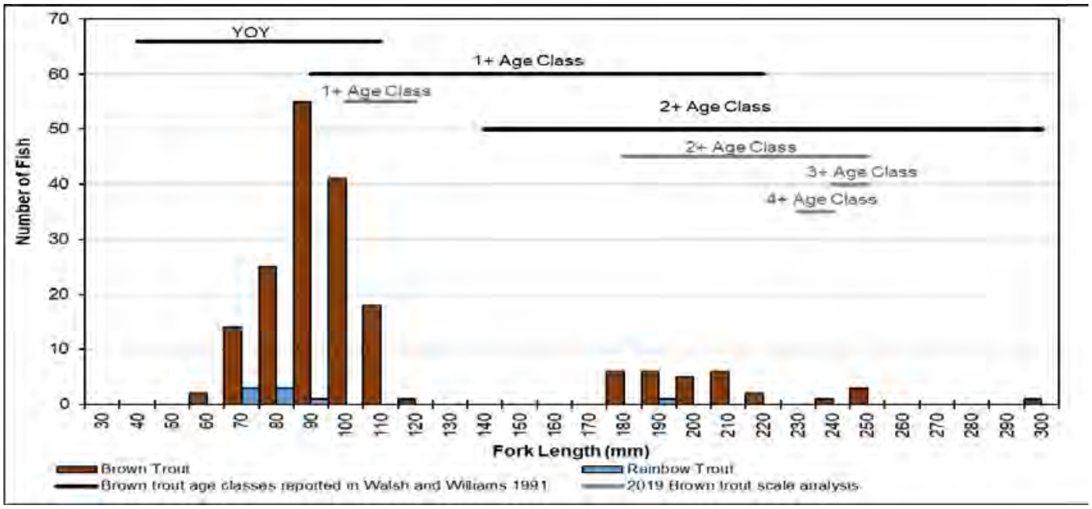


FIGURE 3.1 LENGTH AND AGE DATA FOR BROWN TROUT COLLECTED IN IFIM REACH 2
Note: Data from Stillwater Sciences (*in press*)

For purposes of this analysis, these data support the assumption that natural recruitment to the Creek's brown trout population is not limiting. It also demonstrates that the size of adult brown trout is relatively small. This is not unusual in a small, high gradient stream such as Bishop Creek. Brown trout growth tends to be more favorable in lower gradient runs and riffles with adjacent deep pools (Raleigh 1986, Scott and Crossman, 1973). Consistent with that, the Stillwater Sciences survey found larger adult fish in samples collected in intake pools as well as low gradient runs such as those found in Reach 10.

Limiting factors

Substrates in Bishop Creek are predominantly composed of cobble, gravel, and boulder which are considered optimal for both lifestages of brown trout; therefore, substrates are *not* a limiting factor. However, most of the Bishop Creek study reaches (except for areas represented by Reach 10, and the braided channel area of Reach 8), feature high gradient channels, many of which are 3 percent or greater. In such circumstances, velocity appears to be the factor limiting juvenile brown trout WUA at higher flows. Velocities greater than 1-foot per second are generally suboptimal or marginal (*i.e*. HSC rated as less than 0.8) for juveniles whereas optimal adult velocity extends out to 1.5-feet per second. For adults, optimal depths were limited at most flow. Depths less than 2 feet are suboptimal, whereas juveniles are more tolerant of shallower water - optimal depth for juveniles range down to less than 1 foot. This results in a relatively low amount of WUA available for the adult lifestage at most flows relative to the juvenile lifestage. Because of the differing range of depth and velocity tolerances, the rising and falling limbs of the WUA/flow curves for these lifestages frequently conflict with each other. A similar pattern is evident for juvenile and adult Owens sucker. A flow that is suitable for one lifestage likely will not be ideal for the other.

In such circumstances, a habitat-based flow recommendation will have to determine a way to either prioritize or balance habitat needs among conflicting lifestages, in such a way that the result is reasonable and supports both resource management and Project operation objectives. One technique would be to prioritize a lifestage consistent with management goals. In the case of Bishop Creek, the goal is to support a self-sustaining wild brown trout population, and in Reaches 1 and 2, also provide habitat suitability capable of supporting wild populations of Owens sucker and Owens speckled dace[4]. Maintaining wild populations means that recruitment from younger lifestages should be optimized. As noted above, available information indicates that spawning and fry recruitment is adequate. Therefore, the juvenile lifestage (and perhaps young adult) is the lifestage from where larger adults are recruited. Selection of a flow that favors this lifestage should support continued recruitment to the adult population.

The length frequency of adult fish in Bishop Creek pose an additional consideration. Few adult fish in the creek system are larger than 250 millimeters (mm) (approximately 10 inches). In lower-gradient river systems with more typical brown trout mesohabitat, adult trout tend be larger (i.e. 300 mm or more). Larger fish such as those would in fact be expected to utilize the depths and velocities reflected in the HSC for that lifestage. However, the smaller sizes of Bishop Creek adult trout are more in line with juveniles in many systems, and therefore their ichthyomechanics in terms of navigating velocities is likely more in line with the juvenile lifestage criteria. Taken together, these two considerations suggest that giving greater weight to the juvenile lifestages of brown trout and Owens sucker may be appropriate to develop flow recommendations in the study reaches.

[4] Owens speckled dace HSC are being prepared by the CDFW for use in this model, but are not yet available

3.1 ADDITIONAL STUDY AND ANALYSIS

The following additional tasks are required to complete the Bishop Creek Flow Needs Study.

1. **Habitat suitability for Owens speckled dace in reaches 1 and 2.** HSC for this species are being prepared by the CDFW for TWG review. Following review and discussion these criteria will be finalized and incorporated into the model for the applicable reaches. SCE will conduct the additional modeling runs and develop a memorandum summarizing results.
2. **HCM analysis of reaches 4 and 6.** It was not possible to conduct the field work for these two reaches during 2019. Assuming that logistics are favorable, it is anticipated that these data will be gathered during 2020. SCE will then conduct the field work, analysis and develop a supplemental memorandum summarizing results.
3. **HCM analysis of Birch and McGee Creeks.** SCE anticipates consulting further with the TWG to develop a focused field scope to address this issue during 2020. Assuming that logistics are favorable, it is anticipated that these data will be gathered during 2020. SCE will conduct the field work, analysis, and develop a supplemental memorandum summarizing results.

4.0 REFERENCES

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APPENDIX A

CONSULTATION RECORD

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APPENDIX B

STUDY TRANSECTS

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APPENDIX C

STUDY SITE PHOTOS

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APPENDIX A

CONSULTATION RECORD

BISHOP CREEK PROJECT
AQUATIC MESOHABITAT SURVEY

TO:	Bishop Relicensing TWG
FROM:	Brandon Kulik, Kleinschmidt
CC	Matt Woodhull, Southern California Edison Finlay Anderson, Kleinschmidt
SUBJECT:	Aquatic Mesohabitat Survey - Summary of Field Efforts and Data Analysis
DATE:	September 21, 2019

Southern California Edison (SCE) is currently undergoing relicensing for the Bishop Creek Hydroelectric Project (FERC Project No. 1394) (Project), utilizing the Integrated Licensing Process (ILP) pursuant to 18 CFR § 5.6, with additional consultation conducted early in the process to allow certain field studies to be implemented without delay. During consultation the Fisheries Technical Working Group (TWG) identified the need for an Instream Flow Incremental Methodology (IFIM) study to assess and potentially refine the existing minimum flow requirements below the Project's spillways. Existing minimum flows are based on the results of an IFIM study conducted during the prior relicensing (EA, 1986). The IFIM study would be supported by a Physical Habitat Simulation (PHABSIM) model, and as such, SCE subsequently developed a study plan in consultation with the TWG to address the issue which calls for a mesohabitat survey the Bishop Creek study area as a precursor for selecting study sites for further PHABSIM modeling. This memo summarizes the aquatic mesohabitat survey (Survey) field methodology employed in September 2019, as well as preliminary recommendations for the IFIM site selection.

The purpose of this survey was to map the distribution and abundance of aquatic mesohabitat in Bishop Creek, quantitatively characterize the types of fluvial aquatic habitats that occur within the Project study area, provide a basis for locating PHABSIM study sites, and to present preliminary recommendations consistent with the approved study plan. Following review of this information, SCE will seek confirmation from the TWG members to proceed with the next phase of study, which is to gather hydraulic data on transects within each study site.

The study area spans approximately 22 miles of creek (Figure 1) including:

1. Bishop Creek from Plant 6 upstream to the confluence of the Middle and South Forks.
2. Middle Fork Bishop Creek upstream to the Sabrina Lake spillway channel.
3. South Fork Bishop Creek upstream to the South lake spillway channel.

Bishop Creek. This portion of the study area was divided into a total of six hydrologic reaches on Bishop Creek, numbered beginning from downstream to upstream. Flows in Reaches 1 and 2 are influenced by releases from the Intake 6 and Intake 5 spillways, respectively. Reach 3 flow is influenced by releases from Intake 4 and Coyote Creek discharge; Reach 4 is solely influenced by releases from Intake 4. Reach 5 is influenced by releases from Intake 3; Reach 6 receives flow from Intake 2 (on the Middle Fork) and the South Fork of Bishop Creek.

Middle Fork Bishop Creek. Reach 7 is influenced by releases from Intake 2; Reach 8 is influenced by releases from Sabrina Lake.

South Fork Bishop Creek. Reach 9 is influenced by releases from the Intake 2 diversion; Reach 10 is influenced by releases from South Lake.

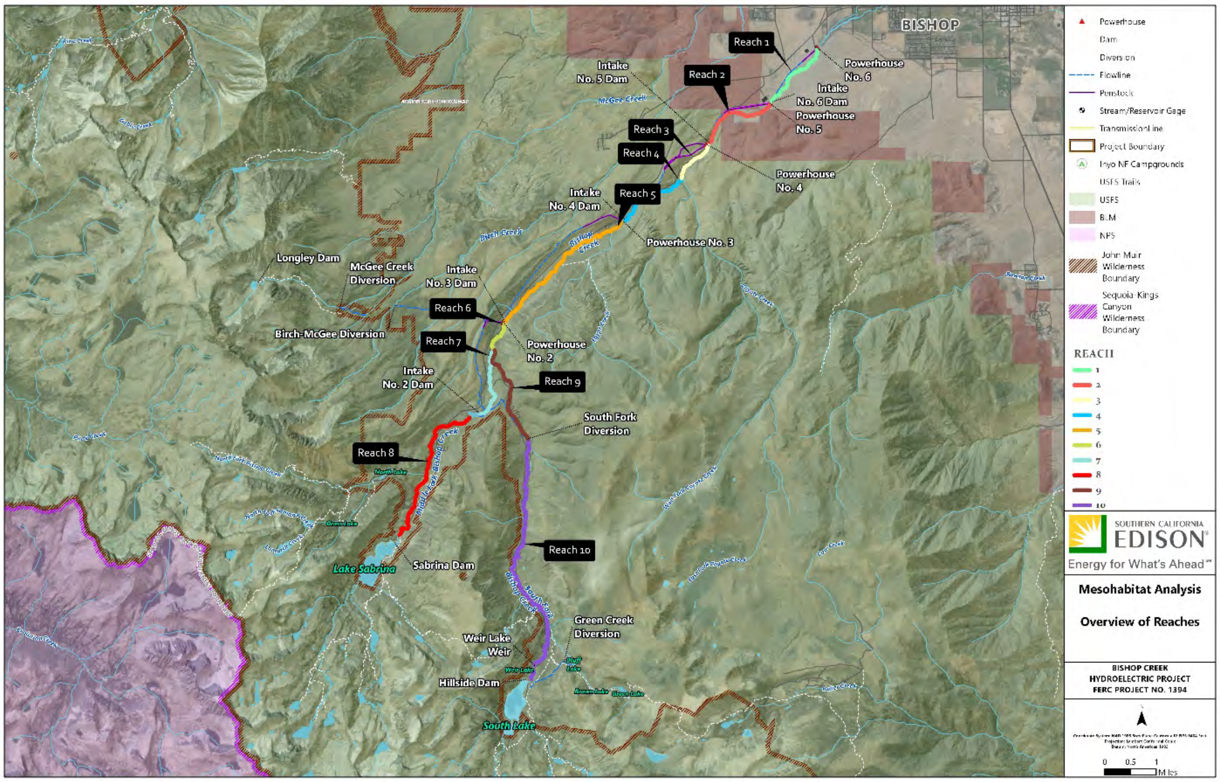

FIGURE 1 BISHOP CREEK IFIM STUDY AREA.

FIELD DATA COLLECTION

Data were collected via an aerial drone survey, on September 9-14, 2019, with flow in all creek reaches held to current base flows (approximately 15 cubic feet per second [cfs] with some reach-specific variation). This, as well as adequate lighting and water clarity, allowed stream channel features to be clearly visible. A Parrot Anafi drone was deployed, equipped with a high-resolution camera (*21 megapixels in wide angle mode; Lens: 84-degree field of view, 4K High density video*) and global positioning system (GPS) to provide spatial accuracy.

The three-person field team consisted of a Federal Aviation Administration (FAA)-certified (FAA 2019) drone pilot to operate the aircraft, a spotter to maintain line-of-sight drone contact and an aquatic biologist to record mesohabitat types, boundaries, cover quality and substrate. The drone was flown in a continuous upstream direction to the limit of visibility, after which the drone returned to the launch site and was transported to the next consecutive upstream launch location. Over 60 launch locations were required to cover the entire study area.

The drone was generally flown at a height above ground of 30 to 50 feet, unless navigation temporarily required otherwise. This altitude provided good overall channel coverage and excellent image clarity for purposes of defining substrate particle size and cover quality. The drone was operated from downstream to upstream at a slow rate of speed, with the camera oriented downward. The drone hovered immediately above each mesohabitat boundary so that a photo could be obtained with embedded metadata to geo-locate boundaries. The photo also captured relevant substrate and cover information, and recorded latitude/longitude and altitude metadata. Occasionally, one additional photo with the camera oriented upstream at an oblique angle was taken to characterize an entire mesohabitat segment.

The pilot and the biologist monitored the controller video screen view as the drone moved slowly upstream. The process was repeated each time a significant change in dominant substrate, cover type and quality, or the boundary with the next mesohabitat type was encountered. For each section the pilot and biologist noted the mesohabitat types, dominant substrates, cover types, and cover quality based on direct observation and professional judgement.

Mesohabitat substrate types were classified after Flosi (2010). Dominant substrates were classified as: bedrock, boulder (small, medium or large), cobble, etc. Cover quality was recorded using the scale recommended by Flosi (2010). Handwritten data were recorded to document each individual photo and summarize the relevant mesohabitat type, substrate, and cover as observed during the flight. Drone data were downloaded to a laptop computer for detailed review at the end of each day's survey; latitude and longitude of each photo were entered in ArcMap and reviewed to independently verify spatial accuracy.

DATA ANALYSIS

Metadata written to each image file, including but not limited to the drone's location (latitude, longitude, altitude) in World Geodetic System 1984 (WGS84), were used to georeference the photographic images. Coordinates were then used to georeference the center of each image within ArcGIS Pro (2019). Based on field notes, original photographs, and professional judgement, the field GIS technician and biologist transcribed (via polygon) the boundaries of the identified mesohabitat areas on these images for further assessment. The individual polygon lengths capturing the linear distance along the creek of each mesohabitat unit were then summed within each reach to calculate the relative abundance of each mesohabitat with each study reach.

PRELIMINARY RESULTS

The study area consisted of 116,496 linear feet (22 miles) of riverine aquatic stream habitat, comprised of riffle, run, pool, cascade, pocket pool, step pool and sand bar mesohabitats (Table 1). Both high gradient and low gradient riffles were present, and some reach segments contained repeating patterns of multiple short riffles and pools or run and pools such that these were classified as riffle/pool, run/pool, cascade/step pool, etc., **complexes**. Reach lengths ranged from 3,383 ft (Reach 6) to over 30,000 ft (Reach 10). Mesohabitat tended to be dominated by riffles and cascades, with runs and pools being relatively minor and scattered features. Detailed maps of the distribution of individual mesohabitat units can be found in Appendix A.

TABLE 1 RELATIVE ABUNDANCE OF MESOHABITATS IN REACHES 1 THROUGH 10 IN BISHOP CREEK, INYO COUNTY, CALIFORNIA.

REACH/MESOHABITAT	LENGTH (FT)	% OF TOTAL/REACH
1	**7,832.4**	**6.72%**
Riffle	3,343.8	42.69%
Riffle/Pool	3,118.6	39.82%
Run	772.9	9.87%
Pool	597.2	7.62%
2	**8,810.2**	**7.56%**
Riffle	7,720.7	87.63%
Cascade	1,021.1	11.59%
Run/Shallow Pool	68.4	0.78%
3	**4,592.2**	**3.94%**
Riffle	3,375.9	73.51%
Cascade	621.8	13.54%
Pool	594.5	12.95%
4	**8,042.3**	**6.90%**
Riffle	3,412.6	42.43%
Cascade	2,038.3	25.34%
Step Pool	1,857.6	23.10%
Riffle/Pool	464.2	5.77%
Pocket Pool	141.3	1.76%
Pool	128.3	1.60%
5	**17,300.4**	**14.85%**
Cascade	10,065.8	58.18%
Riffle	3,587.0	20.73%
Cascade/Riffle	3,053.4	17.65%
Plunge Pool	458.4	2.65%
Pocket Pool	135.8	0.79%
6	**3,383.2**	**2.90%**
Cascade	1,924.7	56.89%
High Gradient Riffle	982.7	29.05%
Riffle	475.8	14.06%
7	**7,978.6**	**6.85%**
High Gradient Riffle	4,257.0	53.35%
Cascade	2,380.2	29.83%
Riffle	1,195.8	14.99%
Riffle/Pool	145.6	1.82%

REACH/MESOHABITAT	LENGTH (FT)	% OF TOTAL/REACH
8	**17,144.6**	**14.72%**
Riffle	5,010.3	29.22%
Cascade	5,002.3	29.18%
High Gradient Riffle	3,544.3	20.67%
Run	2,111.4	12.32%
Run/Pool	805.4	4.70%
Pool	294.3	1.72%
Cascade/Step Pool	160.7	0.94%
Sand Bar	133.0	0.78%
Riffle/Pool	83.0	0.48%
9	**11,110.2**	**9.54%**
Cascade	4,523.8	40.72%
Low Gradient Riffle	2,819.2	25.38%
Riffle	1,935.2	17.42%
High Gradient Riffle	1,555.8	14.00%
Step Pool	276.2	2.49%
10	**30,301.8**	**26.01%**
High Gradient Riffle	11,038.8	36.43%
Low Gradient Riffle	8,950.3	29.54%
Cascade	7,136.8	23.55%
Run	3,046.6	10.05%
Riffle	129.3	0.43%
Grand Total	**116,496.0**	**100.00%**

Reach 1

Reach 1 extends from Plant 6 upstream to the Intake 6 forebay pool spillway and is 7,832 feet (1.5 miles). The reach is generally 15-25 feet wide; substrate is dominated by small and large boulder and patches of cobble substrate, with a narrow band of riparian vegetation comprised of bushes and some small tree canopy (Photo plates 1 and 2). Riffle and pockets of pool/riffle complex mesohabitat types dominate this reach, collectively accounting for approximately 83% of the reach (Table 1). Runs (10%) and larger pools (8%) accounted for the balance of mesohabitat.

PHOTO PLATE 1 REPRESENTATIVE RIFFLE/POOL AND POOL MESOHABITAT IN REACH 1, BISHOP CREEK.

PHOTO PLATE 2 EA (1986) REACH 1 IFIM STUDY SITE

Reach 2

Reach 2 extends from the inflow to the Plant 6 forebay, upstream to the Intake 5 spillway and is 8,810 feet (approximately 1.8 miles) long. The reach is similar to Reach 1; generally 15-20 feet wide; substrate is dominated by small boulder and patches of cobble, with a narrow band of riparian vegetation comprised of bushes and some small tree canopy (Photo plates 3 and 4), and includes several split channels. However, this reach is incrementally steeper and thus riffle mesohabitat dominates this reach (88%) and isolated cascades are evident (12%). Pool and run mesohabitat is very limited (less than 1%) (Table 1).

PHOTO PLATE 3 **REPRESENTATIVE RIFFLE AND CASCADE MESOHABITAT IN REACH 2, BISHOP CREEK.**

PHOTO PLATE 4 **EA (1986) REACH 2 IFIM STUDY SITE**

Reach 3

Reach 3 extends from the inflow to the Plant 5 forebay, upstream to the confluence with Coyote Creek and is approximately 4,592 feet (0.9 miles) long. The reach is generally 10-15 feet wide; substrate is dominated by boulder, with a wider band of riparian vegetation comprised of bushes and some taller tree canopy than found in Reaches 1 and 2 (Photos 5 and 6). This reach is incrementally steeper than Reach 2 and thus riffle mesohabitat dominates this reach (74%) and cascades are evident (14%). Small pool mesohabitat also comprises about 13% of the mesohabitat (Table 1) in this reach.

PHOTO 5 REPRESENTATIVE MESOHABITAT IN REACH 3, BISHOP CREEK.

PHOTO 6 EA (1986) REACH 3 IFIM STUDY SITE

Reach 4

Reach 4 extends from the confluence with Coyote Creek up to the Intake 4 spillway and is approximately 8,042 feet (1.5 miles) long. The reach is similar to Reach 3, generally 15 feet wide; substrate is dominated by boulders, with a band of riparian vegetation dominated by tree canopy (Photo plates 7 and 8). Riffle mesohabitat dominates this reach (42%) and a subsequent on-the-ground visit confirmed this as very high gradient riffles (i.e., approximately 5% or greater slopes); cascades (25%) and step pools (23%) are also common. Riffle/pool complexes, pocket pools and other pools comprise the balance of the mesohabitat in Reach 4 (Table 1). EA (1986) located a study site in a short segment of high gradient riffle (Photo plate 8).

PHOTO PLATE 7 REPRESENTATIVE RIFFLE AND CASCADE MESOHABITAT IN REACH 4, BISHOP CREEK.

PHOTO PLATE 8 EA (1986). REACH 4 IFIM STUDY SITE.

Reach 5

Reach 5 extends from the inflow to the Intake 4 forebay up to the Intake 3 spillway and is approximately 17,300 feet (3.3 miles) long. The reach is generally 15-20 feet wide; substrate is dominated by boulders, with a somewhat denser band of riparian vegetation dominated by tree canopy as compared to downstream reaches (Photo plate 9). This reach is dominated by cascade mesohabitat (58%); riffle (21%) and cascade/riffle complexes (18%) are also common. Scattered plunge pool and pocket pools comprise the balance of the mesohabitat (Table 1). EA (1986) located a study site in a riffle unit (Photo plate 10).

PHOTO PLATE 9 **REPRESENTATIVE RIFFLE AND CASCADE MESOHABITAT IN REACH 5, BISHOP CREEK.**

PHOTO PLATE 10 **EA (1986) REACH 5 IFIM STUDY SITE.**

Reach 6

Reach 6 extends from the inflow to the Intake 3 forebay pool up to the confluence of the Middle and South forks of Bishop Creek near the Big Pine Campground and is approximately 3,384 feet (approximately 0.6 miles) long. The reach is generally 10 feet wide; substrate is dominated by boulders, with a forested surrounding, and riparian vegetation dominated by tree canopy (Photo plate 11). This reach is dominated by cascade mesohabitat (57%); higher gradient riffles than downstream reaches (29%) and occasional lower gradient riffles (14%) are also present (Table 1). EA (1986) did not include a study site in this reach, but rather positioned one near the South Lake road crossing (Reach 7).


PHOTO PLATE 11 **REPRESENTATIVE HIGH GRADIENT RIFFLE AND CASCADE MESOHABITAT IN REACH 6, BISHOP CREEK.**

Reach 7

Reach 7 extends from the confluence of the Middle and South forks to Intake 2 on the Middle Fork of Bishop Creek and is 7,979 feet (approximately 1.5 miles) long. The reach is generally 10 feet wide; substrate is dominated by boulders, with a forested surrounding, and riparian vegetation dominated by tree canopy (Photo plate 12). This reach is dominated by high gradient riffle (53%) and cascade (30%) mesohabitat; riffle (15%) and occasional riffle-pool (2%) mesohabitats are also present though the pools are extremely small. EA (1986) located a study site in a high gradient riffle unit upstream from the South Lake road crossing (Photo plate 13).


PHOTO PLATE 12 **REPRESENTATIVE HIGH GRADIENT RIFFLE AND CASCADE MESOHABITAT IN REACH 7, MIDDLE FORK, BISHOP CREEK.**

PHOTO PLATE 13 EA (1986) STUDY SITE.

Reach 8

Reach 8 is located on the Middle Fork of Bishop Creek and extends from the Intake 2 forebay up to the Sabrina Lake discharge channel and is 17,145 feet (approximately 3.2 miles) long. The reach is generally 10-15 feet wide; substrate is dominated by boulders, with a forested surrounding, and riparian vegetation is dominated by tree canopy (Photo plate 14). This reach is dominated by riffle (29%), cascade (29%) and high gradient riffle (21%) but also contains significant lower gradient habitats, including consecutive run, run-pool, and pool habitat in the Aspendell vicinity, collectively contributing approximately 19% of the mesohabitat in this reach. Such runs and pools are relatively unique mesohabitats in this watershed and are rich in woody debris cover, scour holes, undercut banks, and overhead cover. The exact location of the EA (1986) IFIM study site in this lower gradient habitat was not well documented. In the event that it cannot be relocated, one possible new location is shown in Photo 15.

PHOTO PLATE 14 REPRESENTATIVE RUN-POOL, RIFFLE, AND CASCADE MESOHABITATS IN REACH 8, MIDDLE FORK BISHOP CREEK.

PHOTO 15 POTENTIAL IFIM STUDY SITE IN REACH 8, MIDDLE FORK BISHOP CREEK, IN ASPENDELL.

Reach 9

Reach 9 is located on the South Fork of Bishop Creek and extends from the confluence with the Middle Fork up to the Intake 2 diversion and is 11,110 feet (approximately 2.1 miles) long. The reach is generally 10 feet wide; substrate is dominated by boulders, with a heavily forested surrounding, and riparian vegetation dominated by tree canopy (Photo plate 16). This reach is dominated by cascades (41%), low gradient riffles (25%), mixed riffles (17%) and high gradient riffles (14%), collectively contributing approximately 97% of the mesohabitat in this reach. The EA (1986) IFIM study site was located in this lower gradient habitat, although the exact location was not well documented, it appears to have been located in the low gradient riffle near the U.S. Forest Service's Four Jeffreys Campground. In the event that the former study site cannot be located, a proposed new location is shown in Photo 17.

PHOTO PLATE 16 REPRESENTATIVE HIGH GRADIENT/CASCADE AND LOWER GRADIENT RIFFLE MESOHABITATS IN REACH 9, SOUTH FORK BISHOP CREEK.

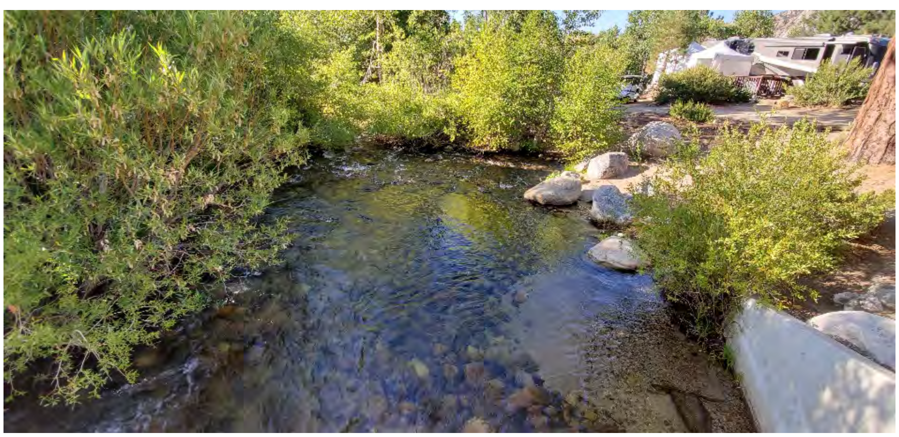

PHOTO 17 PROPOSED REACH 9 IFIM STUDY SITE.

Reach 10

Reach 10 is located on the South Fork of Bishop Creek and extends from the Intake 2 diversion up to the South Lake spillway channel and is 30,301 feet (approximately 5.7 miles) long. The reach is generally 10 feet wide; substrate is dominated by boulders, with a heavily forested surrounding in high gradient segments, and riparian vegetation dominated by tree canopy (Photo plate 18). This reach is generally high gradient, dominated by high gradient riffle (36%), low gradient riffle (30%), and cascades (24%), collectively contributing approximately 90% of the mesohabitat in this reach. However, almost 10% of the reach (approximately 3,000 feet) is comprised of meandering run habitat, with sand and gravel substrates, and extensive meadow surrounding with riparian brush. The runs feature excellent undercut banks as well as large boulder object cover. The EA (1986) IFIM study site was located in this lower gradient habitat and is shown in Photo plate 19.

PHOTO PLATE 18 REPRESENTATIVE HIGH GRADIENT/CASCADE AND RUN MESOHABITATS IN REACH 10, SOUTH FORK, BISHOP CREEK.

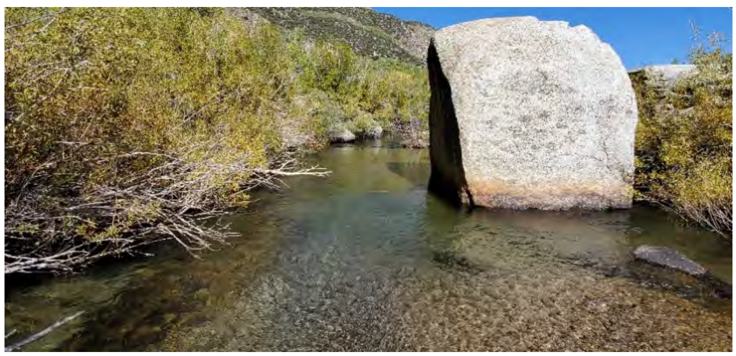

PHOTO PLATE 19 APPROXIMATE LOCATION OF EA (1986) IFIM STUDY SITE.

DISCUSSION

This investigation found a nearly identical distribution of mesohabitats to those narratively described in the original IFIM study (EA, 1986). The Bishop Creek watershed is generally dominated by high gradient, boulder-rich mesohabitats such as high gradient riffles and cascades. Lower gradient mesohabitats such as low gradient riffles, runs and pools occur in isolated patches, particularly in the Middle and South forks. There are very few large, deep, riverine pools other than intake forebays; however small pocket- and step-pools typically 6-12 feet long are interspersed among cascades and riffle complexes.

The persistence of stable base flows in Bishop Creek resulting from the existing minimum flow releases has contributed to the growth of dense riparian vegetation along the entire creek (E. Read, *personal communication*, 2018) as evidenced in photos. This has enhanced the woody debris contributions to the stream, which provide good bankside and overhead cover suitability for stream fishes, especially trout. During the 2019 fishery survey of the creek, most adult trout collected in high gradient reaches were concentrated in these shelters (Stillwater Sciences, *unpublished data in press*).

Preliminary IFIM Study Site Recommendations

SCE proposes to consult further with the TWG to finalize IFIM study sites and select transects within study sites. Many of the historic EA (1986) IFIM study reaches were located during this survey, although relatively few original transect headpins were found. These sites are generally representative of habitat features of each respective reach that are usable to adult and juvenile brown trout, and appear to be adequate for the current study with a few exceptions, as noted below. The following are SCE's preliminary recommendations for PHABSIM model study sites.

Reach 1. Recommend adopting the historic study site; focus on riffle, and riffle/pool mesohabitats.

Reach 2. Recommend adopting the historic study site; focus on riffle mesohabitat.

Reach 3. Recommend adopting the historic study site; focus on riffle mesohabitat.

Reach 4. Suitable holding habitat for brown trout is limited to pocket pools and step pools (see Photo plate 7). The remainder of habitats are very high gradient that would not likely hold juvenile or adult brown trout and will model poorly. An alternative would be to develop stage-discharge curves for representative pools to quantify wetted area and depth from empirical measurements. The TWG should discuss and evaluate this alternative.

Reach 5. Recommend adopting the historic study site; focus on riffle mesohabitat.

Reach 6. Suitable holding habitat for brown trout is limited to pocket pools and step pools (see Photo plate 11). Most segments are very high gradient, and would not likely hold juvenile or adult brown trout and will model poorly. An alternative would be to develop stage-discharge curves for representative pools to quantify wetted area and depth from empirical measurements. The TWG should discuss and evaluate this alternative.

Reach 7. Recommend adopting the historic study site; focus on riffle mesohabitat.

Reach 8. Recommend locating a site in the low gradient riffle/run mesohabitat near Aspendell. This area was extremely productive during the 2019 fishery survey (Stillwater Sciences, *in press*) and thus appears to be very productive adult brown trout habitat and is also more readily accessible to anglers than most of the remaining reach.

Reach 9. Recommend locating a site in the vicinity of the historic low gradient riffle mesohabitat study site near Four Jeffreys Campground.

Reach 10. Recommend locating a site in run mesohabitat. This type of habitat comprises over 3,000 feet and appears to be very productive adult brown trout habitat, with abundant cover and lower-velocity refugia conducive to supporting brown trout and is also more readily accessible to anglers than most of the remaining reach.

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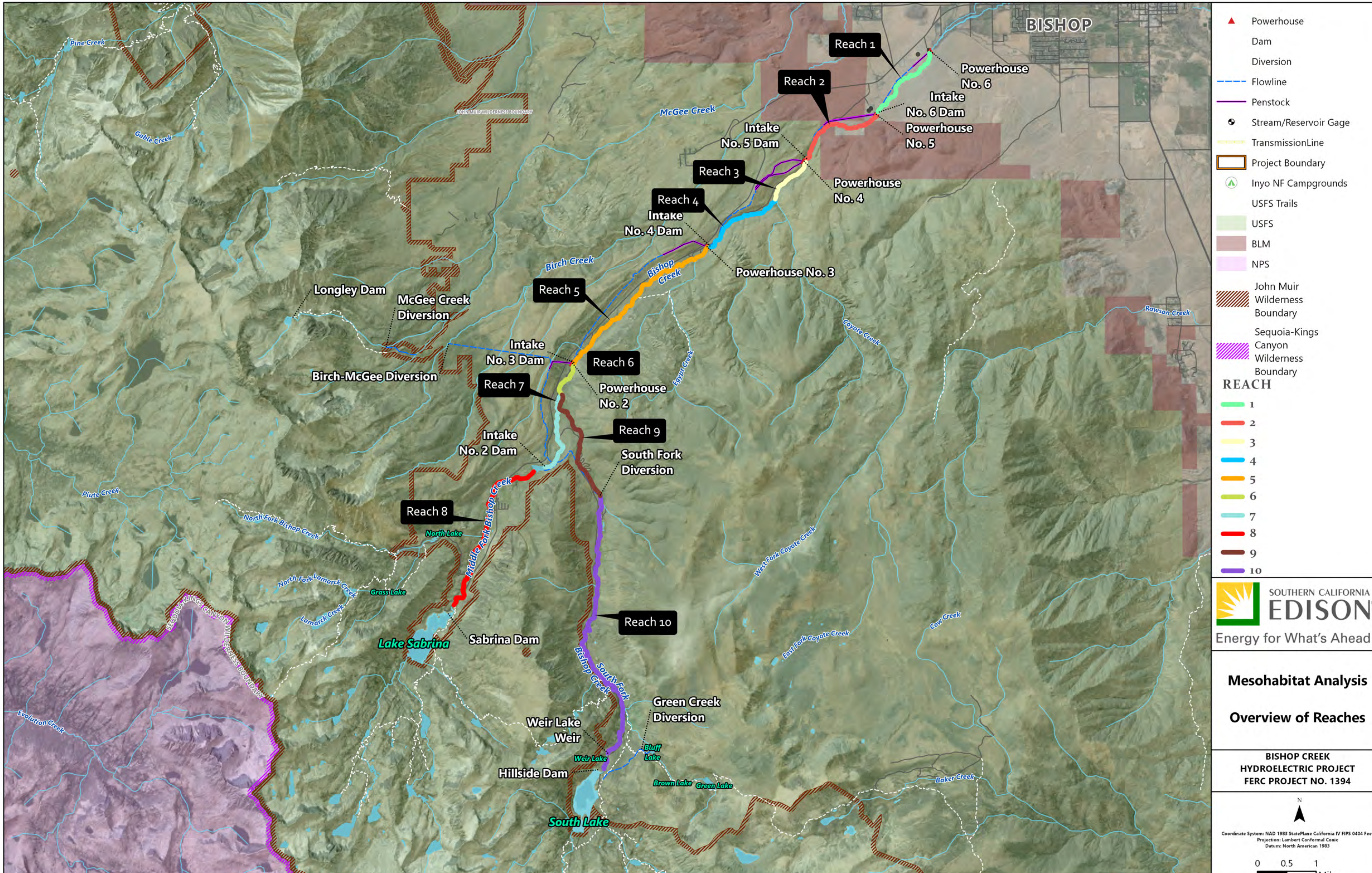
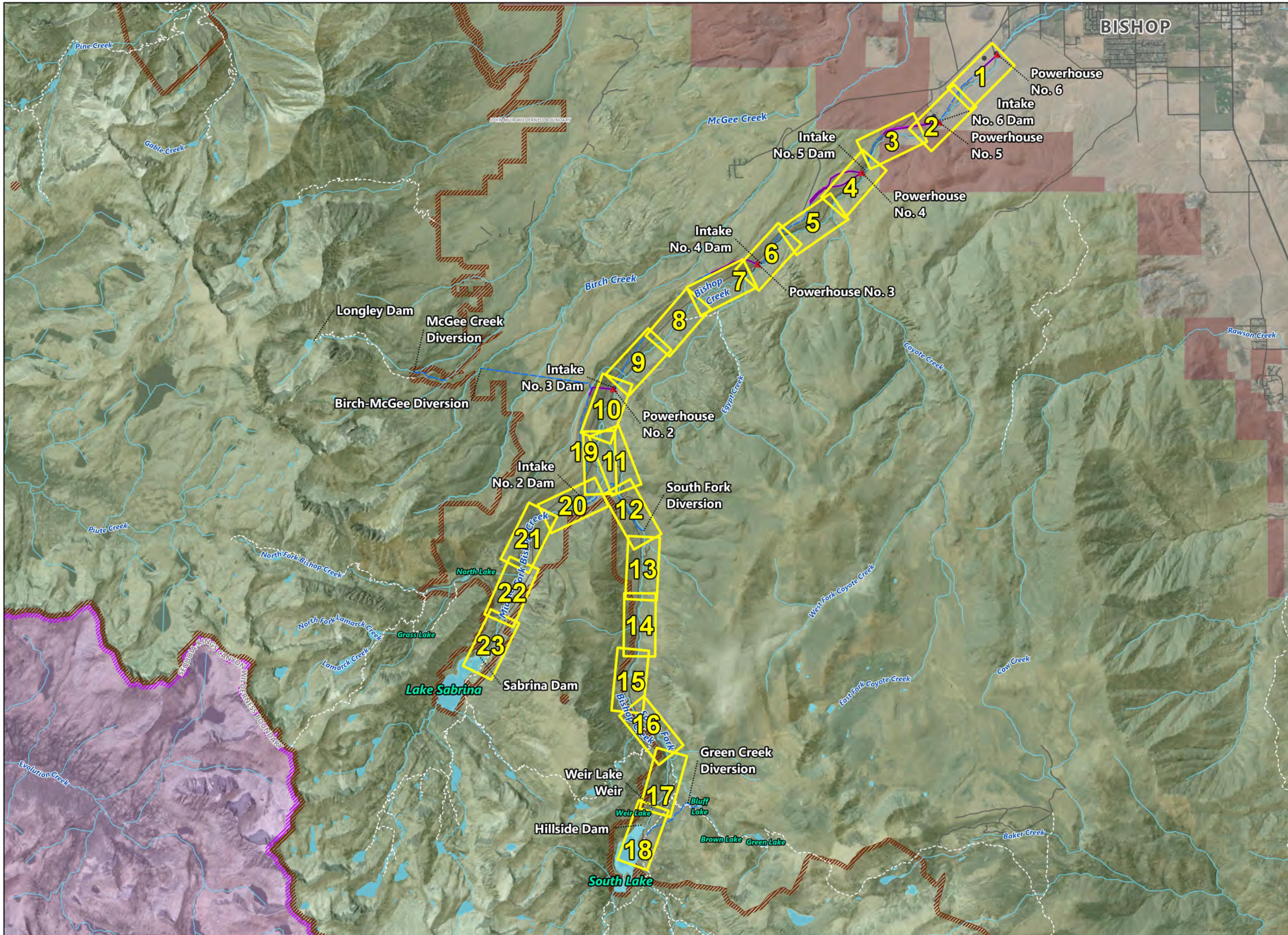
Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 2010. California Salmonid Stream Habitat Restoration Manual. Fourth Edition. State of California Dept. of Fish and Game Wildlife and Fisheries Division. 525 pp.

APPENDIX A to

DETAILED MESOHABITAT SEGMENT MAPS



BISHOP
Reach 1
Reach 2
Reach 3
Reach 4
Reach 5
Reach 6
Reach 7
Reach 8
Reach 9
Reach 10
Powerhouse No. 6
Intake No. 6 Dam
Powerhouse No. 5
Intake No. 5 Dam
Powerhouse No. 4
Intake No. 4 Dam
Powerhouse No. 3
Intake No. 3 Dam
Powerhouse No. 2
Intake No. 2 Dam
South Fork Diversion
Longley Dam
McGee Creek Diversion
Birch-McGee Diversion
Sabrina Dam
Lake Sabrina
Weir Lake Weir
Hillside Dam
Green Creek Diversion
South Lake
North Lake
Grass Lake
Weir Lake
Bluff Lake
Brown Lake
Green Lake
Pine Creek
Gable Creek
McGee Creek
Birch Creek
Bishop Creek
Piute Creek
North Fork Bishop Creek
Middle Fork Bishop Creek
North Fork Lamarck Creek
Lamarck Creek
Evolution Creek
Bishop Creek South Fork
Egypt Creek
Coyote Creek
West Fork Coyote Creek
East Fork Coyote Creek
Cow Creek
Baker Creek
Rawson Creek
JOHN MUIR WILDERNESS BOUNDARY
SEQUOIA-KINGS CANYON WILDERNESS BOUNDARY
Powerhouse
Dam
Diversion
Flowline
Penstock
Stream/Reservoir Gage
TransmissionLine
Project Boundary
Inyo NF Campgrounds
USFS Trails
USFS
BLM
NPS
John Muir Wilderness Boundary
Sequoia-Kings Canyon Wilderness Boundary
REACH
1
2
3
4
5
6
7
8
9
10
SOUTHERN CALIFORNIA EDISON
Energy for What's Ahead℠
Mesohabitat Analysis
Overview of Reaches
BISHOP CREEK HYDROELECTRIC PROJECT
FERC PROJECT NO. 1394
N
Coordinate System: NAD 1983 StatePlane California IV FIPS 0404 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983
0
0.5
1
Miles



- Powerhouse
- Dam
- Diversion
- Flowline
- Penstock
- Stream/Reservoir Gage
- TransmissionLine
- Project Boundary
- Inyo NF Campgrounds
- USFS Trails
- USFS
- BLM
- NPS
- John Muir Wilderness Boundary
- Sequoia-Kings Canyon Wilderness Boundary

SOUTHERN CALIFORNIA EDISON®
Energy for What's Ahead℠

Mesohabitat Analysis

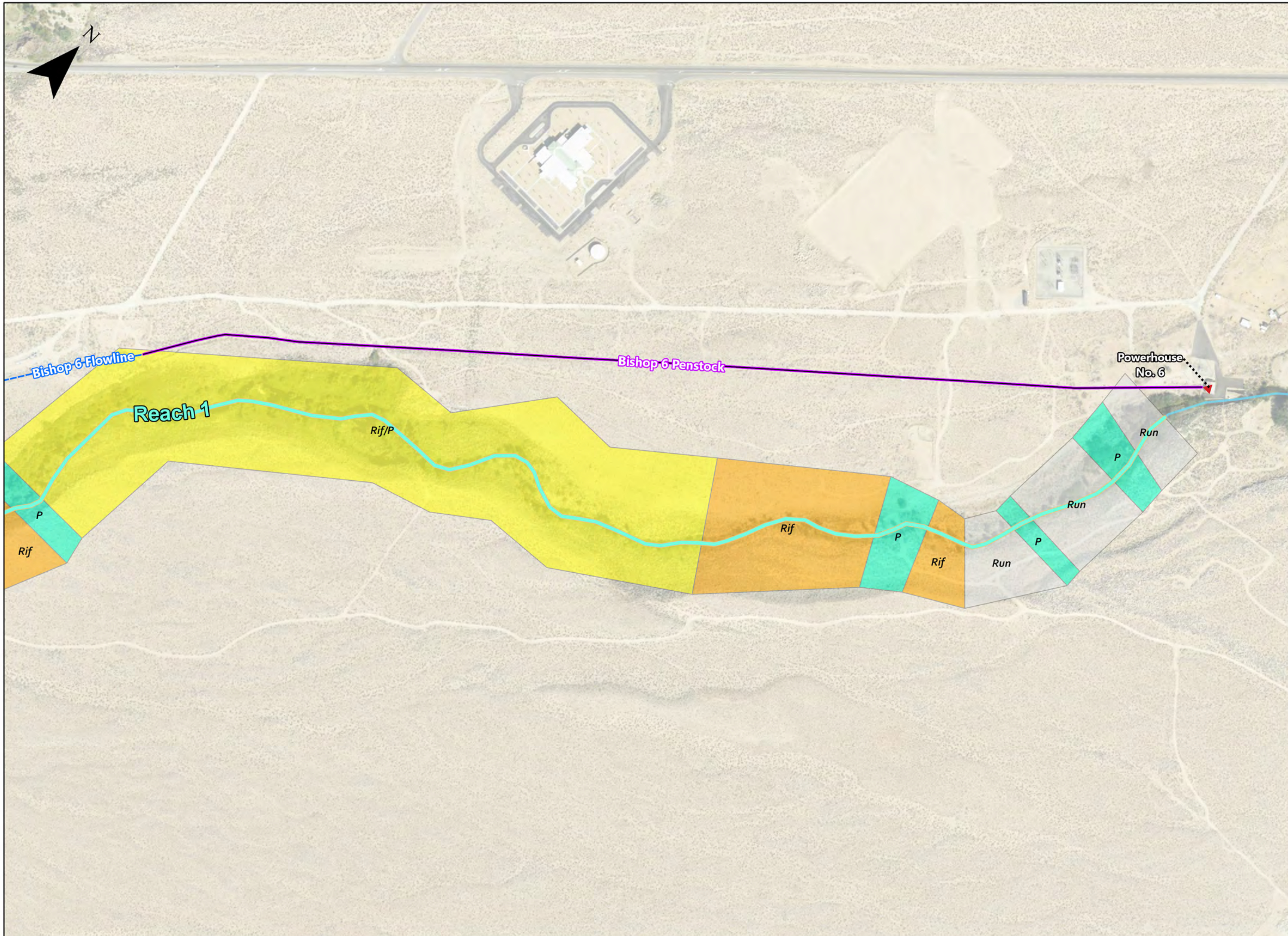
Overview of Sheets

BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394

N

Coordinate System: NAD 1983 StatePlane California IV FIPS 0404 Feet
Projection: Lambert Conformal Conic
Datum: North American 1983

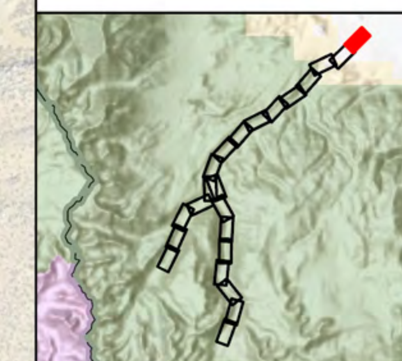
0 0.5 1 Miles



Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach

Mesohabitat Type

Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PlP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)



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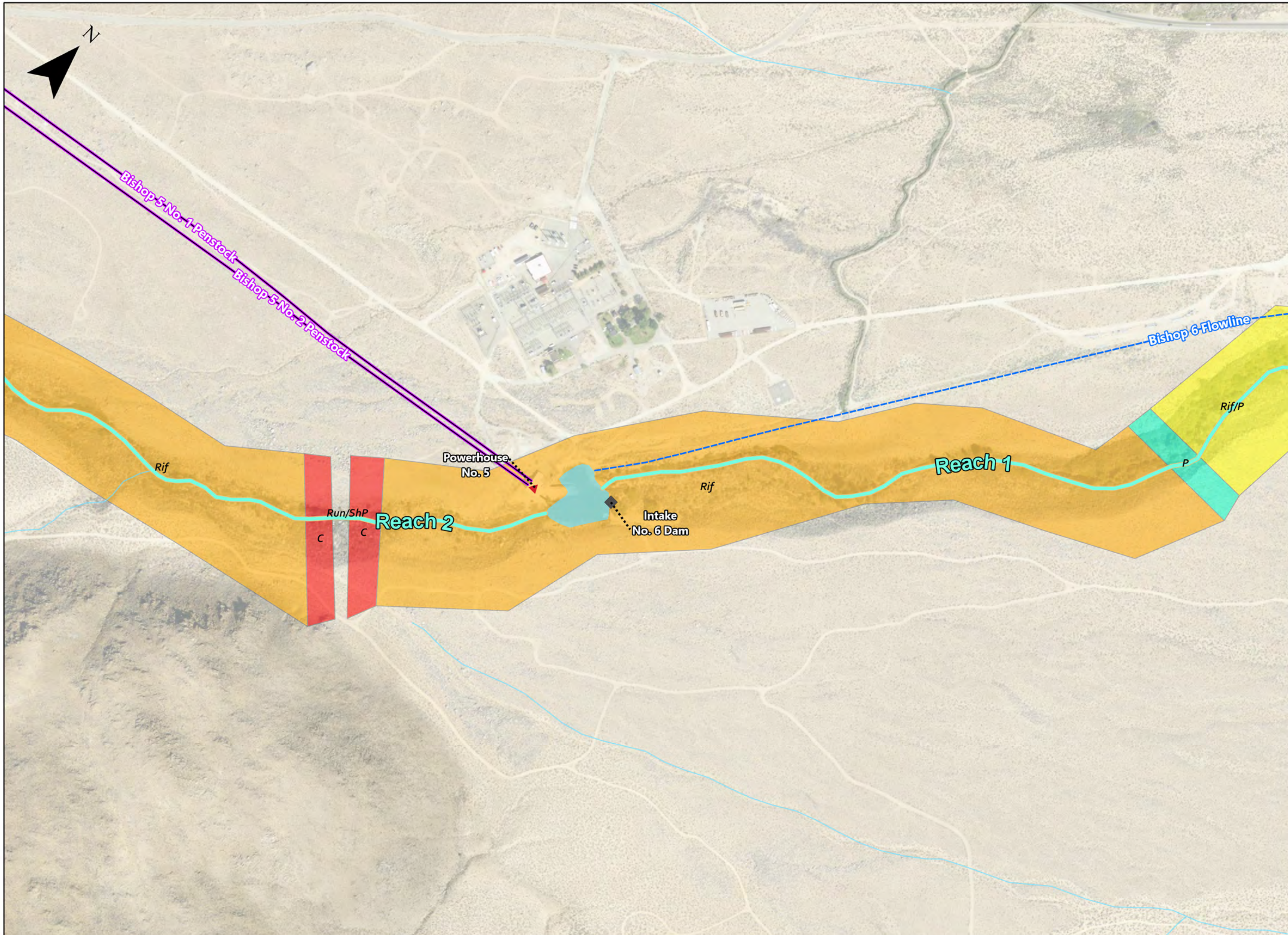
Mesohabitat Analysis

Map No. 1

BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394

0 245 490 Feet



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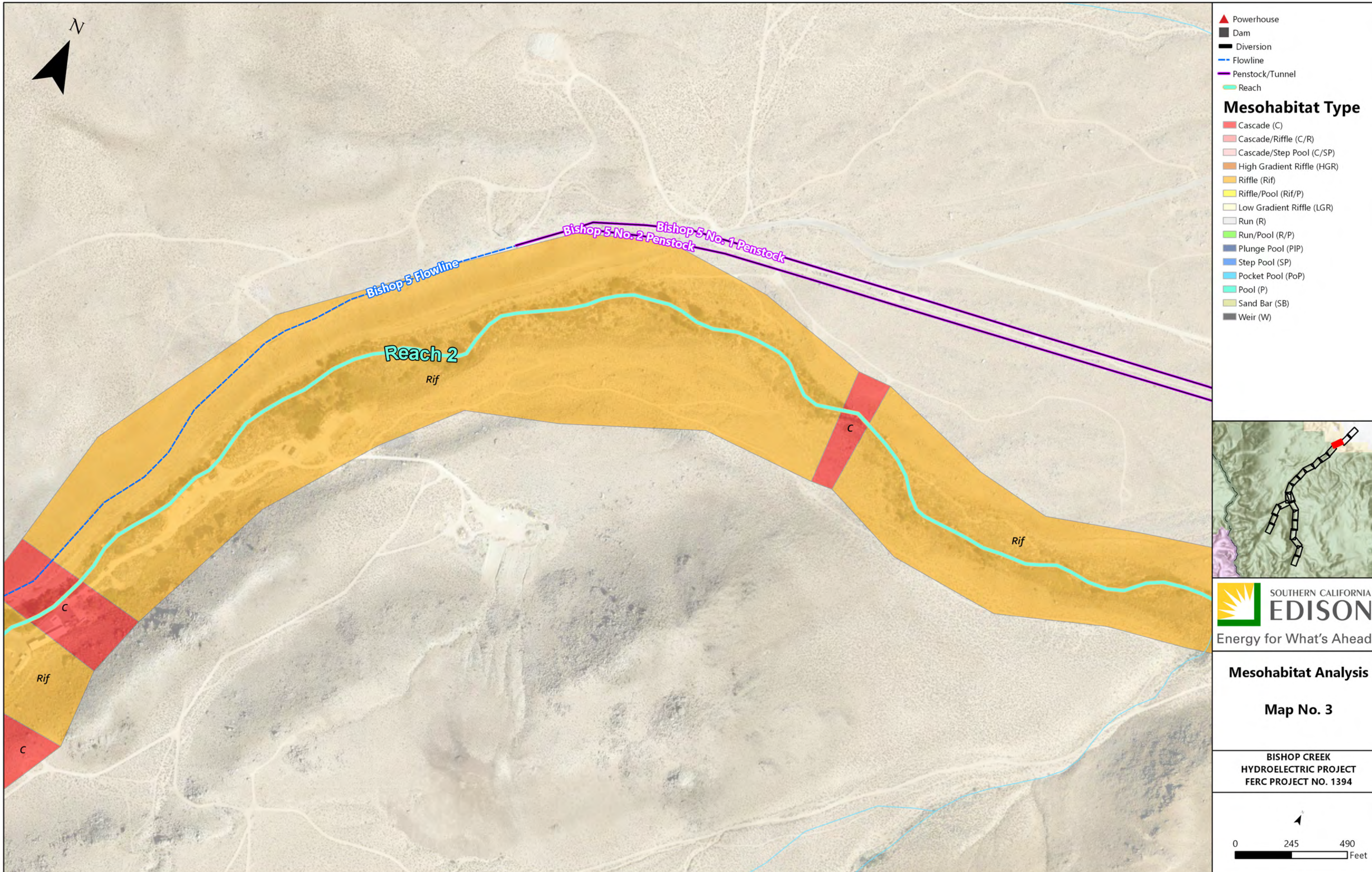
Mesohabitat Analysis

Map No. 2

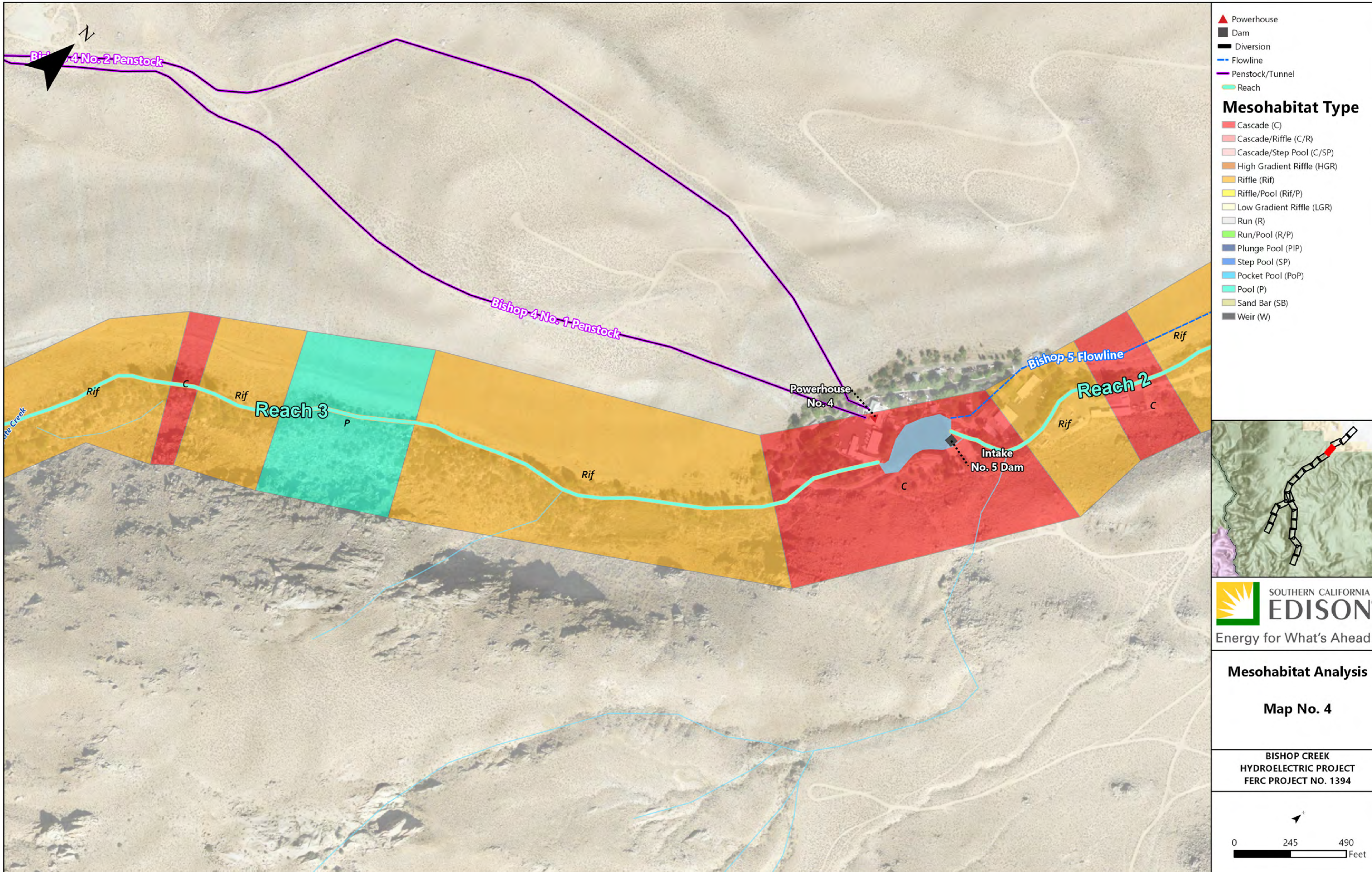
BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394



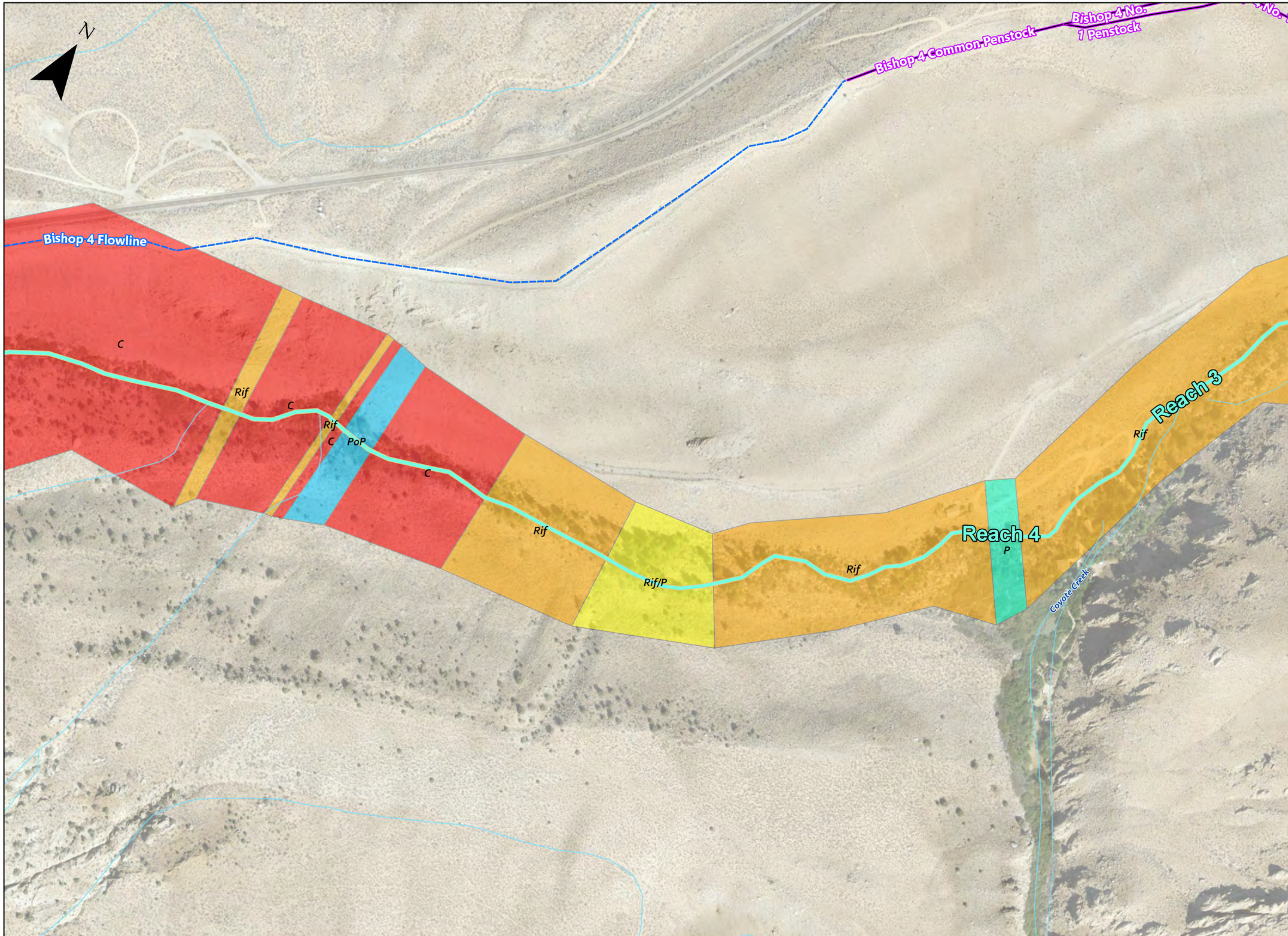
Mesohabitat Analysis

Map No. 3

BISHOP CREEK
HYDROELECTRIC PROJECT
FERC PROJECT NO. 1394



Bishop 4 No. 2 Penstock
Bishop 4 No. 1 Penstock
Bishop 5 Flowline
Powerhouse No. 4
Intake No. 5 Dam
Reach 3
Reach 2
Rif
C
P
Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach
Mesohabitat Type
Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PlP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)
SOUTHERN CALIFORNIA EDISON
Energy for What's Ahead℠
Mesohabitat Analysis
Map No. 4
BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394
0 245 490 Feet



Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach

Mesohabitat Type

- Cascade (C)
- Cascade/Riffle (C/R)
- Cascade/Step Pool (C/SP)
- High Gradient Riffle (HGR)
- Riffle (Rif)
- Riffle/Pool (Rif/P)
- Low Gradient Riffle (LGR)
- Run (R)
- Run/Pool (R/P)
- Plunge Pool (PlP)
- Step Pool (SP)
- Pocket Pool (PoP)
- Pool (P)
- Sand Bar (SB)
- Weir (W)

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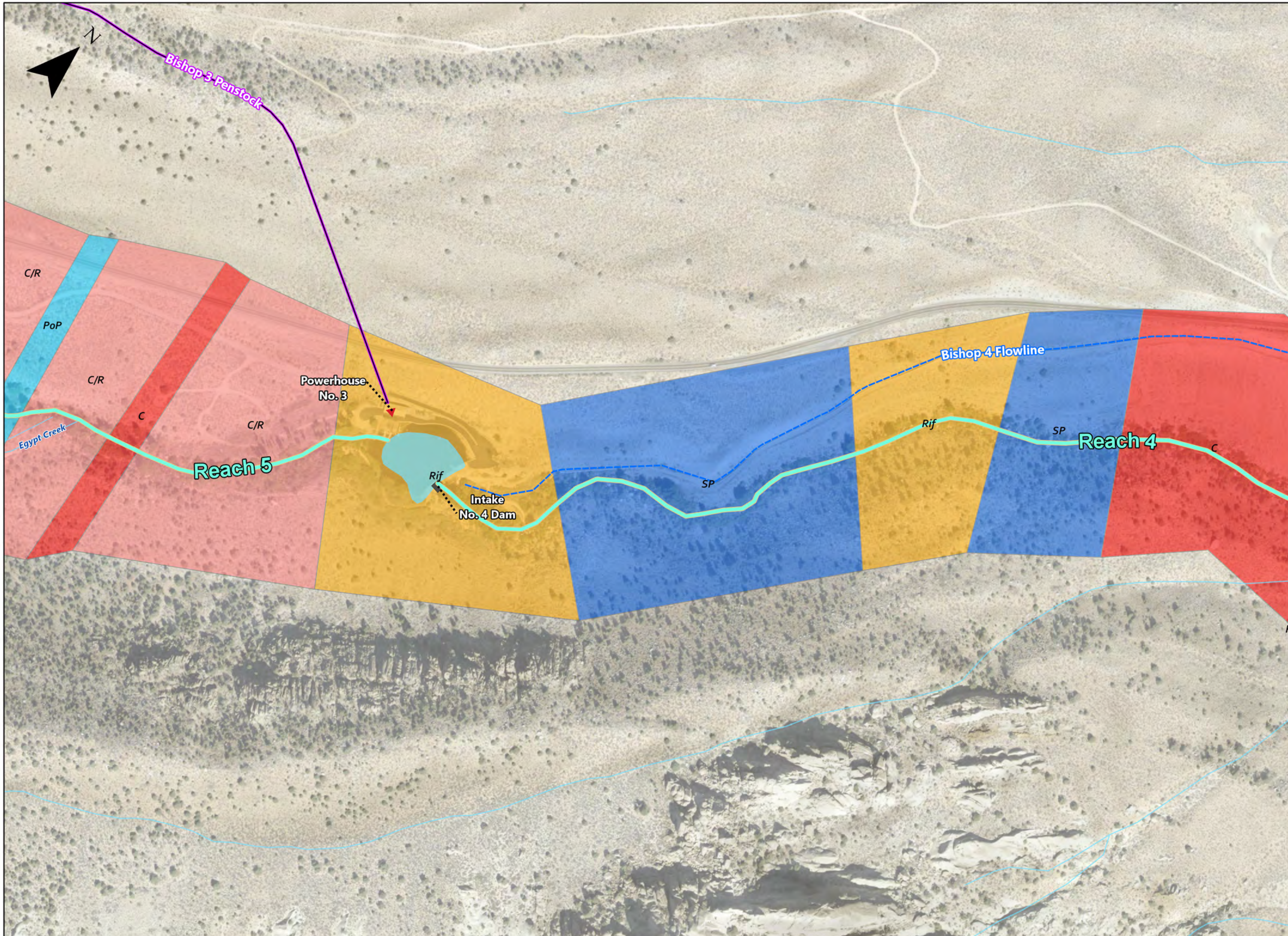
Mesohabitat Analysis

Map No. 5

BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394

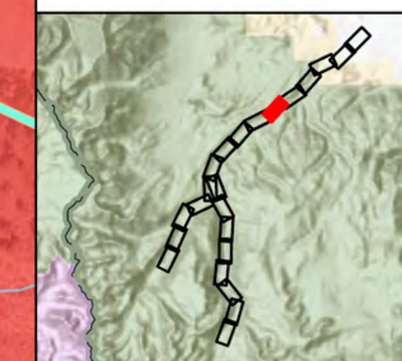
0 245 490 Feet



Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach

Mesohabitat Type

Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PlP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)



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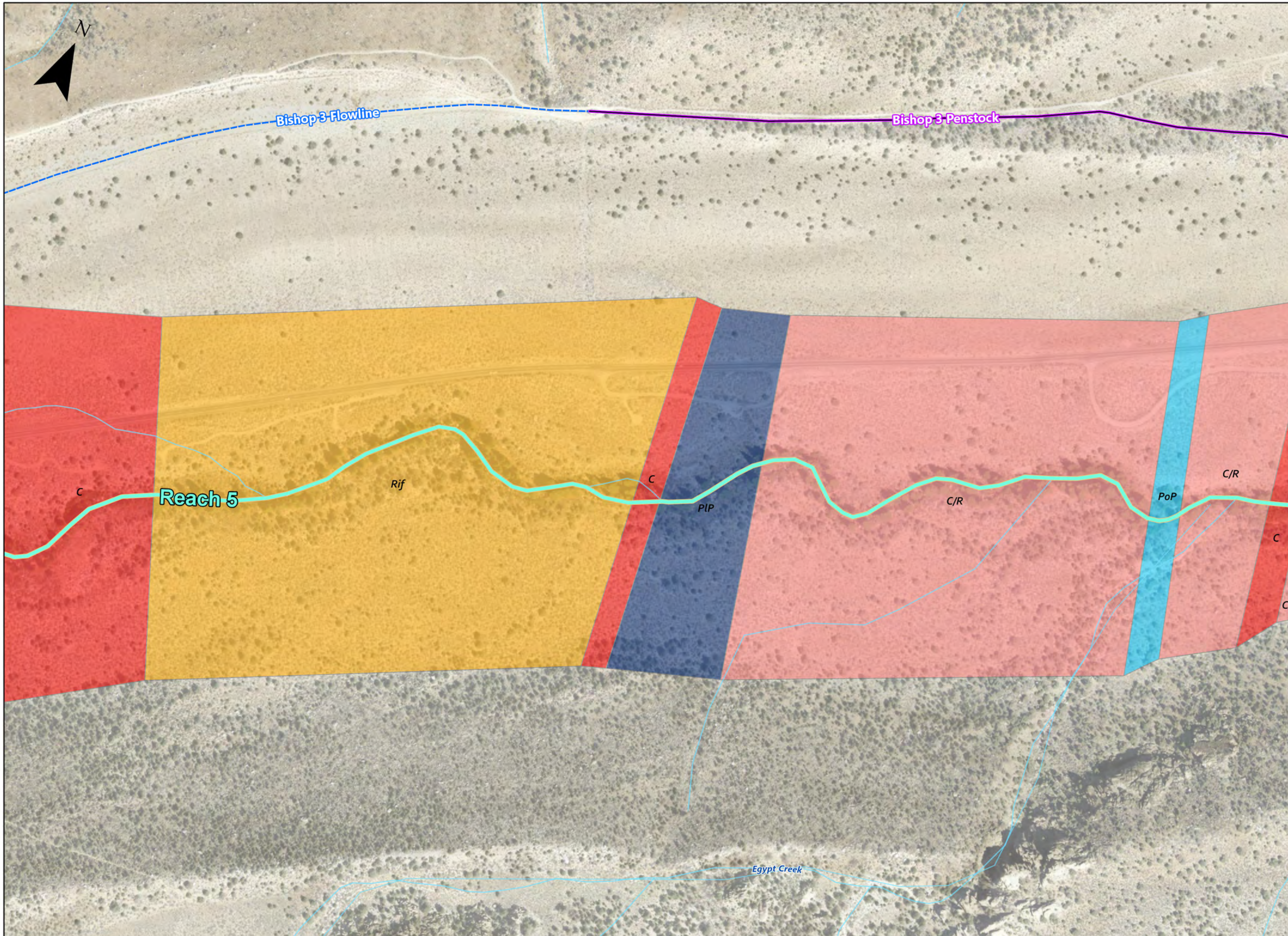
Mesohabitat Analysis

Map No. 6

BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394

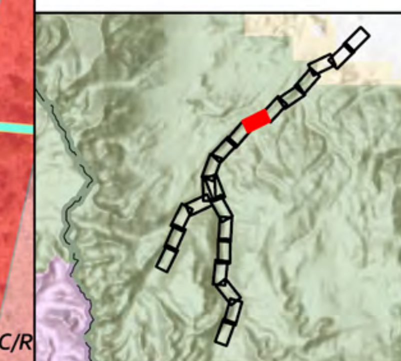
0 245 490 Feet



Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach

Mesohabitat Type

Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PlP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)



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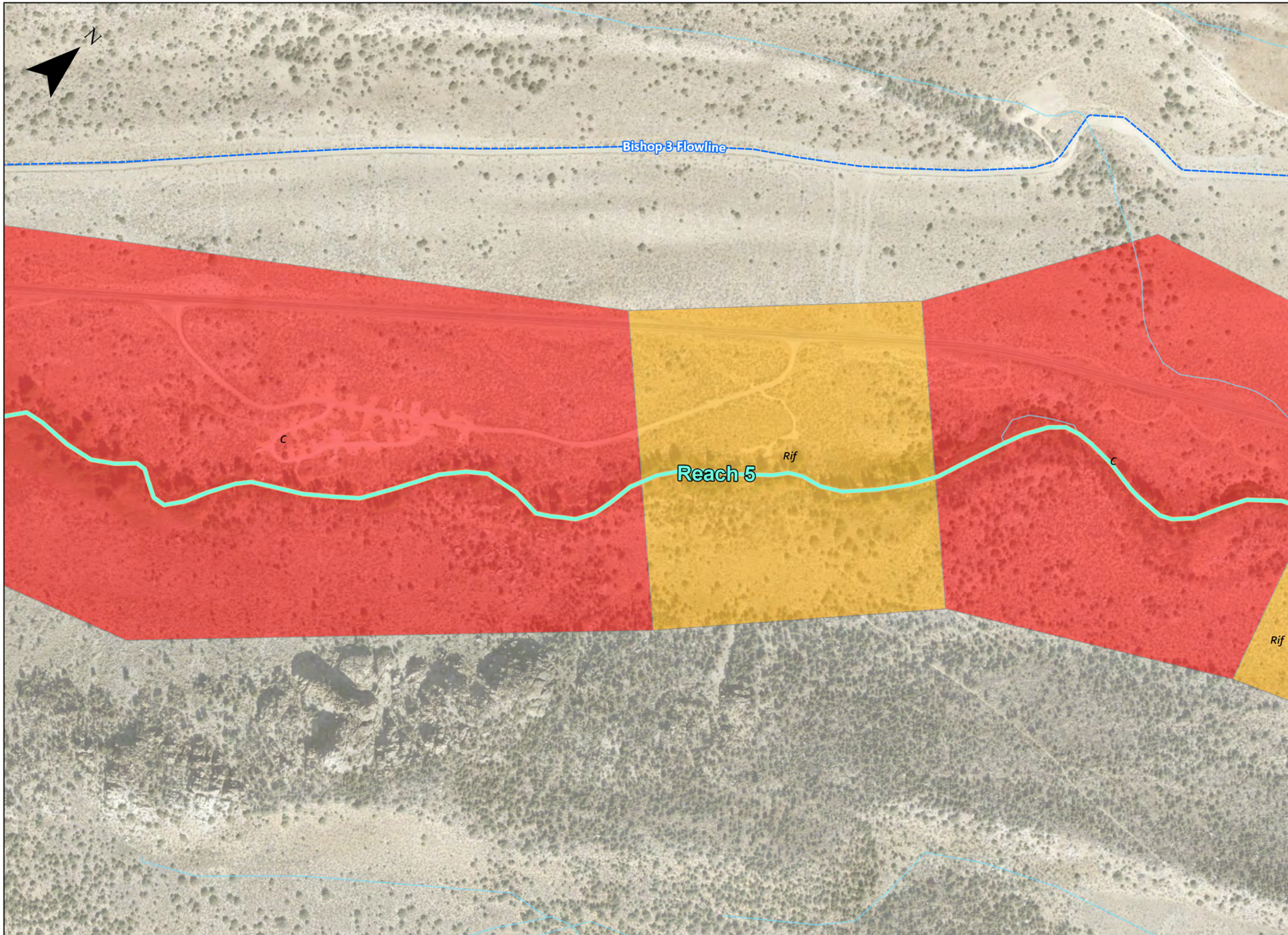
Mesohabitat Analysis

Map No. 7

BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394

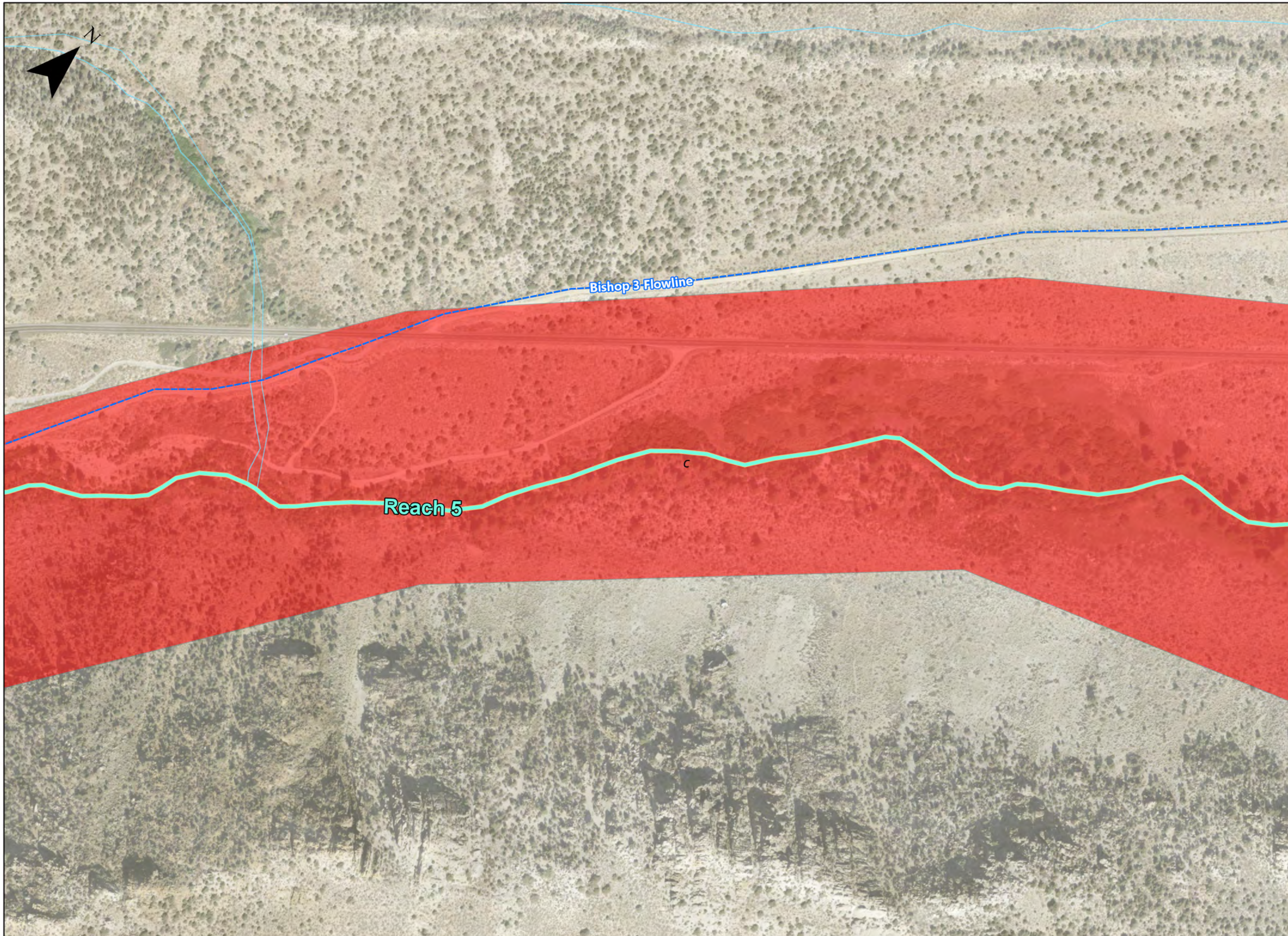
0 245 490 Feet



Mesohabitat Analysis

Map No. 8

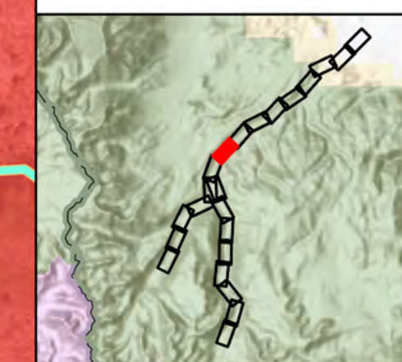
BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394



Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach

Mesohabitat Type

Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PlP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)



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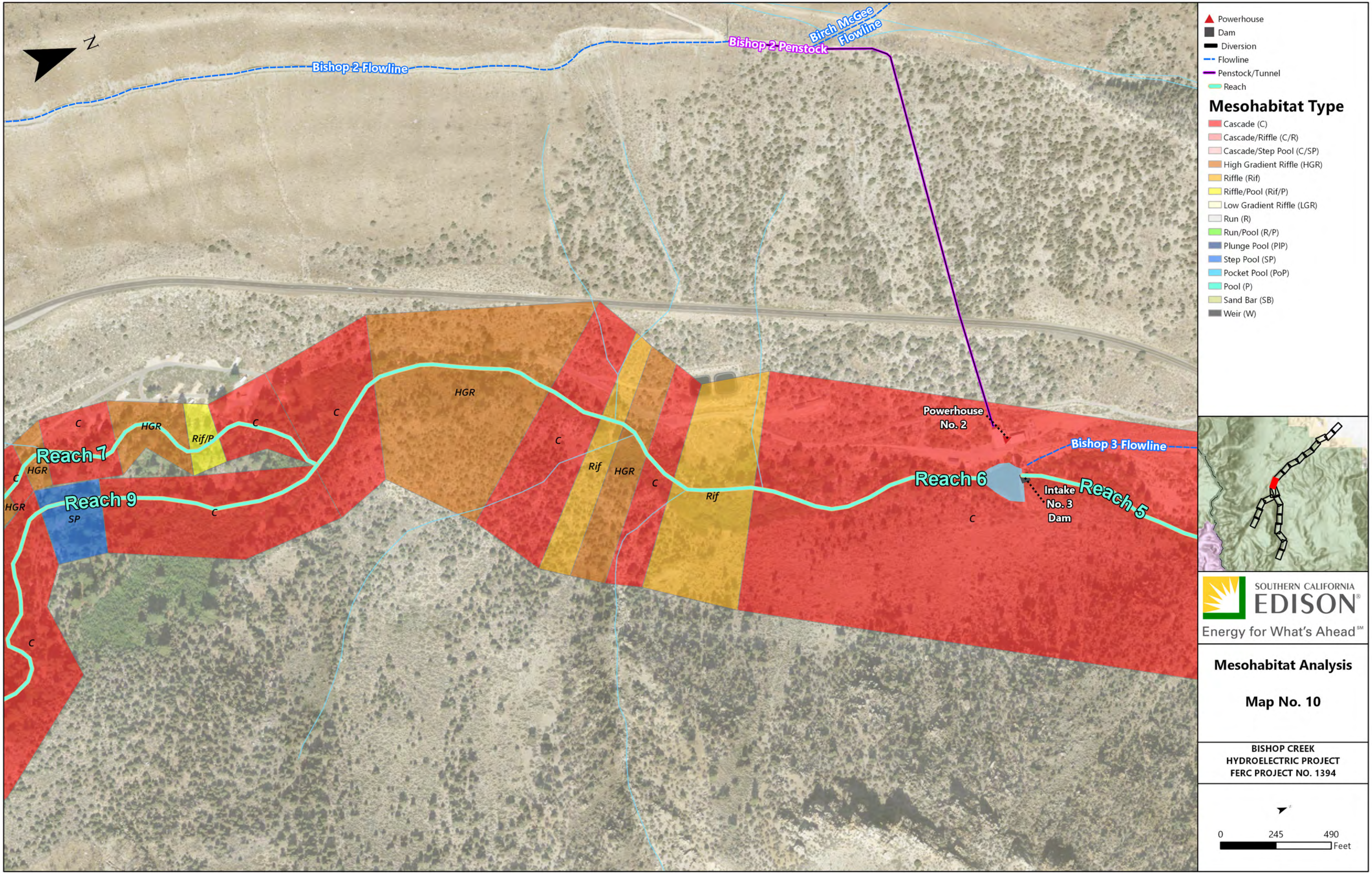
Mesohabitat Analysis

Map No. 9

BISHOP CREEK
HYDROELECTRIC PROJECT
FERC PROJECT NO. 1394

0 245 490 Feet



Bishop 2 Flowline
Bishop 2 Penstock
Birch McGee Flowline
Bishop 3 Flowline
Powerhouse No. 2
Intake No. 3 Dam
Reach 7
Reach 9
Reach 6
Reach 5
HGR
C
Rif/P
SP
Rif
Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach
Mesohabitat Type
Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PlP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)
SOUTHERN CALIFORNIA EDISON
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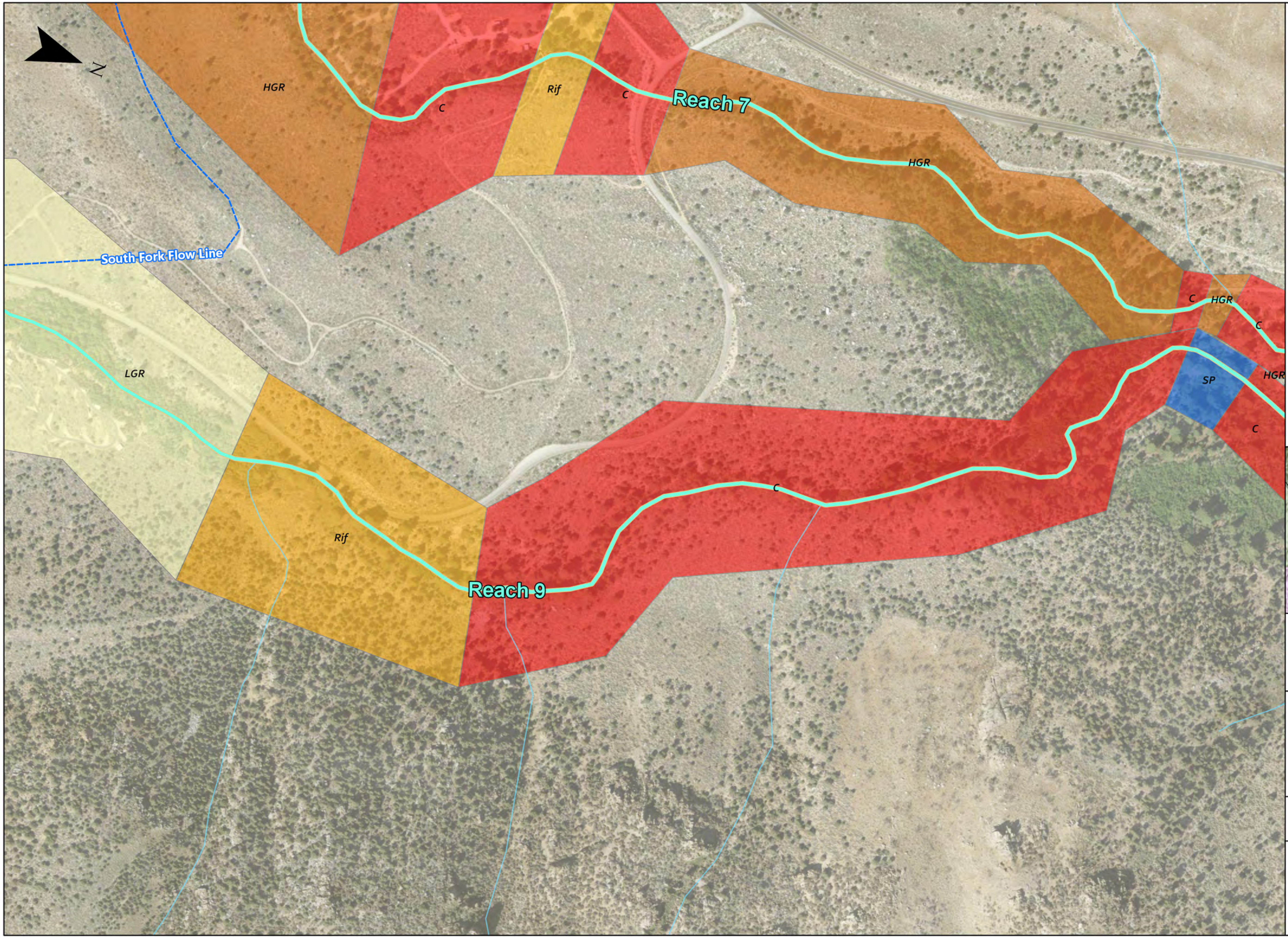
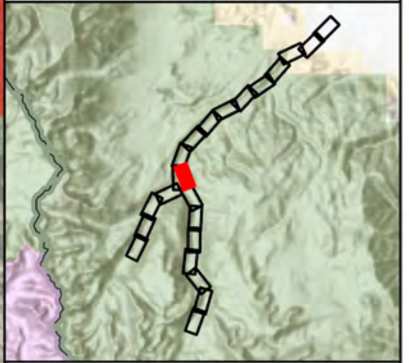
Mesohabitat Analysis
Map No. 10
BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394
0 245 490 Feet



Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach

Mesohabitat Type

Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PIP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)



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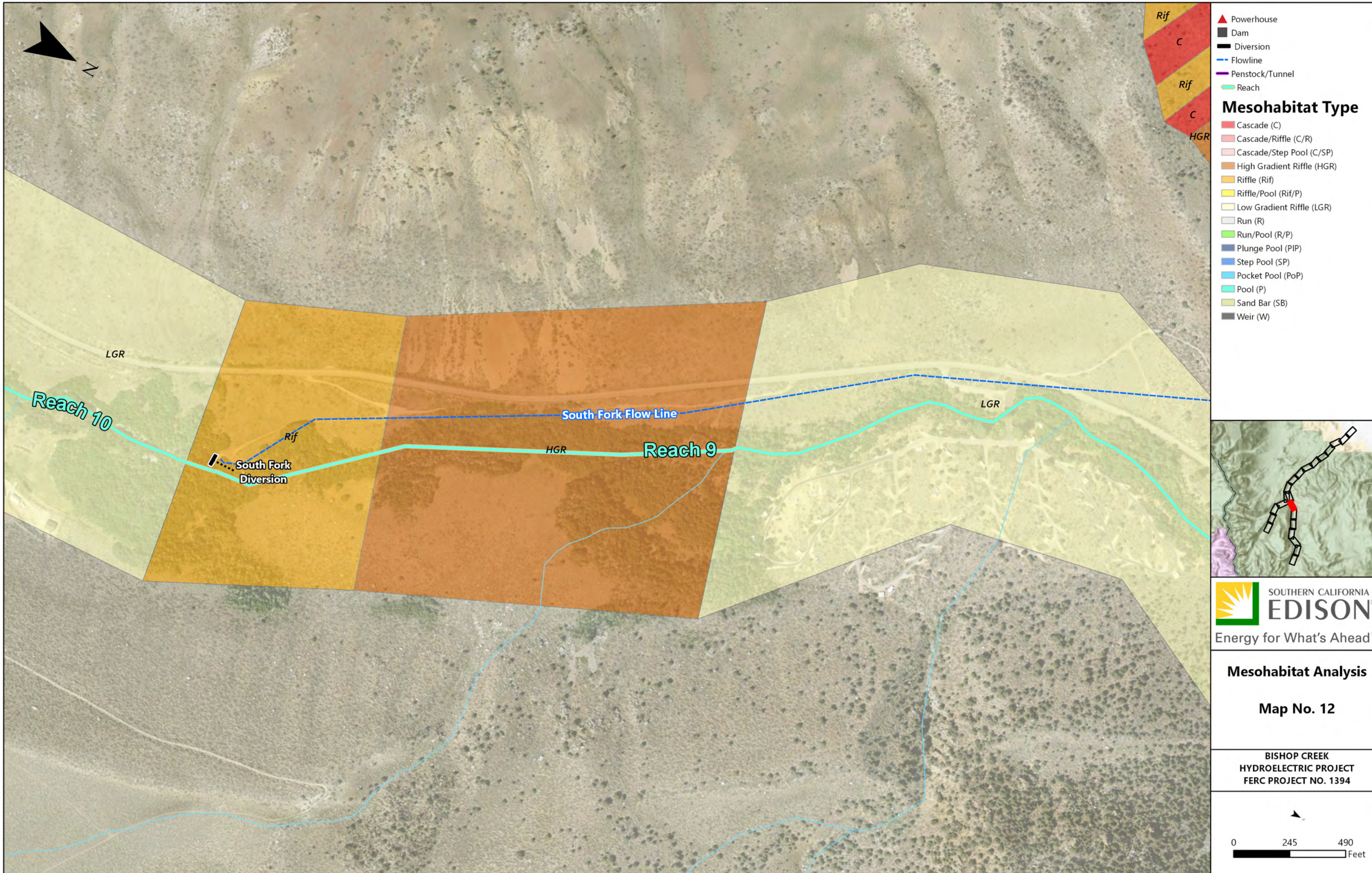
Mesohabitat Analysis

Map No. 11

BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394

0 245 490 Feet



N
Rif
C
Rif
C
HGR
LGR
Reach 10
Rif
South Fork Diversion
South Fork Flow Line
HGR
Reach 9
LGR
Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach
Mesohabitat Type
Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PIP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)
SOUTHERN CALIFORNIA EDISON
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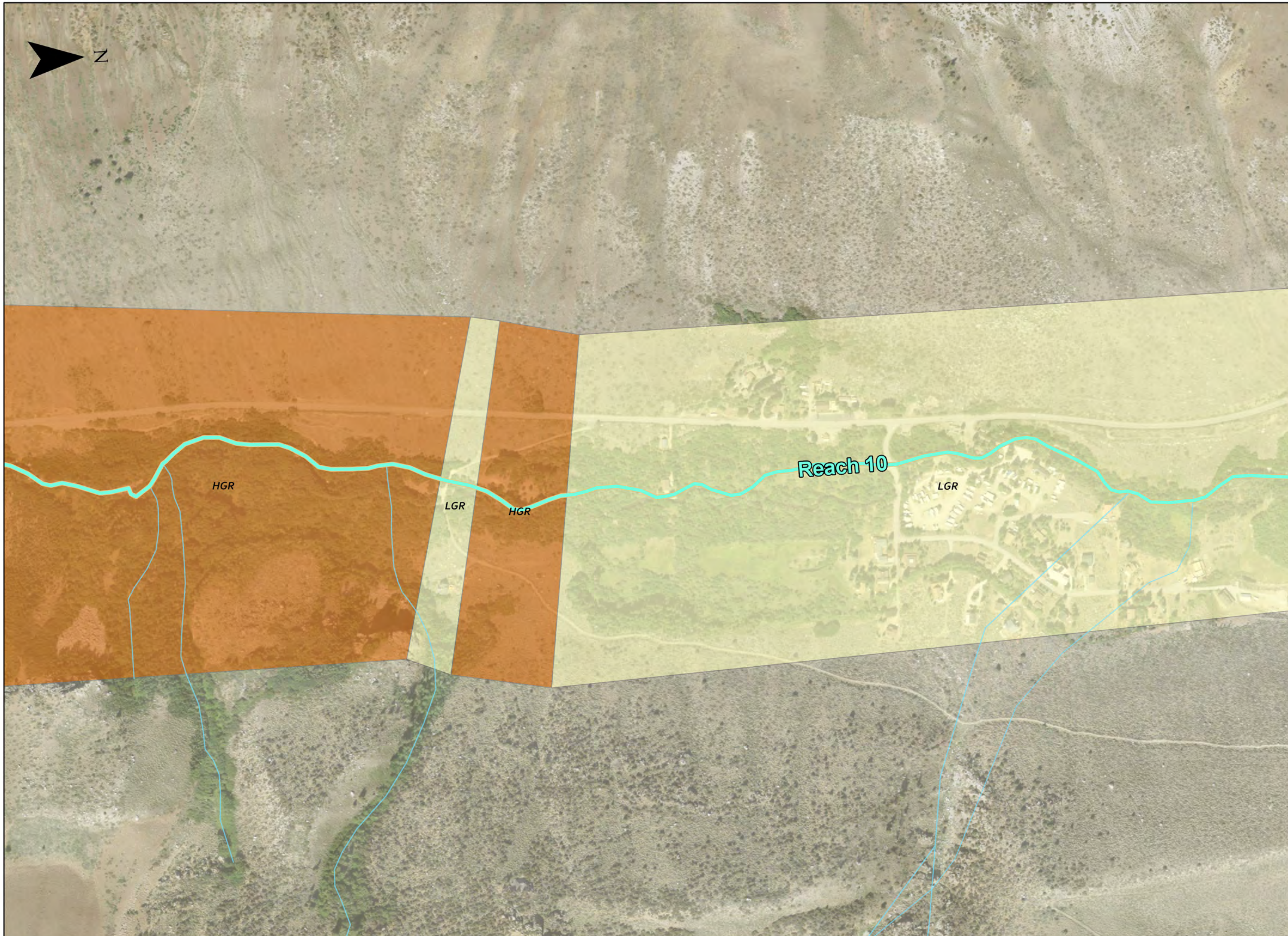
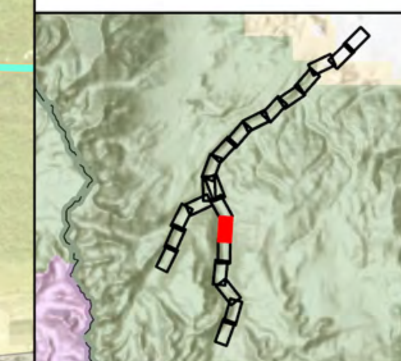
Mesohabitat Analysis
Map No. 12
BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394
0 245 490 Feet



Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach

Mesohabitat Type

Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PlP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)



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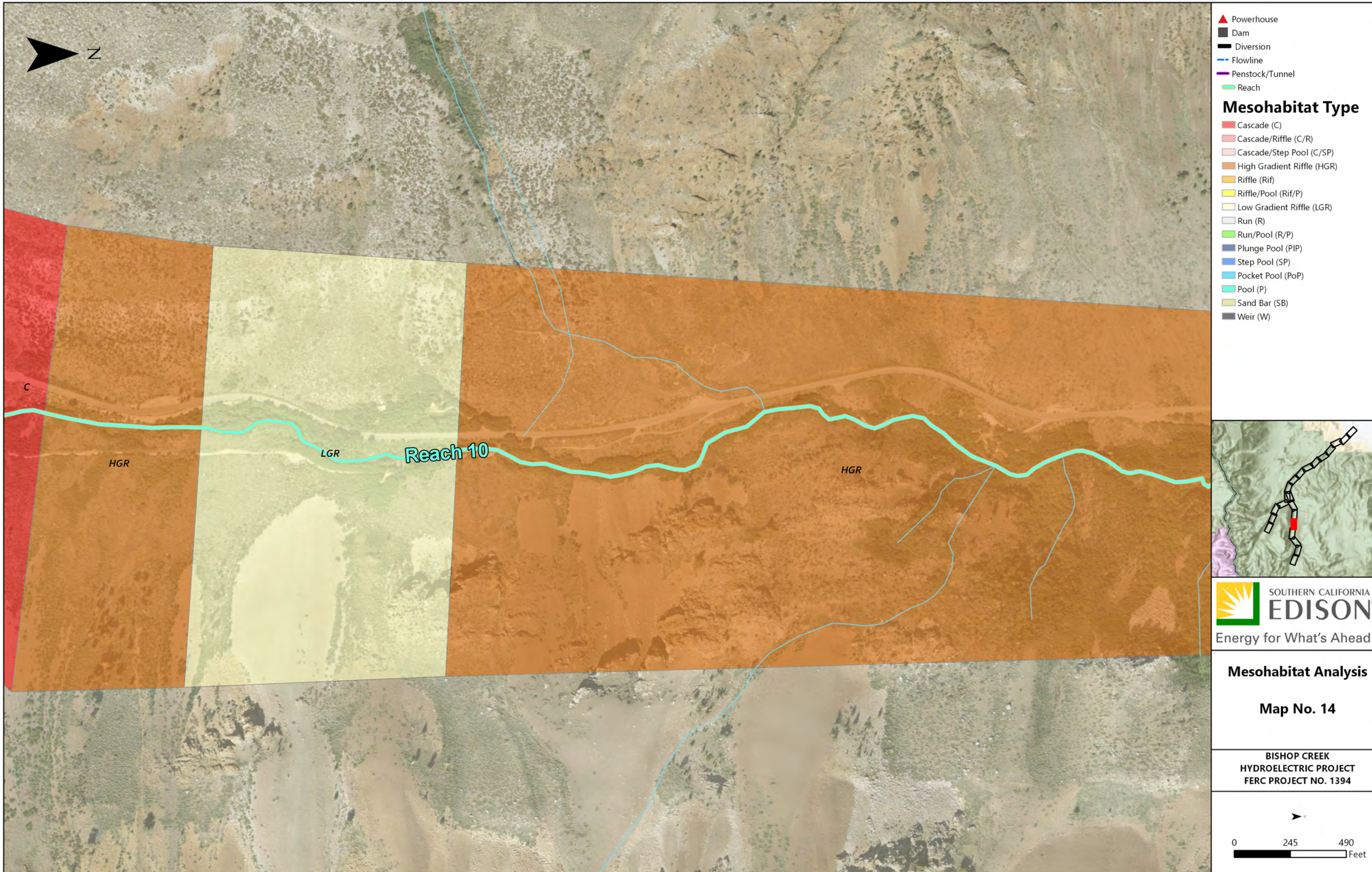
Mesohabitat Analysis

Map No. 13

BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394

0 245 490 Feet



N
C
HGR
LGR
Reach 10
HGR
Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach
Mesohabitat Type
Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PlP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)
SOUTHERN CALIFORNIA EDISON
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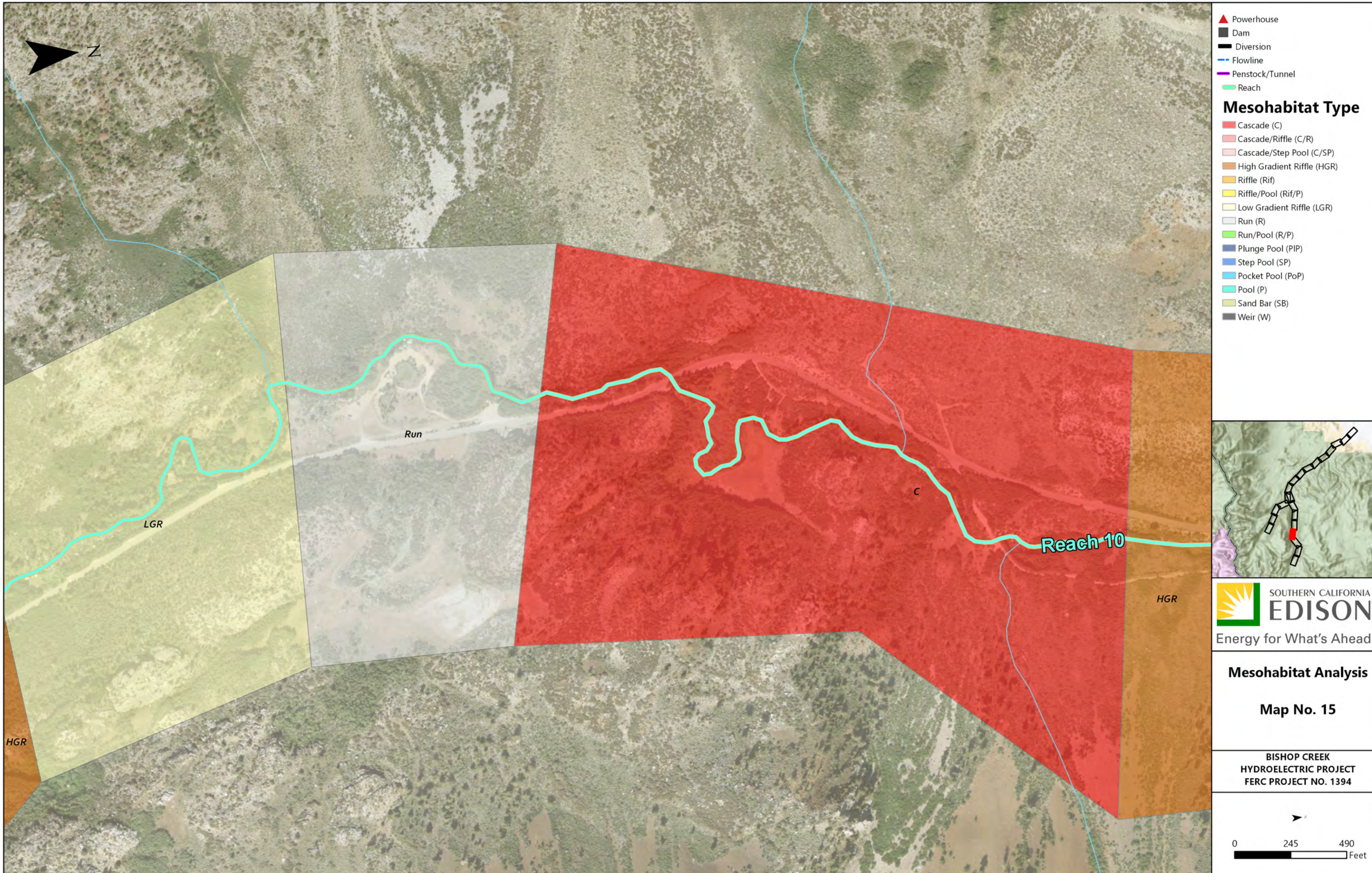
Mesohabitat Analysis
Map No. 14
BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394
0 245 490 Feet



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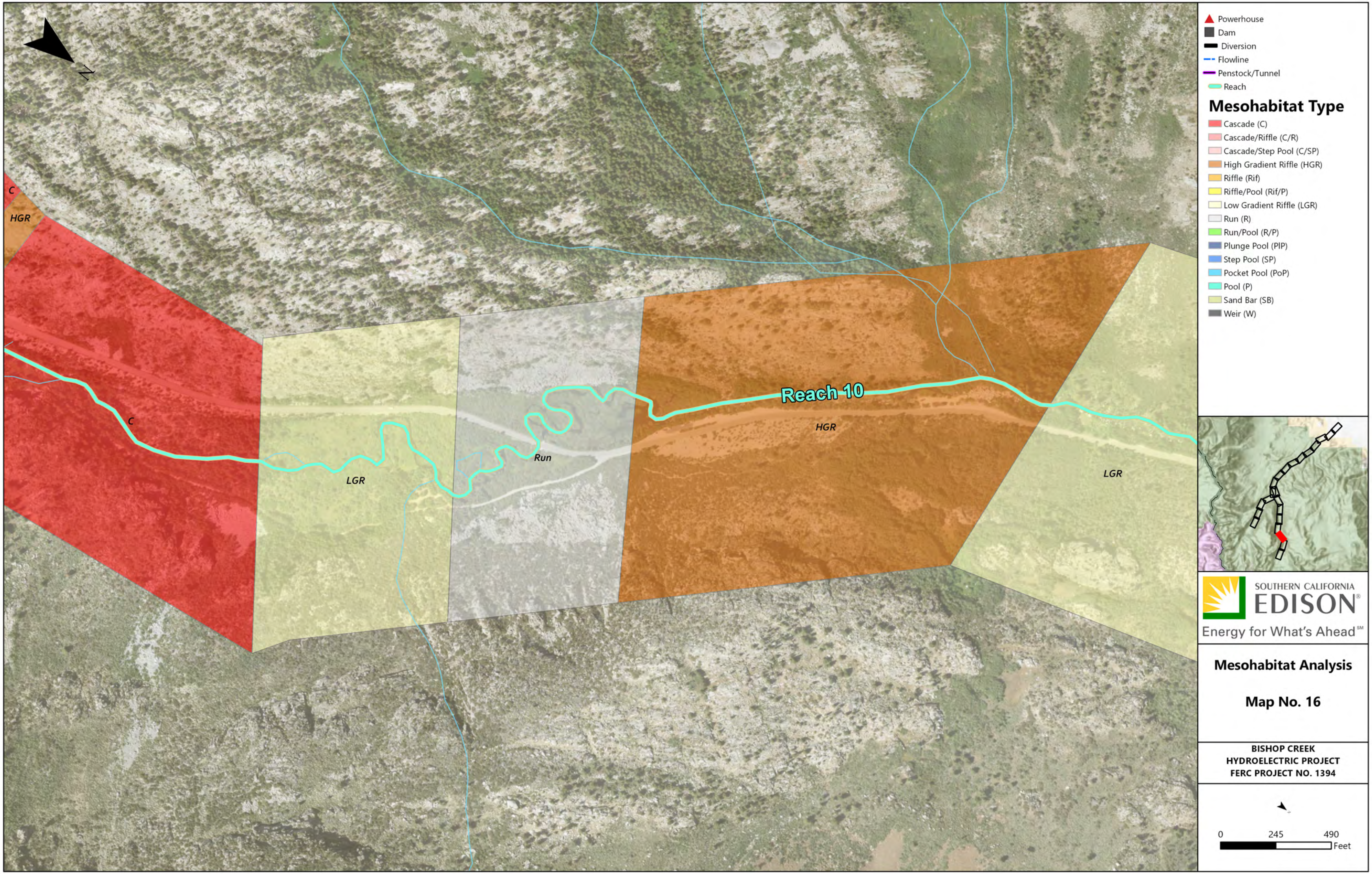
Mesohabitat Analysis

Map No. 15

BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394



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Mesohabitat Analysis

Map No. 16

BISHOP CREEK HYDROELECTRIC PROJECT
FERC PROJECT NO. 1394

Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach

Mesohabitat Type

Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PlP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)

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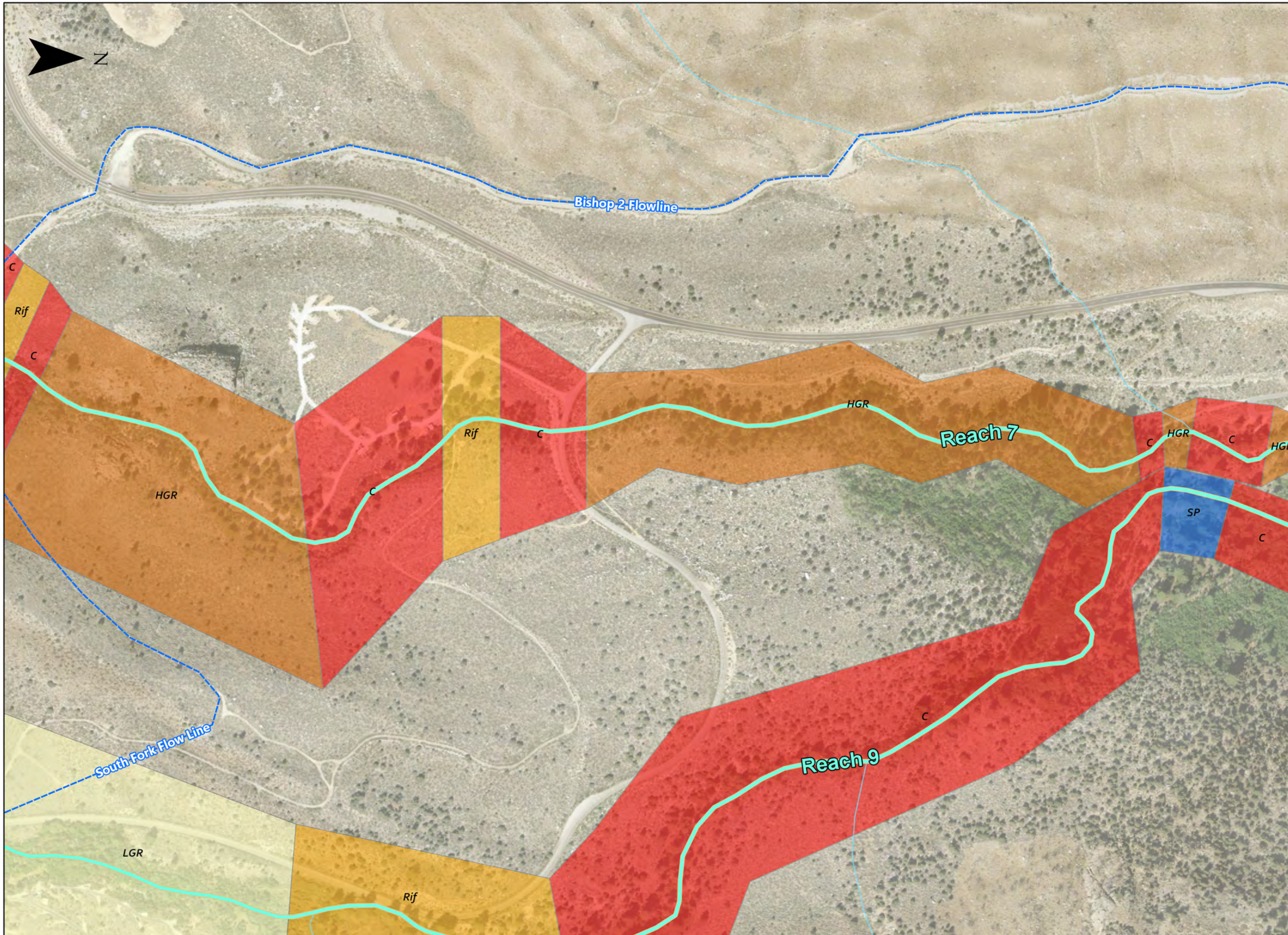
Mesohabitat Analysis

Map No. 17

BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394

0 245 490 Feet

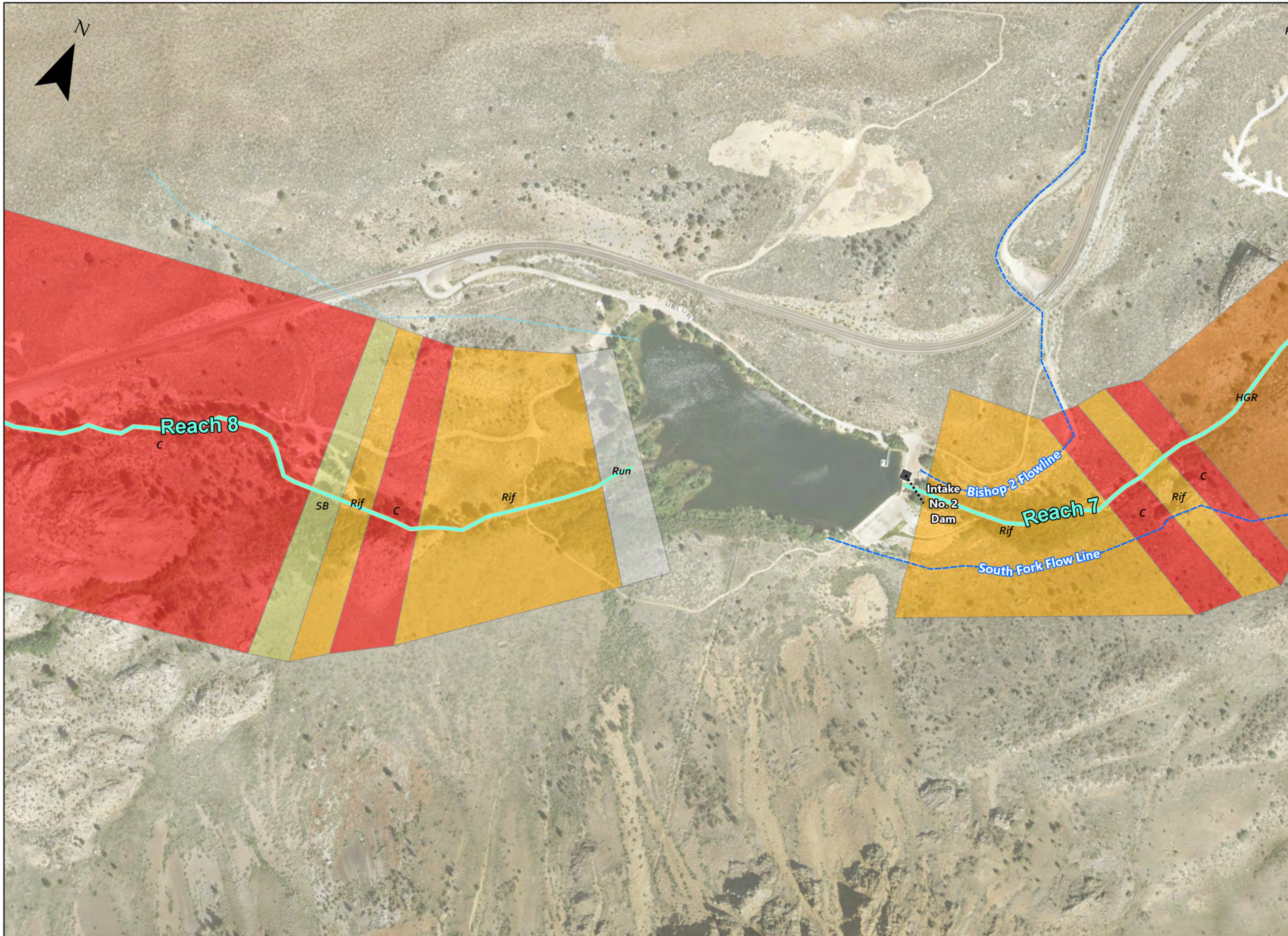
N
South Lake Dam Tunnel
Hillside Dam
Green Creek Flow Line
Reach 10
HGR
LGR
HGR
C
Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach
Mesohabitat Type
Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PlP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)
SOUTHERN CALIFORNIA EDISON
Energy for What's Ahead
Mesohabitat Analysis
Map No. 18
BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394
0 245 490 Feet



Mesohabitat Analysis

Map No. 19

BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394



Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach

Mesohabitat Type

Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PlP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)

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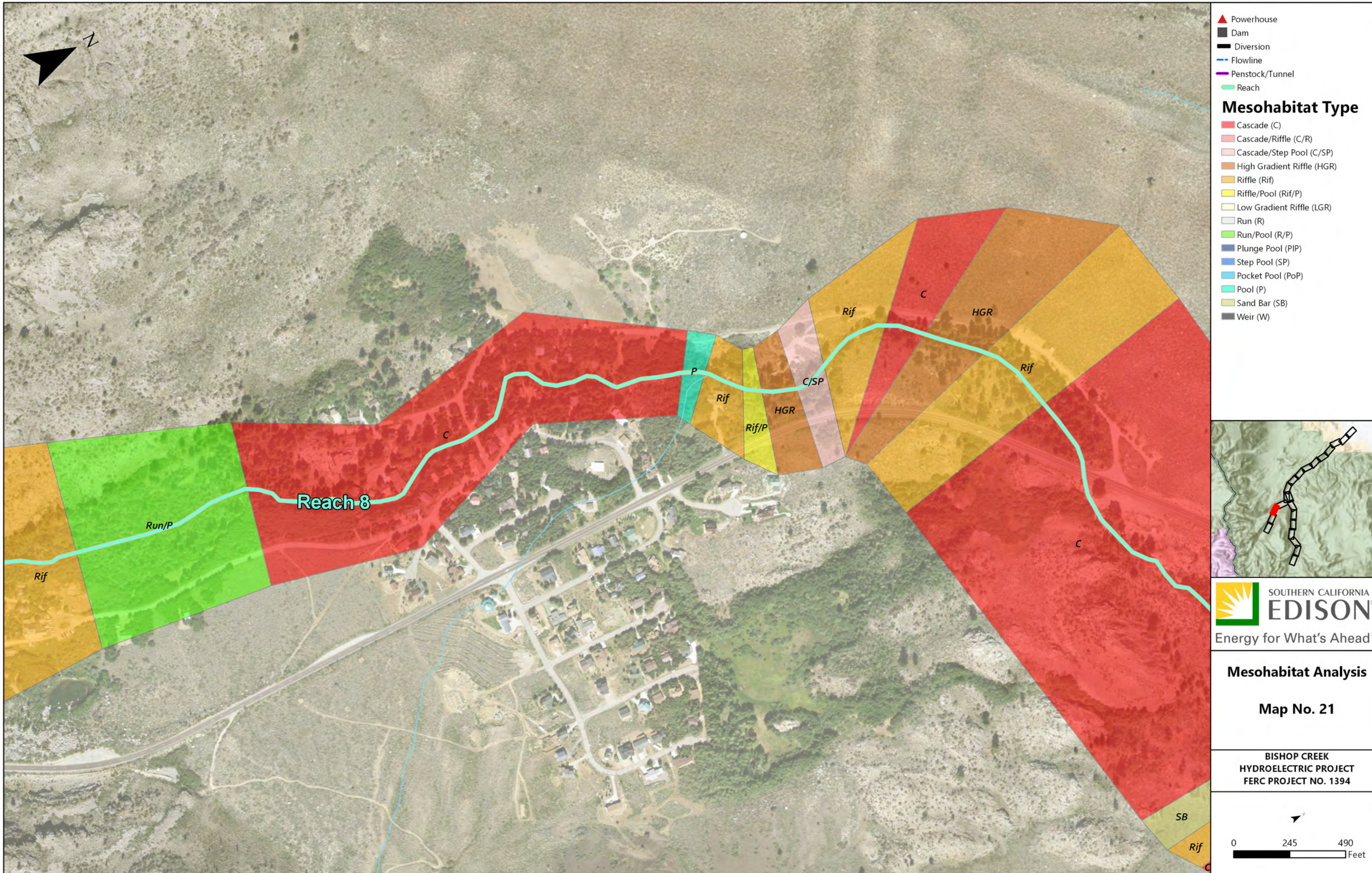
Mesohabitat Analysis

Map No. 20

BISHOP CREEK
HYDROELECTRIC PROJECT
FERC PROJECT NO. 1394

0 245 490
Feet



N
Reach 8
Rif
Run/P
C
P
Rif
Rif/P
HGR
C/SP
Rif
C
HGR
Rif
C
SB
Rif
Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach
Mesohabitat Type
Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PlP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)
SOUTHERN CALIFORNIA EDISON
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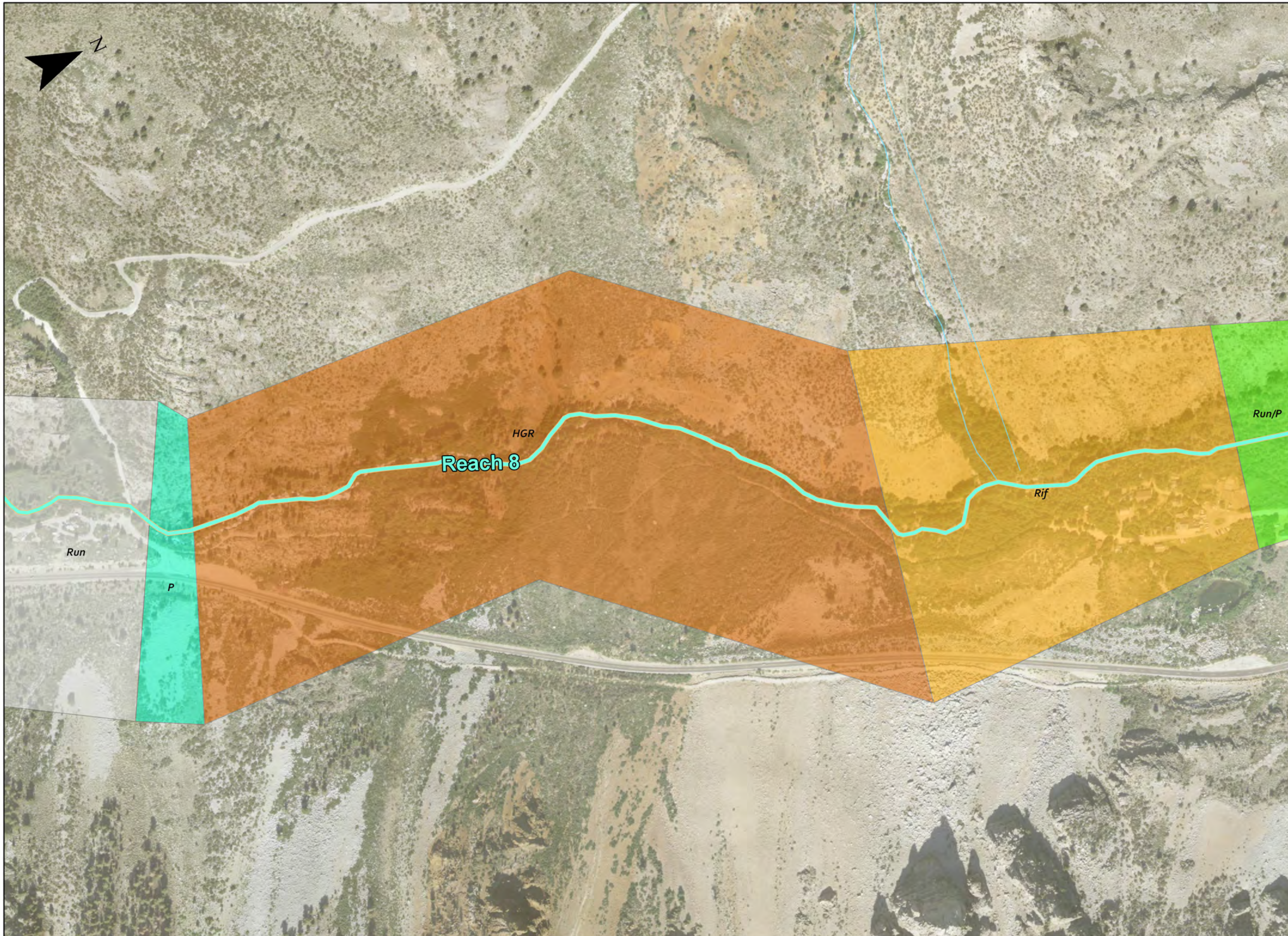
Mesohabitat Analysis
Map No. 21
BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394
0 245 490 Feet



Powerhouse
Dam
Diversion
Flowline
Penstock/Tunnel
Reach

Mesohabitat Type

Cascade (C)
Cascade/Riffle (C/R)
Cascade/Step Pool (C/SP)
High Gradient Riffle (HGR)
Riffle (Rif)
Riffle/Pool (Rif/P)
Low Gradient Riffle (LGR)
Run (R)
Run/Pool (R/P)
Plunge Pool (PlP)
Step Pool (SP)
Pocket Pool (PoP)
Pool (P)
Sand Bar (SB)
Weir (W)

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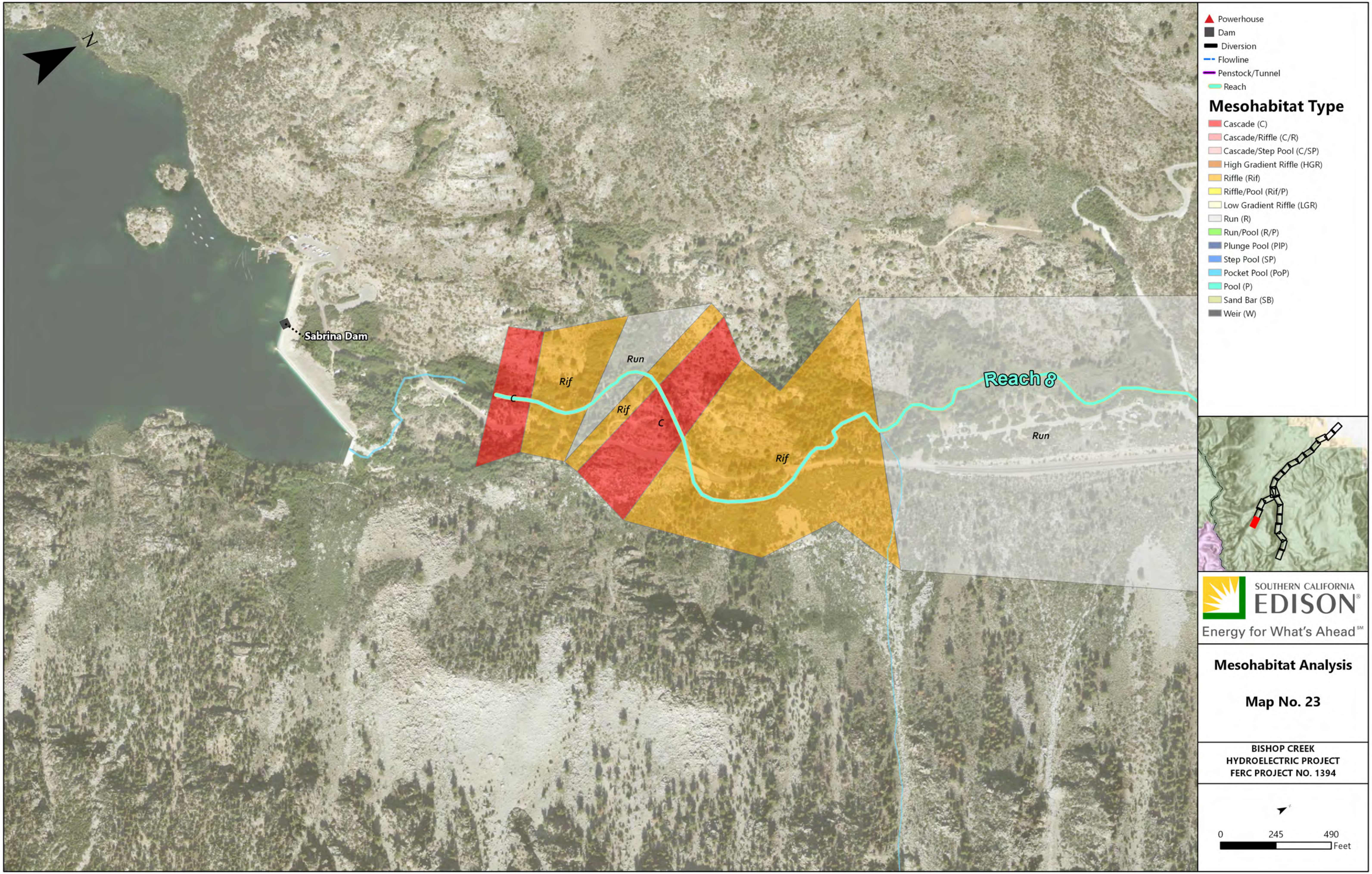
Mesohabitat Analysis

Map No. 22

BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394

0 245 490 Feet



Mesohabitat Analysis

Map No. 23

BISHOP CREEK HYDROELECTRIC PROJECT FERC PROJECT NO. 1394

BISHOP CREEK PROJECT
INSTREAM FLOW NEEDS

TO: Bishop Relicensing TWG

FROM: Brandon Kulik, Kleinschmidt

CC Matt Woodhull, Southern California Edison
Finlay Anderson, Kleinschmidt

SUBJECT: PHABSIM transect selection - Summary of conference call

DATE: October 25, 2019

Southern California Edison (SCE) is currently undergoing relicensing for the Bishop Creek Hydroelectric Project (FERC Project No. 1394) (Project), utilizing the Integrated Licensing Process (ILP) pursuant to 18 CFR § 5.6, with additional consultation conducted early in the process to allow certain field studies to be implemented without delay. During consultation the Fisheries Technical Working Group (TWG) identified the need for an Instream Flow Incremental Methodology (IFIM) study to assess and potentially refine the existing minimum flow requirements below the Project's spillways. Existing minimum flows are based on the results of an IFIM study conducted during the prior relicensing (EA, 1986). The IFIM study will be supported by a Physical Habitat Simulation (PHABSIM) model, and as such, SCE subsequently developed a study plan in consultation with the TWG to address the issue which calls for a mesohabitat survey the Bishop Creek study area as a precursor for selecting study sites for further PHABSIM modeling. During September 2019, SCE conducted a mesohabitat survey (See memo of October 4, 2019) that informed the TWG 's initial selection of reach-specific study sites. This memo summarizes transect selection decisions completed by the TWG on the conference call of October 24, 2019.

The TWG convened a webinar-format conference call on October 24 to scrutinize detailed aerial drone photography and high-resolution video flyovers of each reach. Each flyover was reviewed and discussed. Movie clips were rerun and paused at candidate transect locations and boundaries. An image was harvested from each video so that specific collectively selected transects could be marked to document decisions.

Reaches are numbered sequentially from downstream to upstream following the pattern established in the prior IFIM Study (*EA Engineering, Science and Technology, Inc. 1988*). Reach boundaries occur at key hydrologic influences such as spillways and confluences of major tributaries including Coyote Creek, and the Middle and South forks of Bishop Creek, for a total of 10 reach segments. For purposes of this memo, transects have been provisionally numbered sequentially from downstream to upstream, following standard PHABSIM protocol.

A study site was located in each reach. The TWG agreed that the focus should be on **critical** habitat rather than **representative** habitat. Critical habitat refers to those mesohabitats that are strategic to the targeted species and life stages regardless of whether it is a commonly-occurring mesohabitat or not. For example, the mesohabitat mapping survey demonstrated that cascades, high gradient riffles and plunge pools are dominant mesohabitats in most of the reaches. However, it was agreed that the target species (*Brown trout, Owens sucker and speckled dace*) all prefer the less commonly-occurring lower gradient mesohabitat such as pools, runs and lower gradient riffles. The TWG further targeted a minimum of three transects per study site to ensure that natural variability of stream morphology, cover and hydraulics was adequately captured. The exact number of transects per reach would, however, be governed by local site-specific stream channel complexity.

It was also recognized that the high gradient of reaches 4 and 6 resulted in such a high degree of cascade and plunge pool hydraulics that modeling was infeasible. Instead the group agreed that Habitat Criteria Modeling (HCM) approach suggested by Tristan Leong (USFS) would be substituted[1].

The subject reaches are shown in Figure 1.

Bishop Creek. This portion of the study area was divided into a total of six hydrologic reaches on Bishop Creek, numbered from downstream to upstream. Flows in Reaches 1 and 2 are influenced by releases from the Intake 6 and Intake 5 spillways, respectively. Reach 3 flow is influenced by releases from Intake 4 and Coyote Creek discharge; Reach 4 is solely influenced by releases from Intake 4. Reach 5 is influenced by releases from Intake 3. Reach 6 receives flow from both the Middle Fork and the South Fork of Bishop Creek.

Middle Fork Bishop Creek. Reach 7 is influenced by releases from Intake 2; Reach 8 is influenced by releases from Sabrina Lake.

South Fork Bishop Creek. Reach 9 is influenced by releases from the Intake 2 diversion; Reach 10 is influenced by releases from South Lake.

[1] The HCM relies on obtaining empirical measurements at specific flow “snapshots” with no simulation or extrapolation to other flows.

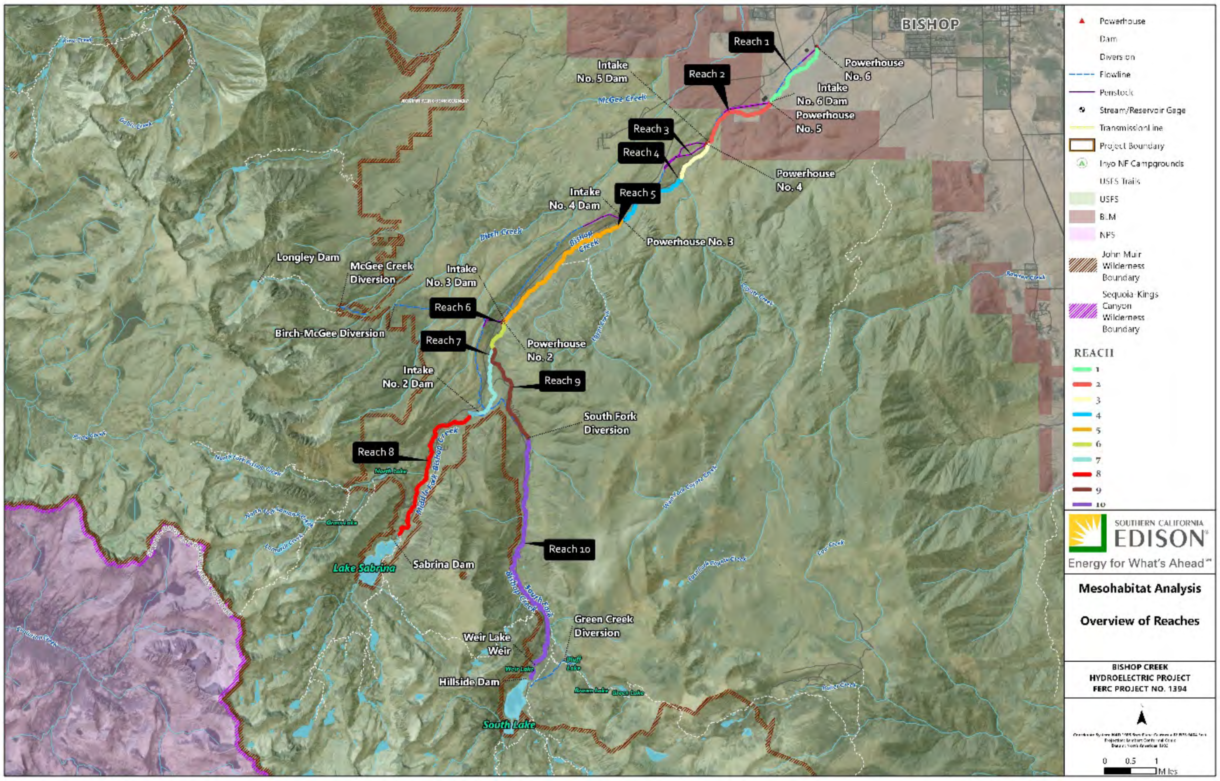


FIGURE 1 BISHOP CREEK IFIM STUDY AREA.

SUMMARY

Reach 1

Critical mesohabitat in this reach was identified as the repeating pattern of low gradient riffle/shallow pool complexes. The overall pattern repeats, but there are variations in microhabitat features such as channel geometry, substrate, and presence/absence of point bars.

PHOTO PLATE 1 REACH 1, BISHOP CREEK.

Reach 2

Mesohabitat in this reach is dominated by riffles separated by steeper cascades. The IFIM study site was located in a section of riffle, mixed with shallow pools that likely transition to runs at higher flows. A total of four transects were selected to characterize both riffles and pool/runs

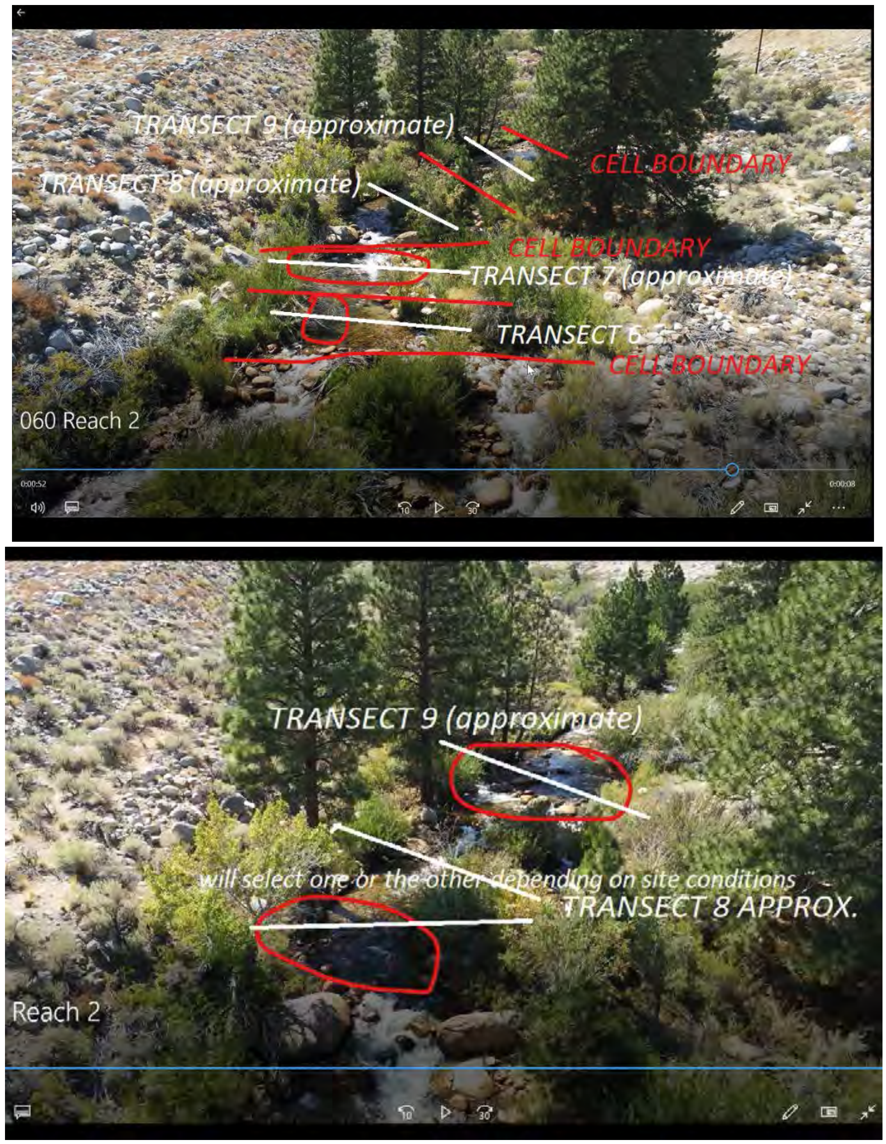


PHOTO PLATE 2. STUDY SITE 2, BISHOP CREEK. (*SECOND PHOTO SHOWS TRANSECTS 8 AND 9 MORE CLEARLY*)

Reach 3

Critical habitat in Reach 3 is dominated by riffle mesohabitat with scattered small pools. A total of four transects were selected to depict both pool and riffle habitat variations.

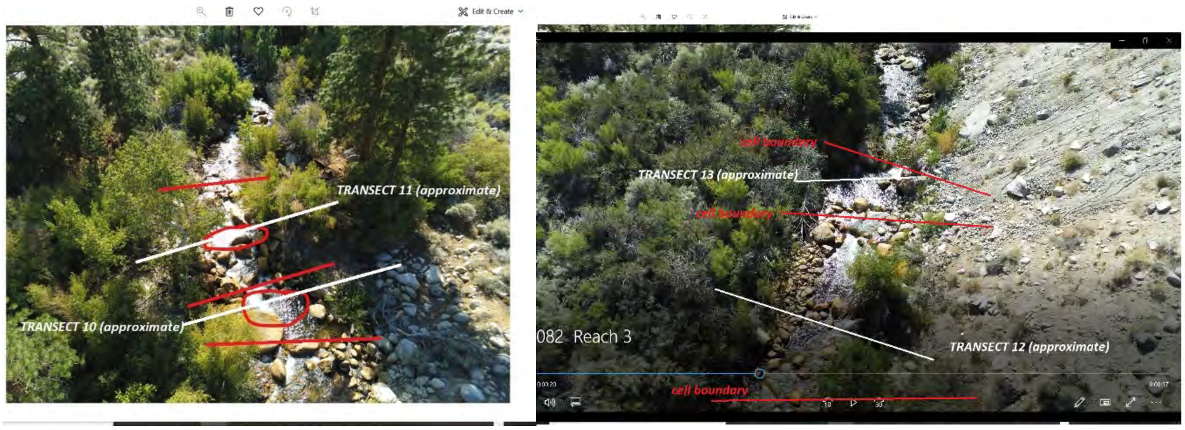


PHOTO PLATE 3 REACH 3 IFIM STUDY SITE

Reach 4

Reach 4 is dominated by very high gradient riffles (i.e., approximately 5% or greater slopes); cascades (25%) and step pools (23%) . The TWG concluded that this site would be best documented using the HCM methodology. It was agreed that the field team could select two pools to survey. Each pool should depict a balance of different cover quality and volume conditions to the extent possible.

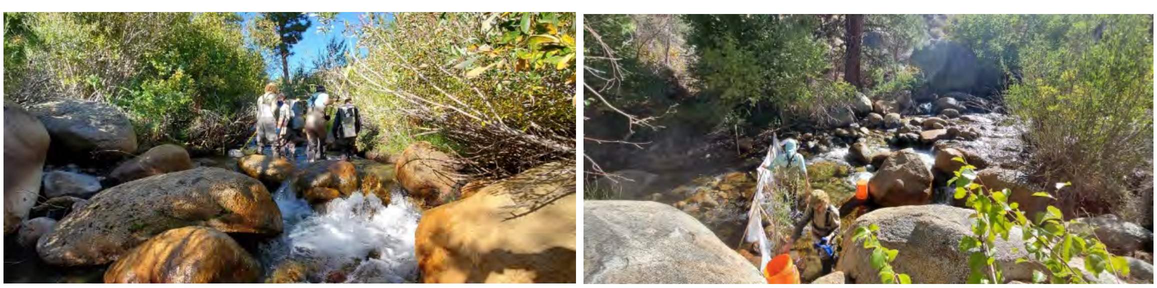


PHOTO PLATE 4. CASCADE/STEP POOL MESOHABITAT IN REACH 4, BISHOP CREEK.

Reach 5

Reach 5 is dominated by cascade mesohabitat (58%); riffle (21%) and cascade/riffle complexes. The TWG determined that the lower gradient riffle habitat was the most critical in this reach. Three transects were selected to account for natural channel variability.

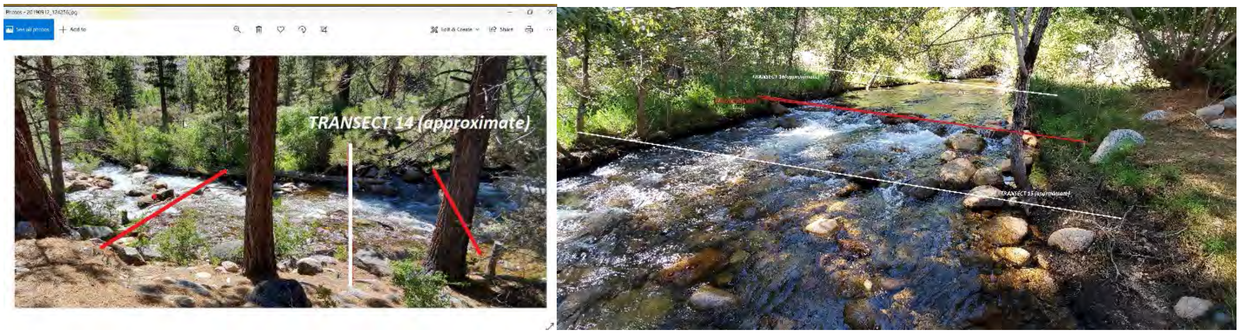


PHOTO PLATE 5. STUDY SITE 5, BISHOP CREEK.

Reach 6

Reach 6 is dominated by cascade mesohabitat. It will receive the same treatment as Reach 4.

Reach 7

Reach 7 is dominated by high gradient riffle (53%) and cascade (30%) mesohabitat; riffle (15%) and occasional riffle-pool (2%) mesohabitats are also present. Pools are extremely small. The TWG determined that the lower gradient riffle habitat was the most critical in this reach. Three transects were selected to account for natural channel variability and to capture both riffle and pool mesohabitats.

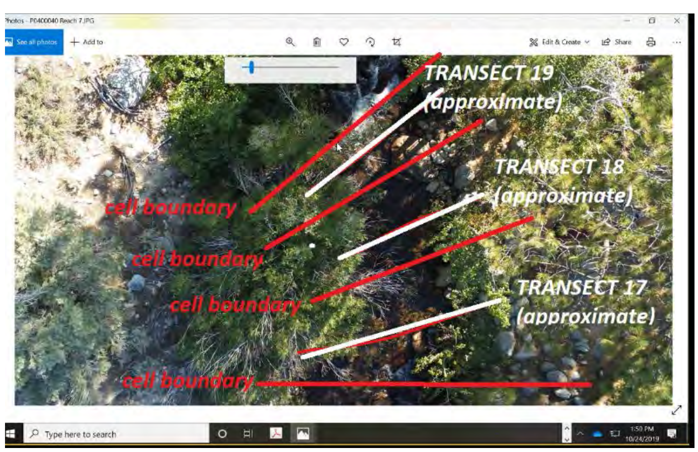


PHOTO PLATE 6. STUDY SITE 7, BISHOP CREEK.

Reach 8

Reach 8 contains significant low gradient habitats, including consecutive run, run-pool, and pool habitat in the Aspendell vicinity, collectively contributing approximately 19% of the mesohabitat in this reach. This area has numerous braided channels, woody debris and varied substrates. Such expansive complexes are relatively unique in this watershed and are rich in woody debris cover, including scour holes, undercut banks, and overhead cover. The TWG concluded that this was the most critical habitat to model in this reach. However, after review of video and photos, it was concluded that a site visit would be required to adequately select transects[2]. It is anticipated that 3 or 4 transects may be required to characterize the critical mesohabitat in this reach.

PHOTO PLATE 7. REPRESENTATIVE RUN-POOL, RIFFLE, MESOHABITAT IN REACH 8, MIDDLE FORK BISHOP CREEK.

Reach 9

Reach 9 is dominated by cascades and riffles. The TWG determined that low gradient riffles were the critical habitat in this reach, located a study site in the low gradient riffle near the U.S. Forest Service's Four Jeffreys Campground, and selected three transects to portray natural stream channel variability. The study site boundary will be established to avoid any hydraulic influence of the road bridge.

[2] A site visit has been tentatively scheduled for November 4, 2019.

Kleinschmidt

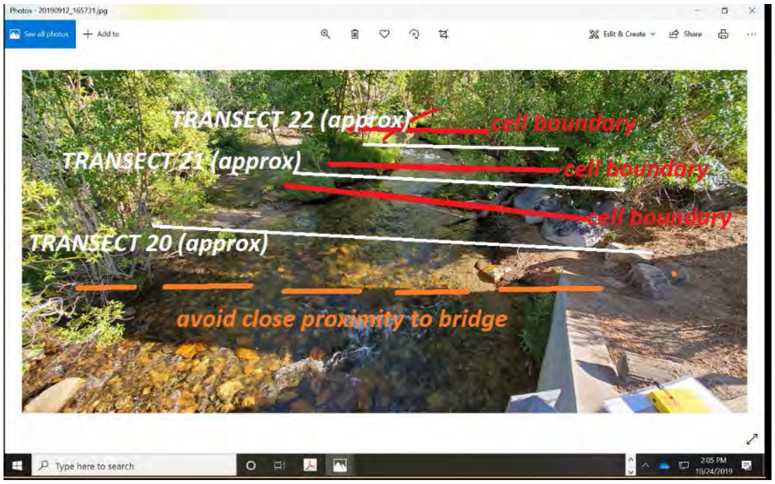


PHOTO PLATE 8 STUDY SITE 9, SOUTH FORK BISHOP CREEK.

Reach 10

Reach 10 is generally high gradient, but also is comprised of meandering run habitat, with sand and gravel substrates, and extensive meadow surrounding with riparian brush. The runs feature excellent undercut banks as well as large boulder object cover. The TWG concluded that this was the most critical habitat to model in this reach. Two study sites were selected. Although channel conditions are relatively uniform, Site 10 A (at the lower end of this mesohabitat unit) includes run-pool characteristics with gravel dominated substrate, along with undercut banks and large object cover; Site 10A (at the upper end of this unit) is a riffle/run transition area with cobble and small boulder substrate. A total of four transects will be deployed. It was concluded that the field team could select transect locations at the time of the field study. Photo Plate 9 proposes a conceptual layout of the two sites.

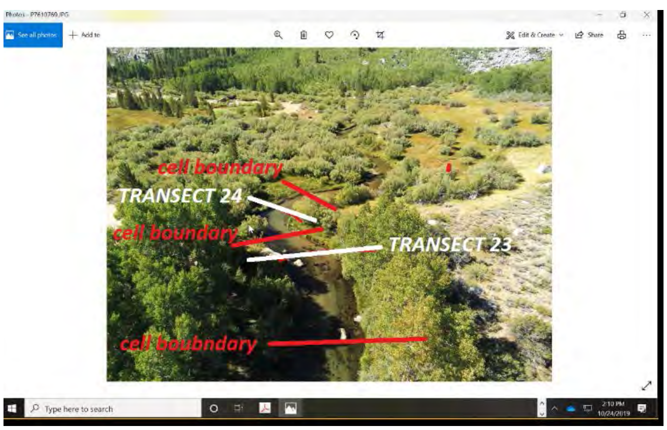


PHOTO PLATE 9. REACH 10 IFIM STUDY SITE, AND PROPOSED TRANSECT LOCATIONS.

Kleinschmidt

SUMMARY

REACH	TRANSECTS	NOTES
Reach 1	5	
Reach 2	4	
Reach 3	3	
Reach 4	2	Pocket pools will be survey using HCM methodology
Reach 5	3	
Reach 6	2	Pocket pools will be survey using HCM methodology
Reach 7	3	
Reach 8	Approximately 4	To be determined by TWG site visit
Reach 9	3	
Reach 10	4	To be located by field crew at time of survey

LITERATURE CITED

EA Engineering, Science and Technology, Inc. (EA). 1988. Instream flow and fisheries report for the Bishop Creek Hydroelectric Project. EA, Lafayette, CA. January 1986. 23 p. plus attachments.

MEMORANDUM

TO:	Bishop Creek Fish and Aquatics Technical Working Group (TWG)
FROM:	Brandon Kulik
DATE:	January 14, 2020
RE:	**INSTREAM FLOW STUDY - HABITAT SUITABILITY CRITERIA**

During scoping in 2018 and 2019 for the Bishop Creek Project relicensing, the Fish and Aquatics TWG discussed the development of the Bishop Creek instream flow study, and the species and lifestages for which Habitat Suitability Criteria (HSC) criteria would be required. This memo memorializes the discussion between the U.S. Forest Service (USFS),California Department of Fish and Wildlife (CDFW), and SCE/Kleinschmidt for developing HSC for following species and lifestages:

- Adult and juvenile brown trout (*Salma trutta*)
- Adult and juvenile Owens sucker (*Catostomus fumeiventris*)
- Adult speckled dace (*Rhinichthys osculus*)

On Friday, January 17, 2020, the USFS and CDFW participated in a conference call with Brandon Kulik from Kleinschmidt Associates, the lead fisheries scientist for the Bishop Creek relicensing. The purpose of the call was to discuss, review, and select the appropriate HSC so that the data analysis for the Bishop Creek Instream Flow Study could proceed. Kleinschmidt completed the primary portion of the field data collection during the 2019 field season. This memo summarizes the information discussed during the January 17, 2020, call and includes the HSC agreed to for brown trout and Owens sucker. Candidate HSC curves for speckled dace are currently unavailable; however, CDFW indicated that it has raw data and that may inform applicable HSC curves for this species. This will be considered separately once it becomes available.

Brown trout (*adult and juvenile*). Prior to the January 17 conference call, the USFS and CDFW recommended reviewing the following curve sources:

- HSC from the original Bishop Creek IFIM Study (EA Science and Engineering (1986), which were based on work by Acientuno (unpublished data),
- Strakosh, *et al*. (2003) (adult lifestage only), and,
- Bovee (1978).

All curve sets appear to be based on preference or habitat use studies (*i.e*., frequency analysis based on empirical measurements of the depths, velocities, and substrates that are volitionally chosen by the subject species and lifestages).

Original Bishop Creek HSC. There were concerns from the TWG regarding the applicability of these curves to the present study. It was noted that the depth and velocity curves have a series of cover-conditional alternatives,[1] including “No Cover,” “Overhead Cover,” “Object Cover,” and “Combined.” However, the study report lacks a functional definition of what constitutes these cover types in terms of proximity to the transect locus, the extensiveness of such cover, and how they should be applied. It also does not clarify what “Combined” conditions look like. These curves also have anomalies for velocity that may be artifacts of small sample sizes. Because of these uncertainties, the TWG agreed that use of the original Bishop Creek HSC would be eliminated as a potential analysis approach.

Strakosh et al. (2003). These HSC were developed rigorously in a small stream environment arguably like Bishop Creek in terms of channel sizes, depths, and instream cover conditions. Thus, the TWG agreed that they are reasonably realistic for use on the Bishop Creek study. These criteria only apply to the adult life stage.

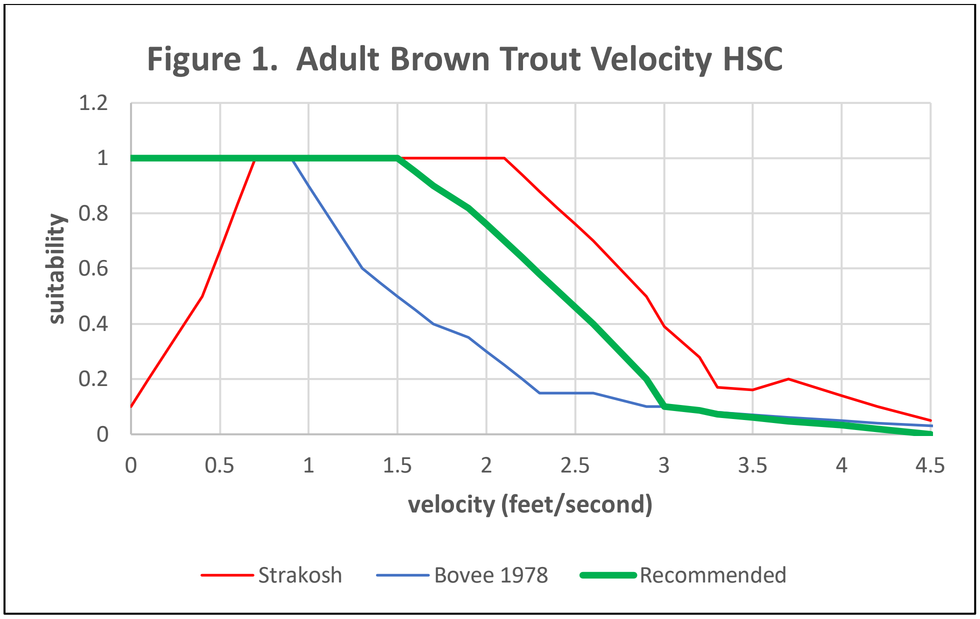
Bovee (1978). While these curves are the oldest of the three options considered, the TWG noted that they have robust data sources from many independent observations and continue to be used throughout many studies.

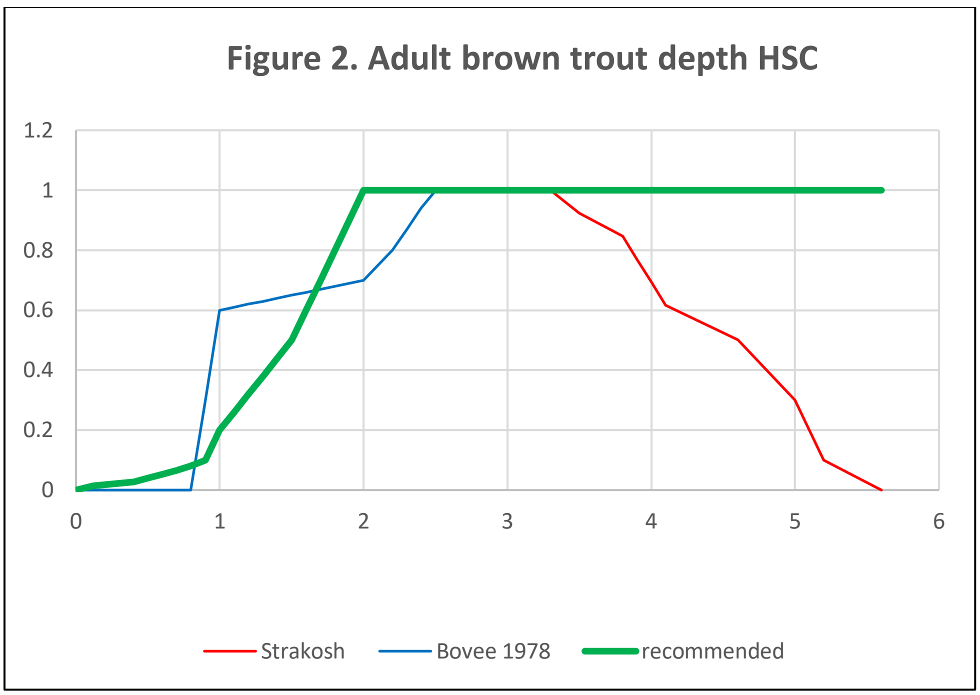
The TWG agreed to use HSC from the Bovee (1978) and Strakosh *et al.* (2003) curves, with some minor modifications. Those modifications are discussed and presented below.

Adult brown trout

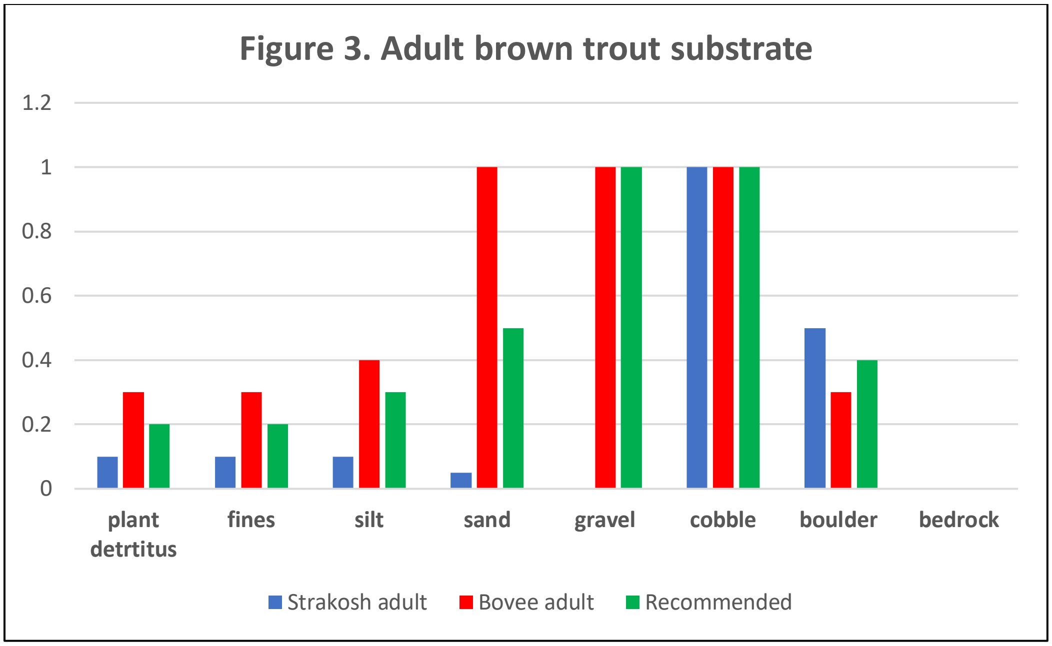
For adult brown trout velocity criteria, the TWG agreed to adopt Bovee (1978) for velocities of 1.5 feet per second (fps) or less, but modify the curves so that suitability decreases to 0.1 at a velocity of 3.0 fps and falls to 0.0 at 4.5 fps (Figure 1). For adult brown trout depth criteria, it was agreed to use the ascending arm of Strakosh *et al*., (2003) and the descending arm of Bovee (1978) (Figure 2).

[1] Cover-conditional criteria assume that fish will tolerate different ranges of depth and velocity depending on the presence or absence of various cover conditions.



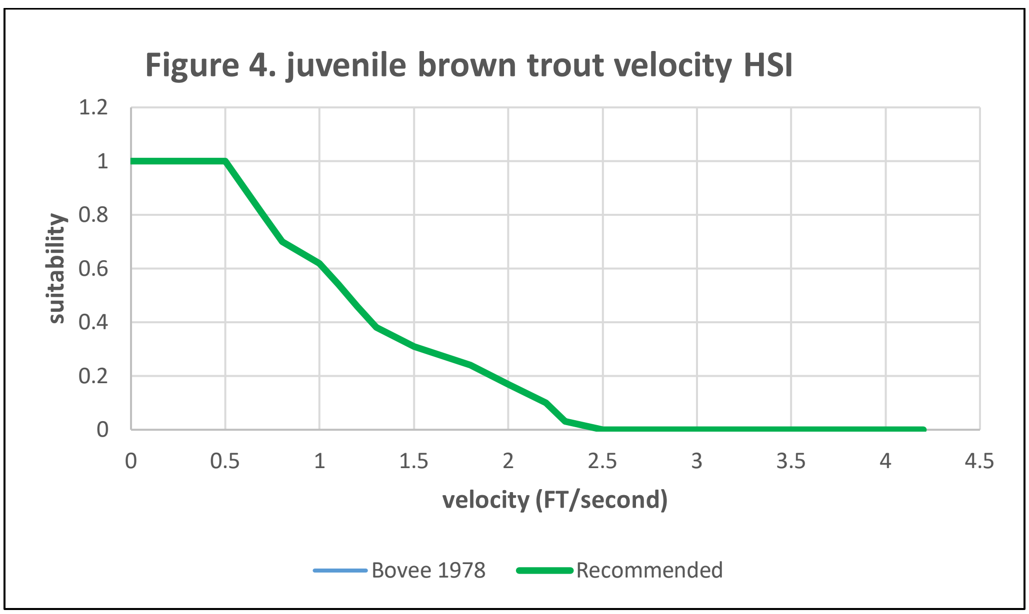


Gravel boulder and cobble are the most common substrates in Bishop Creek; Gravel and boulder are rated by Bovee (1978) as optimal for adult brown trout (Figure 3). Strakosh *et al.* (2003) does not include gravel as a substrate type. Other substrates (*e.g.*, bedrock, boulder) are generally rated by both authors as less suitable for adult brown trout, although with differing values. Bovee (1978) rates sand as optimal, whereas Strakosh *et al*. (2003) rates it as poor. Where there is a disparity among authors, the TWG proposes to adopt an intermediate value (Figure 3).

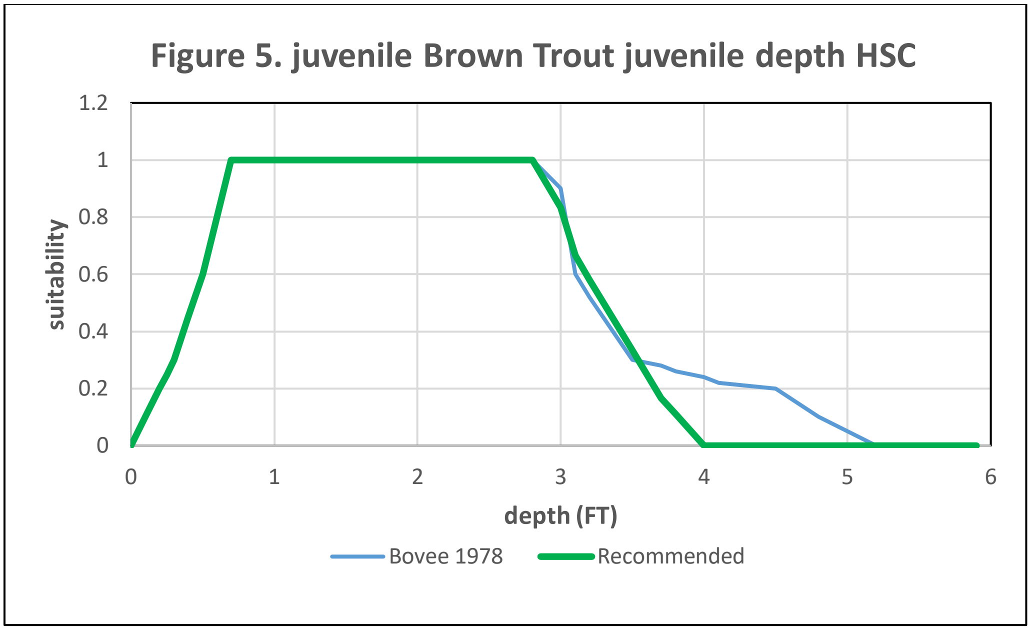


Juvenile brown trout

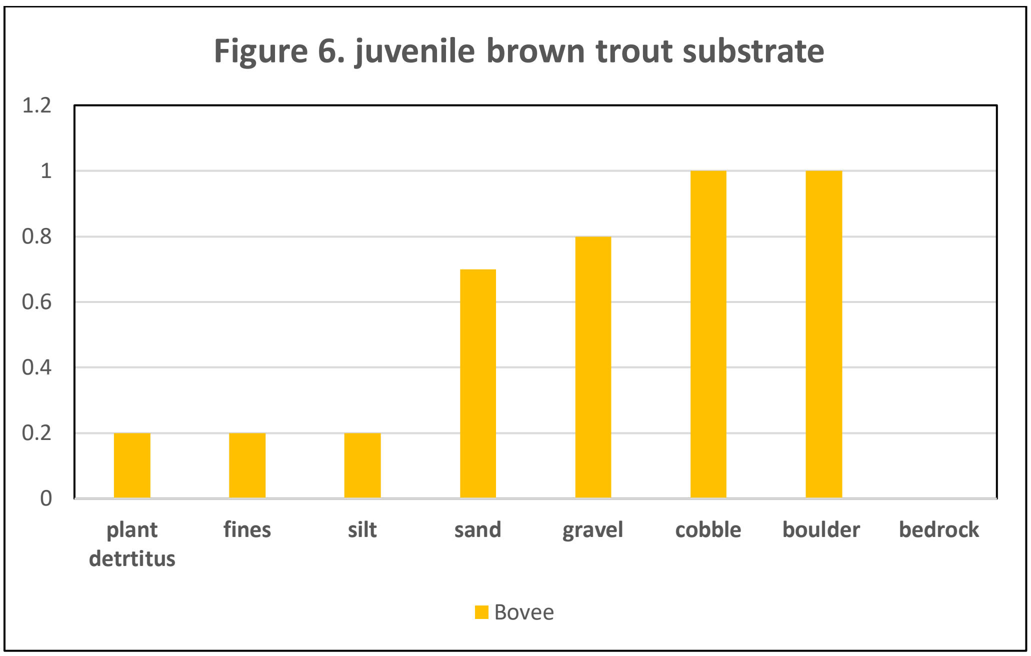
For juvenile velocity criteria, it was agreed to adopt Bovee (1978) for the entire range of velocities (Figure 4). For depth criteria, it was agreed to use the ascending arm of Bovee (1978) and modify the descending arm to be unsuitable (HSC=0.0) above 4 fps (Figure 5).



Kleinschmidt



For juvenile brown trout substrate criteria, the TWG agreed to adopt Bovee (1978) (Figure 6).



Adult and Juvenile Owens sucker

The TWG members concluded that habitat use for Owens sucker was similar to that of Sacramento sucker (*Catostomus occidantalis*) for which HSC were available. HSC curves for Sacramento sucker were provided courtesy of Dan Teater of the USFS (personal communication, December 19, 2019, with Tristan Leong, USFS) as they have been successfully used in recent PHABSIM models in California (T. Leong, *personal communication*). Figure 7 – Figure 10 show the agreed-to velocity and depth criteria for adult and juvenile Owens sucker. CDFW noted during the January 17, 2020, call that Owens sucker are adaptable to a wide range of substrates, and detailed substrate preferences are not currently available for the species. Based on this, for purposes of this model the TWG agreed to consider all substrates as optimal (HSC value of 1.0).

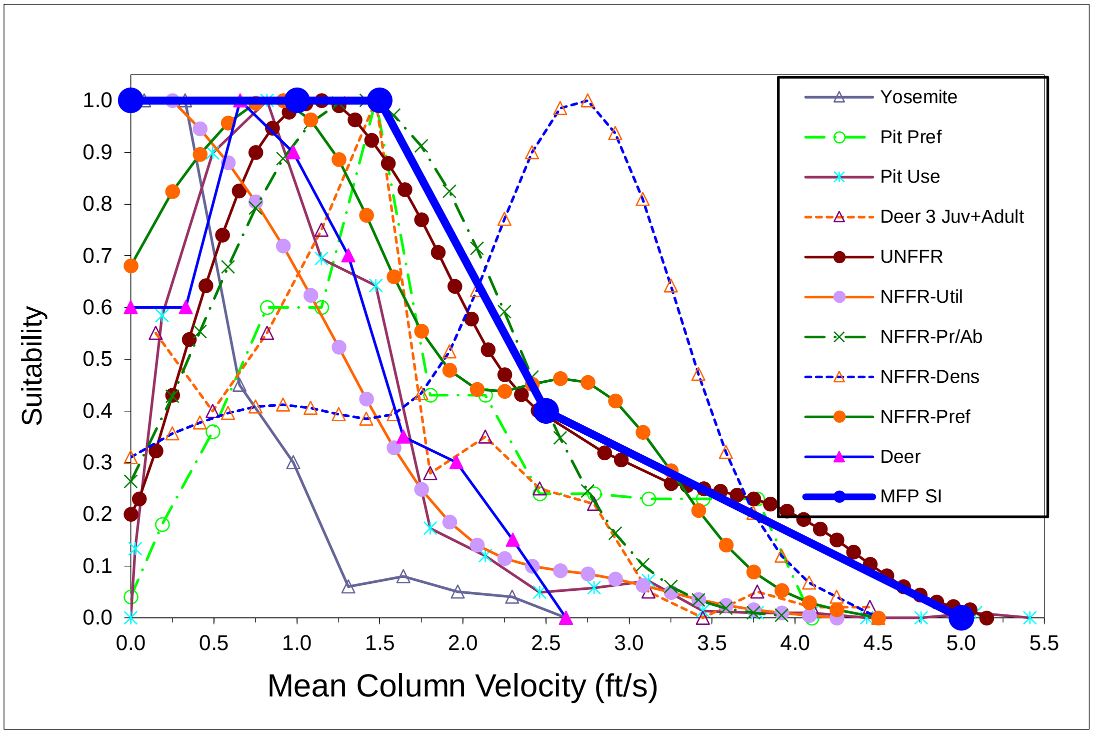


Figure 7. HSI curves for Adult Sacramento sucker velocity suitability based on multiple studies. The heavy blue line indicates the recommended criteria values by author (Dan Teater, personal communication with USFS).

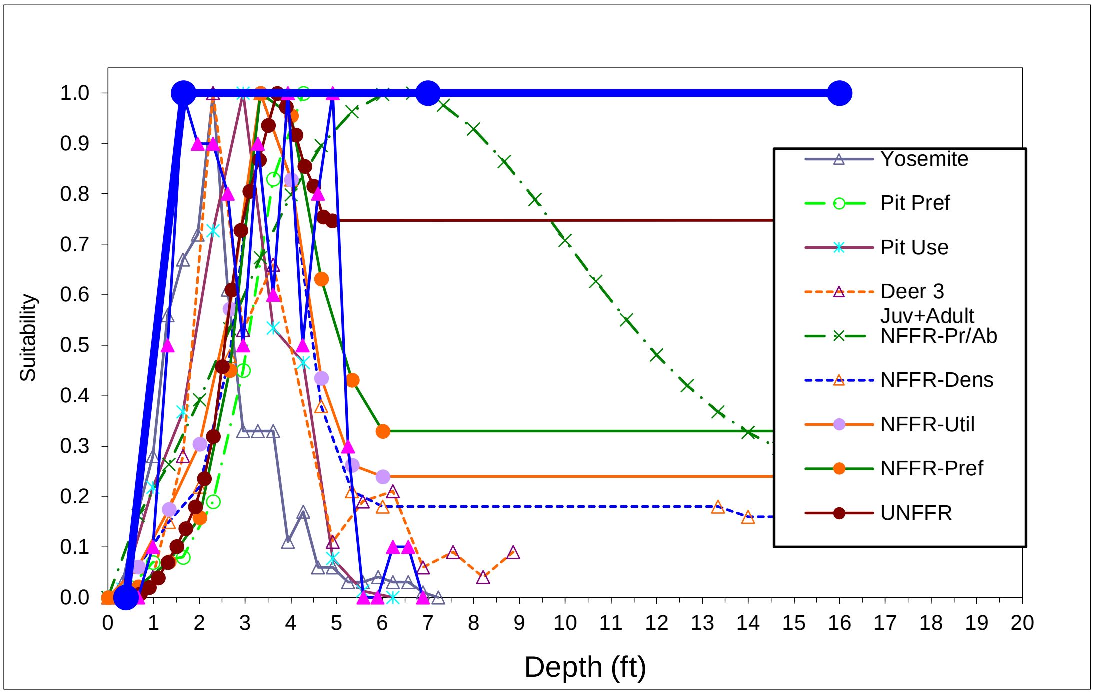


Figure 8. Adult Sacramento sucker depth suitability based on multiple studies. The heavy blue line indicates the recommended criteria values by author (Dan Teater, personal communication with USFS).

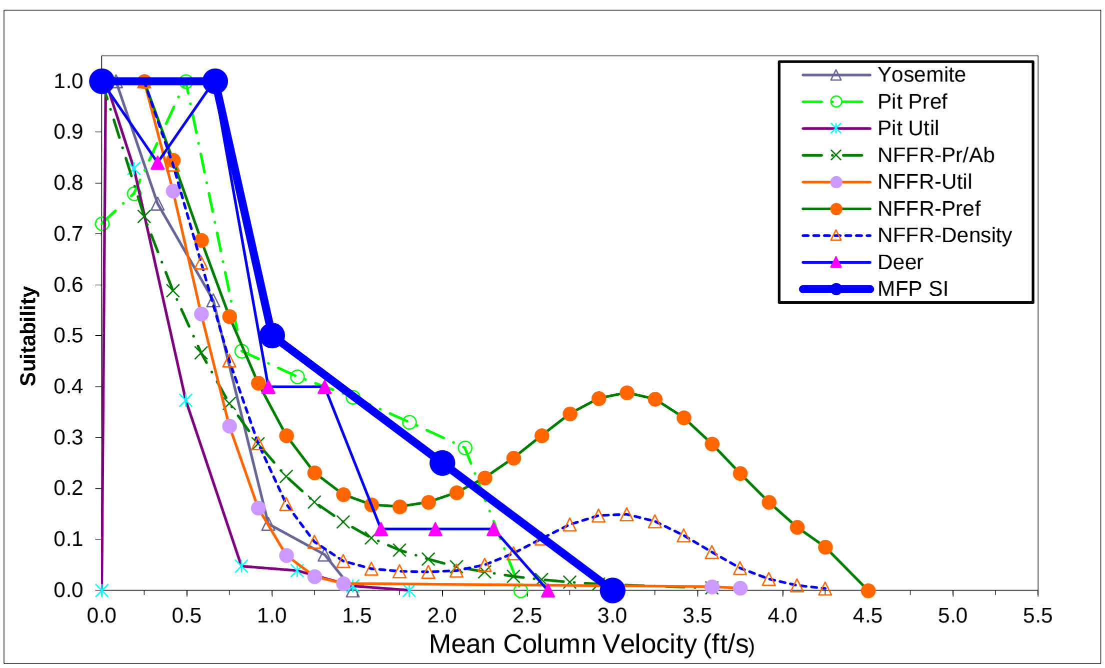


Figure 9. Juvenile Sacramento sucker velocity suitability based on multiple studies. The heavy blue line indicates the recommended criteria values by author (Dan Teater, personal communication with USFS).

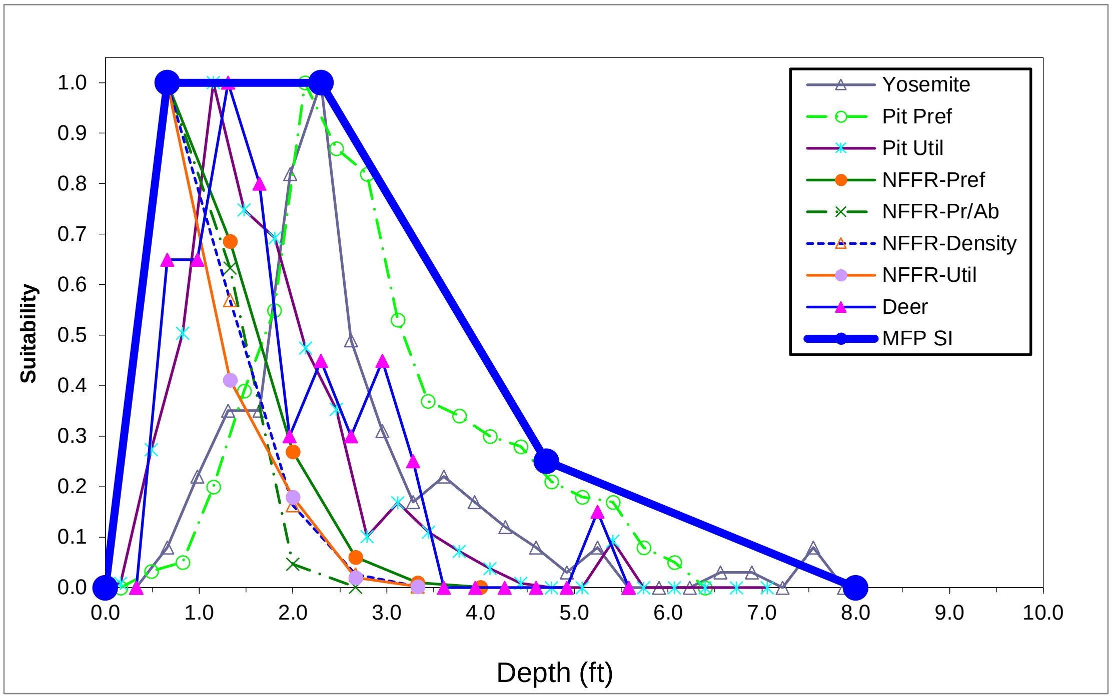


Figure 10. Juvenile Sacramento sucker depth suitability based on multiple studies. The heavy blue line indicates the recommended criteria values by author (Dan Teater, personal communication with USFS).

LITERATURE CITED

Bovee, K.D. 1978. Probability of use criteria for the Family Salmonidae. Instream flow information paper 4. FWS/OBS 78/07. 96 pp.

EA Science Engineering and Technology Inc. 1986. Instream flow and fisheries report for the Bishop Creek Hydroelectric Project. Prepared for Southern California Edison Co. EA, Lafayette, CA. January 1986. 178 pp.

Strakosh, T.R., R.M. Neuman and R. Jacobsen. 2003. Development and assessment of habitat suitability criteria for adult brown trout in southern New England rivers. Ecology of Freshwater Fish: 12:265-274.

From: Buckmaster, Nick@Wildlife <Nick.Buckmaster@wildlife.ca.gov>
Sent: Tuesday, December 24, 2019 1:00 PM
To: Brandon Kulik <Brandon.Kulik@KleinschmidtGroup.com>; Leong, Tristan -FS <tristan.leong@usda.gov>
Subject: RE: Brown Trout HSC Question

Those curves look reasonable for Owens sucker. Owens Suckers seem to be pretty opportunistic in their substrate use- they are a desert fish, and that seems to make for less strict For BT, RT, and BK curves I recommend checking Stream Evaluation Report 87-2, which has Eastern Sierra specific habitat preference criteria for those species. Provided our curves look similar to those curves, I do not think that we will have a problem

Nick Buckmaster
Heritage and Wild Trout Program
California Dept. of Fish and Wildlife
760-872-1110

From: Brandon Kulik <Brandon.Kulik@KleinschmidtGroup.com>
Sent: Tuesday, December 24, 2019 8:35 AM
To: Leong, Tristan -FS <tristan.leong@usda.gov>
Cc: Buckmaster, Nick@Wildlife <Nick.Buckmaster@wildlife.ca.gov>
Subject: RE: Brown Trout HSC Question

Hi Tristan,

Thanks for sending these along, my initial reaction is that the MFP curves look reasonable for the sucker as they follow the trend of the most of the other sources. ? I defer to both of you on the extent to which these sucker curves are a good surrogate for Owens sucker.
what are your thoughts on substrate given that we are dealing with fairly coarse substrates at most sites other than study sites 8 and 10 I tend to think of suckers as gravitating more toward the fines /sand/gravel end of the spectrum (but that may just be my eastern bias)

re brown trout: I will pull and graph the original Bishop HSI against Bovee (1978) (not sure that I have those in my curve library, although I have the old Raleigh "Bluebook" criteria along with a number of curves that we use here in the east as browns are a commonly modeled species). If you can forward the Bovee curve or at least a link to them I can follow through. I can also share some of the curves we have used here in the east taken from streams that are somewhat comparable to Bishop (i.e. relatively small with lots of object cover such as boulders, undercuts snags etc) if you think that will help. I'm a little uncomfortable using rainbow trout criteria at least for the adult lifestage, compared to brown trout, as rainbows seem to be more velocity-tolerant, if not high-velocity specialists. I'm pretty sure that depth criteria would be transferable though. I don't think that substrates are necessarily going to be a limiting factor fo browns as virtually all the dominant substrates we encountered at Bishop (cobble/gravel/ boulder) typically all are rated as “optimal” on any brown trout criteria I have seen.

Thoughts?

Brandon

Happy holidays!

From: Leong, Tristan -FS <tristan.leong@usda.gov>
Sent: Tuesday, December 17, 2019 6:10 PM
To: Brandon Kulik <Brandon.Kulik@KleinschmidtGroup.com>
Cc: Nick.Buckmaster@wildlife.ca.gov
Subject: FW: Brown Trout HSC Question

Hi Brandon,

Attached you will find the curves we’ve used on other projects within the region.

As per the discussion regarding brown trout specific HSC we have a few options all of which I’m open to: 1) Use Bovee 1978, 2) See if we can pull the HSC developed for Bishop Creek from the first relicensing and run that again 3) Use the curves for rainbows as a surrogate for brown trout, which we’ve used extensively throughout this region. I think a comparison of the HSC for each approach would be a good starting discussion.

Secondly, the attached documents contain information for sucker HSC and I believe some dace information that may provide suitable surrogate/proxy for Owens sucker/dace. Nick, your thoughts?

Tristan Leong
Hydroelectric Coordinator

Forest Service
Region 5 Public Services

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c: 530-961-2155
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Caring for the land and serving people

From: Teater, Dan -FS <dan.teater@usda.gov>
Sent: Monday, December 16, 2019 3:26 PM
To: Leong, Tristan -FS <tristan.leong@usda.gov>
Subject: RE: Brown Trout HSC Question

Tristan,

Most of those curves that we used were enveloped literature HSC's. Univariate HSC for rainbow trout spawning and rainbow trout fry, hardhead (juvenile and adult), Sacramento pikeminnow (juvenile and adult), and Sacramento sucker (juvenile and adult) were generated by plotting the most applicable HSC from other streams. From the plotted curves, a single envelope univariate HSC curve for velocity, depth, and substrate was developed.

Attached are some Sac sucker curves and associated metadata. I could not find any HSC's for dace on the projects I worked on.

Let me know if you need anything else.

Dan Teater
Fisheries Biologist

Forest Service
Tahoe National Forest, American River Ranger District

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From: Leong, Tristan -FS
Sent: Monday, December 16, 2019 12:05 PM
To: Teater, Dan -FS <dan.teater@usda.gov>
Subject: RE: Brown Trout HSC Question

Hi Dan,

As a follow up, did you have curves for sucker and dace as well? I need some for Owens sucker and Owens Dace – so surrogate curves would be useful.

Tristan Leong
Hydroelectric Coordinator

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From: Teater, Dan -FS <dan.teater@usda.gov>
Sent: Monday, December 16, 2019 12:00 PM
To: Leong, Tristan -FS <tristan.leong@usda.gov>; Lind, Amy -FS <amy.lind@usda.gov>
Subject: RE: Brown Trout HSC Question

Thanks for reaching out Tristan,

For the **Middle Fork and Yuba-Bear Drum Spaulding Projects**, the primary species and life stages selected for instream flow modeling included rainbow trout (juvenile rearing, adult rearing, and spawning), hardhead (juvenile and adult rearing), and foothill yellow-legged frog (FYLF) (breeding and tadpoles). Also, a guild (or spatial niche) approach was selected to model habitat for all aquatic species (primary and secondary priority species/life stages). The guild/spatial niche approach included the primary species and life stages listed above, as well as secondary species/life stages including juvenile and adult Sacramento pikeminnow, Sacramento sucker, California roach, sculpin species, speckled dace, fry of all the fish species, and macroinvertebrates. **Brown trout** was not identified as a management species by the resource agencies and, therefore, was not evaluated separately as a target species. In the spatial niche analysis, rainbow trout was used as a surrogate for brown trout, as the two species have similar habitat preferences for most life stages.

Also during the instream flow development for the **Yuba River Development Project**, brown trout, small mouth bass and kokanee were not identified as target species for inclusion the PHABSIM study.

As you guys have discussed previously criteria curves for fry and spawning rainbow trout, and fry, juvenile, adult, and spawning brown trout were obtained from published sources (Bovee 1978). Published curves were used because the latter species and life stages were not common in the project area and development of site-specific data would have required excessive time and expense. The Bovee substrate code (Bovee 1978) was used for the spawning life stage of both rainbow and brown trout. The substrate/cover code for rainbow trout fry and for brown trout fry, juvenile, and adult trout was set to non-selectivity in the computer analysis.

Hope this helps, as always let me know if you need anything else from me.

Happy Holidays to you both! ☺

Dan Teater
Fisheries Biologist

Forest Service
Tahoe National Forest, American River Ranger District

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From: Leong, Tristan -FS
Sent: Monday, December 16, 2019 11:52 AM
To: Lind, Amy -FS <amy.lind@usda.gov>; Teater, Dan -FS <dan.teater@usda.gov>
Subject: RE: Brown Trout HSC Question

Never mind, it says Bovee 1978. Thanks!

Tristan Leong
Hydroelectric Coordinator

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From: Lind, Amy -FS <amy.lind@usda.gov>
Sent: Monday, December 16, 2019 11:48 AM
To: Leong, Tristan -FS <tristan.leong@usda.gov>; Teater, Dan -FS <dan.teater@usda.gov>
Subject: RE: Brown Trout HSC Question

Dan can weigh in on Middle Fork, and Yuba-Bear/Drum-Spaulding…

For the Bucks Creek relicensing, we allowed the use of a previous PHABSIM study for both RBT and Brown Trout (attached) and then supplemented that with some demonstration flows.

Amy

Amy Lind
Hydroelectric Coordinator
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631 Coyote St.
Nevada City, CA 95959
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Caring for the land and serving people

Please note my new email, and update your address books.

From: Leong, Tristan -FS
Sent: Monday, December 16, 2019 10:01 AM
To: Teater, Dan -FS <dan.teater@usda.gov>; Lind, Amy -FS <amy.lind@usda.gov>
Subject: Brown Trout HSC Question

Hi Dan & Amy,

In your most recent projects did you guys use any brown trout habitat suitability indices? If so, where might I be able to find a copy – I need to pull some for another project. Would like to use ones we previously approved.

Thanks,

Tristan Leong
Hydroelectric Coordinator

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From: Buckmaster, Nick@Wildlife <Nick.Buckmaster@wildlife.ca.gov>
Sent: Wednesday, January 15, 2020 3:58 PM
To: Leong, Tristan -FS <tristan.leong@usda.gov>; Brandon Kulik <Brandon.Kulik@KleinschmidtGroup.com>
Cc: Shannon Luoma <Shannon.Luoma@KleinschmidtGroup.com>; Moyer, Patricia (Trisha)@Wildlife <Patricia.Moyer@Wildlife.ca.gov>
Subject: RE: first look at potential brown trout HSI

Brandon,
Thanks for reaching out. I agree with your summarization and that the combined curves look off. CDFW agrees with the USFS that more modern curves are appropriate.

I am around this week and next if you want to discuss.

Nick Buckmaster
Heritage and Wild Trout Program
760-872-1110
(cell) 760-920-8391

From: Leong, Tristan -FS <tristan.leong@usda.gov>
Sent: Tuesday, January 14, 2020 2:24 PM
To: Brandon Kulik <Brandon.Kulik@KleinschmidtGroup.com>; Buckmaster, Nick@Wildlife <Nick.Buckmaster@wildlife.ca.gov>
Cc: Shannon Luoma <Shannon.Luoma@KleinschmidtGroup.com>
Subject: RE: first look at potential brown trout HSI

Hi Brandon,

Your summary was excellent, thank you for providing the data. I agree with your synopsis.

I was not aware that the old curves had such discreet and sharp breaks for HSC, and of the weird behavior in adult combined velocity criteria. I am also scratching my head as to how one would use the object criteria now, given that we don't know how these cover criteria were measured in a transect or translatable to our current transects. (This in addition to other problematic issues recreating said study verbatim, rather than following a 1-D approach and running a new model as we are doing.) Scrapping the old data also allows for us to (as I think you put it) factor in other considerations that were not known then, but are discussed and agreed upon generally today that respond to these earlier criticisms of PHABSIM.

Lastly, I agree that the old preference curves are likely a product of sampling bias in so much as the authors (at the time) did not consider that their observations were likely a product of the environment for which they were taken, and very sharp responses in HSC were likely correlated to a lack of diverse habitat for observation purposes.

I'm available next week and parts of this week. Look forward to the discussion.

Tristan Leong
Hydroelectric Coordinator

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From: Brandon Kulik <Brandon.Kulik@KleinschmidtGroup.com>
Sent: Tuesday, January 14, 2020 1:48 PM
To: Buckmaster, Nick@Wildlife <Nick.Buckmaster@wildlife.ca.gov>; Leong, Tristan -FS <tristan.leong@usda.gov>
Cc: Shannon Luoma <Shannon.Luoma@KleinschmidtGroup.com>
Subject: first look at potential brown trout HSI

Good day Tristan and Nick,

The purpose of this email is to continue the discussion of potential adult and juvenile brown trout habitat suitability criteria, for use in the Bishop Creek PHABSIM model, based on your input. I have graphed various candidate Habitat Suitability Criteria (HSC) in Excel, to facilitate a comparison of various HSC options that we have identified. You may recall from recent emails that these include the original HSC used in the 1986 Bishop Creek study, HSC developed by Ken Bovee (1978), and adult brown trout criteria described by Strakosh, et al. (2003). I suggest that we review these results and then get on a quick conference call together to discuss. We can pick a curve set we agree we like, discard curves, combine elements of various curves or explore other options. I see this as a starting point. Some initial notes about each of these sources:

***Old Bishop*:** These were adopted by Emil Morhardt of EA Science and Engineering from Aceituno, (unpublished data). I have not been able to locate the original source, but the depth and velocity curves have a series of cover-conditional alternatives, including No cover, Overhead cover, Object Cover and Combined. Cover-conditional criteria are based on the assumption that fish will tolerate different ranges of depth and velocity depending on the presence or absence of various cover conditions. However the study does not define what exactly constitutes these cover types in terms of proximity to the transect locus and extensiveness of such cover and whether they should be applied at each individual locus along each transect or more broadly at the transect or even study site level. It also does not clarify what the “combined” condition looks like or how it should be applied in the model. These nuances are problematic, but may turn out to be somewhat academic in our particular study once we discuss them.

Strakosh et al (2003). These were developed rigorously in a New England small stream environment arguably similar in terms of channel sizes, depths, and instream cover conditions to what we have in most of the Bishop system. My experience is that these curves have been used successfully in many eastern Brown trout IFIM studies. They are probably more realistic than some curves developed on larger deeper rivers. One consideration is that these criteria only apply to the adult life stage.

Bovee (1978). These curves were developed a while ago but continue to be used throughout many studies

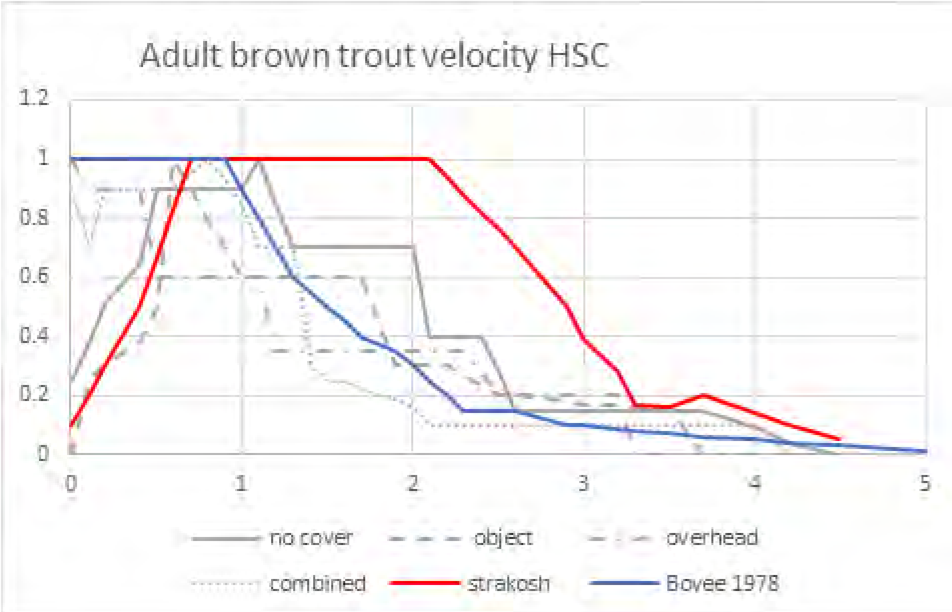
VELOCITY

These are pretty busy looking figures, so I color-coded the three HSC sources by author. The Aceituno cover conditional family of curves are all in gray with different line patterns to distinguish cover conditions.

Adult life stage

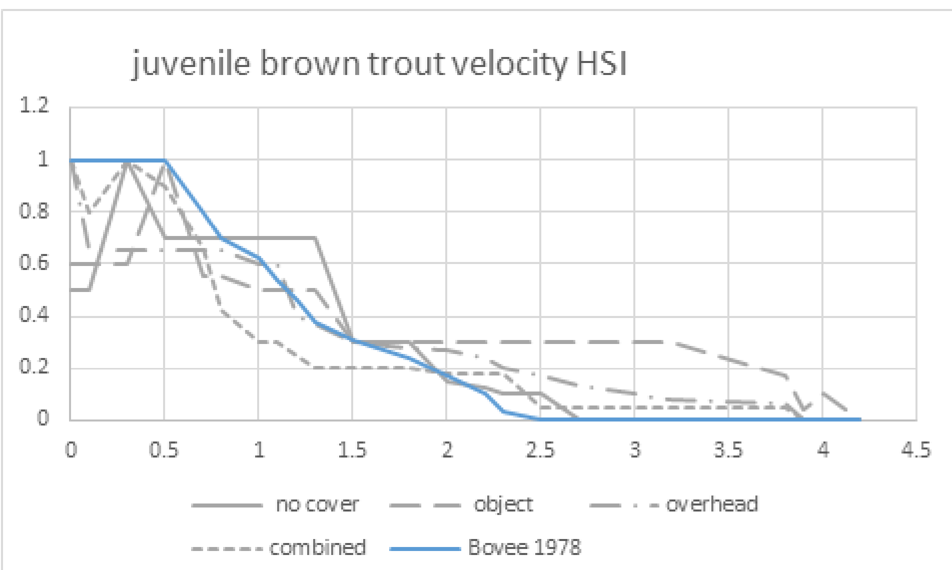
A couple of things are suspect or at least unclear about the Aceituno curves. Note that the “combined” curve briefly dips initially, then rises to a sharp peak then descends. That initial dip is unusual implying some sort of negative suitability response that occurs only at an acute, low velocity. This seems counterintuitive and without any supporting documentation is difficult to justify. In general all the Aceituno curves share a sharp isolated peak of optimal velocity suggesting that trout have relatively high sensitivity to a narrow velocity range. Again this seems counterintuitive for animals living in a physically dynamic environment like a high gradient stream. At the other extreme we have Strakosh which rises at a rate generally similar to the “no cover” Aceituno curve and has a broader optimal range plateau extending from around 0.5 up to roughly 2 ft/sec.

The Bovee curve shows an optimal plateau from 0 up to approximately 0.9 ft/sec after which the descending arm roughly mimics the overhead and object cover curves from Aceituno. I think that the low end of the Bovee curve is recognizing that brown trout adults will often select pool habitat, which of course has areas of zero velocity



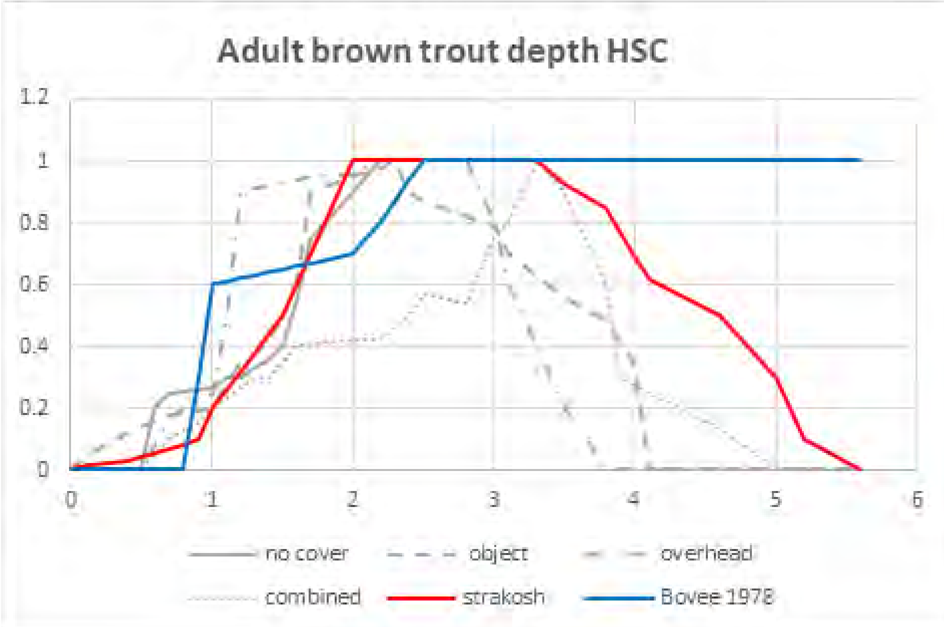
Juvenile life stage

Here we have a similar concern with the Aceituno lower velocity/optimal suitability at the lower end of the flow range having some suspect points, but a general trend of similarity along the descending arm of the various curves. The Bovee curve indicates that velocities great than about 2.5 ft/sec are unsuitable and at the other extreme the Aceituno Object cover curve extends to about 4.25 before becoming unsuitable.



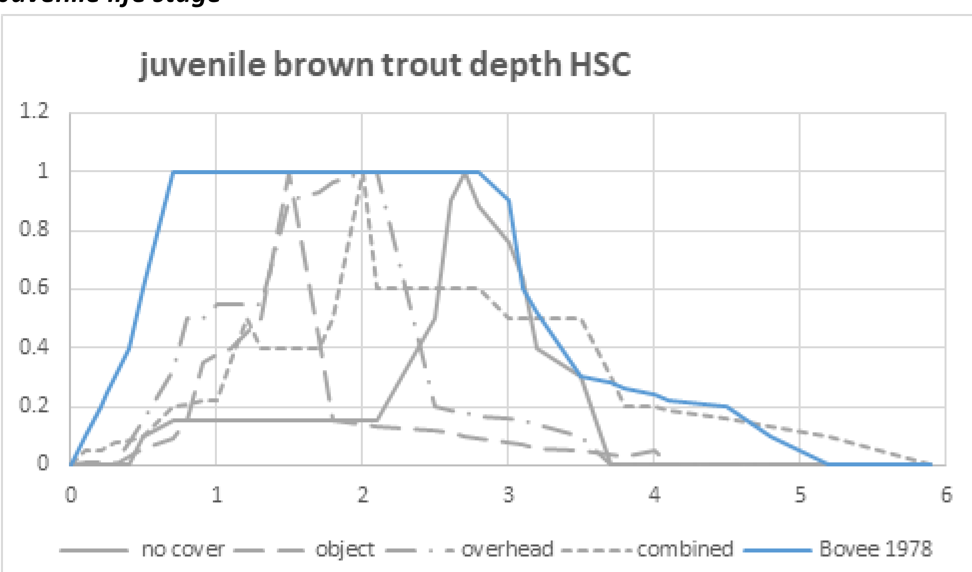
DEPTH

Adult lifestage



While there is some variability amount the ascending arms of each curve, they all generally acknowledge that a depth of 0 is unsuitable, and generally agree that a depth of about 2 ft is optimal. Again the sharp peak of the Aceituno (particularly the "combined" cover) curves seems a bit suspect. Strakosh and Bovee both have greater depth tolerance than does Acietuno, likely recognizing that brown trout inhabit deep pools, whereas Acietuno's data were probably collected in stream environments where pools happened to be small and shallow and thus did not register any habitat preferences at greater depth. In any case the maximum depth issue may be moot in this study as we will have few if any areas great than perhaps 3.5 ft deep, so the model will not likely be sensitive to this end of the curve

Juvenile life stage



Again, the sharp peak of the Aceituno (particularly the "combined" cover) curves seems a bit suspect. Also the shape of "No cover" suitability seems somewhat oversensitive. The Bovee criteria provide a reasonably broad optimal depth range (about 0.7 to 2.8 ft. The rising limb of Bovee as well as the overall shape of the curve also is very consistent with what I was observing for juvenile brown trout when we conducted the stream fish survey back in September.

Please review these results and let me know if you have time later this week or sometime next week to chat about this. I will arrange a conference call line for a mutually convenient time.

Thanks again for your time and assistance.

Brandon

Brandon H. Kulik
Senior Fisheries Scientist
Kleinschmidt
Pittsfield, Maine
207-487-3328

From: Buckmaster, Nick@Wildlife <Nick.Buckmaster@wildlife.ca.gov>
Sent: Friday, February 28, 2020 3:47 PM
To: Brandon Kulik <Brandon.Kulik@KleinschmidtGroup.com>
Subject: Re: Bishop HSC memo comments?

No comment from me- sorry in the field today

Sent from my iPhone

On Feb 28, 2020, at 12:31 PM, Brandon Kulik <Brandon.Kulik@kleinschmidtgroup.com> wrote:

Hi Nick,

I left you a VM earlier - just checking to see if you had any comments beyond what Tristan provided.

Thanks

Brandon

Brandon

Brandon H. Kulik
Senior Fisheries Scientist
Kleinschmidt
Pittsfield, Maine
207-487-3328

APPENDIX B

STUDY TRANSECTS

Appendix B

Transect Cross Sections

Reach 1

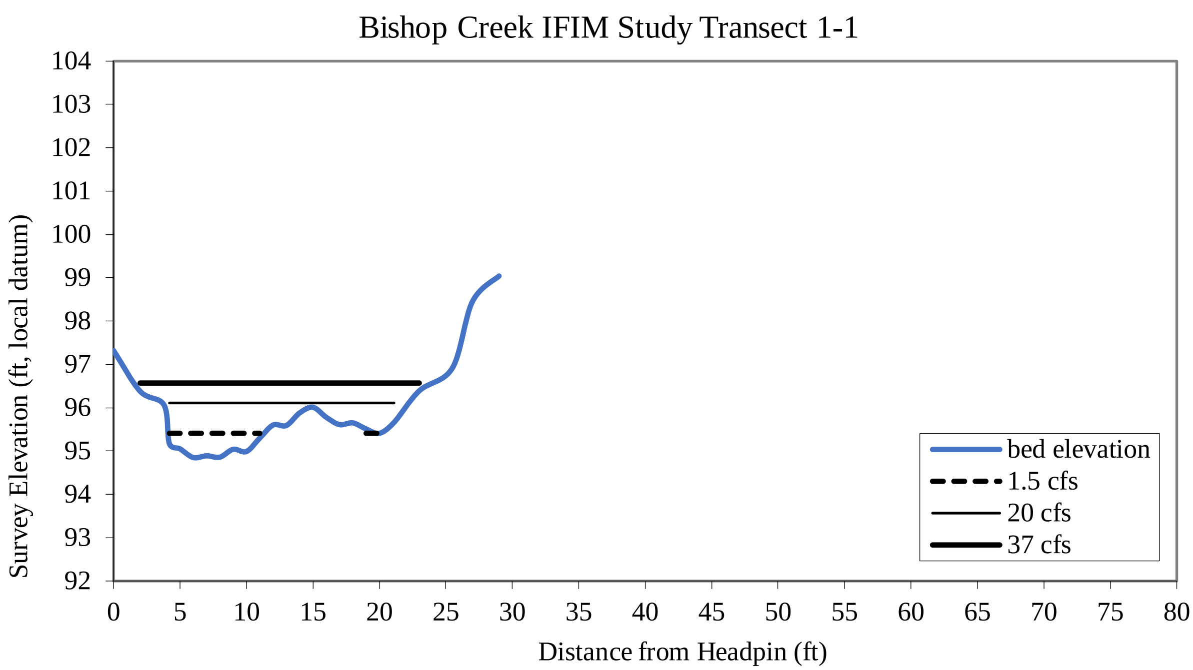


Figure B-1: Transect 1-1 cross section, looking upstream.

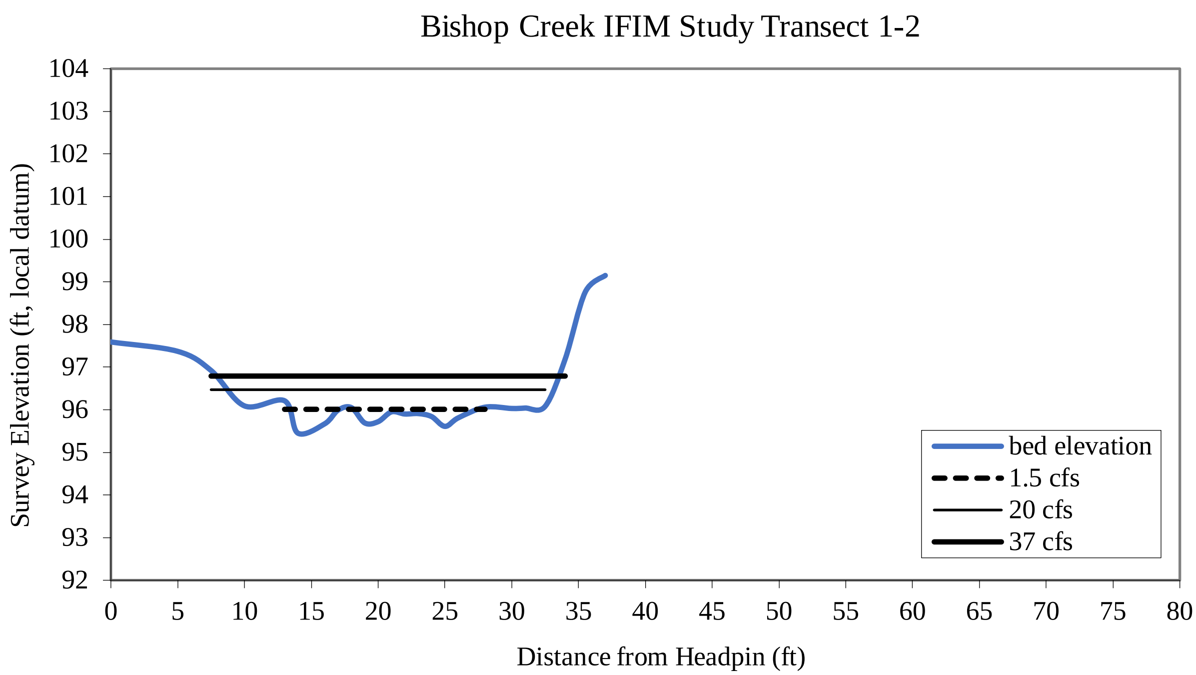


Figure B-2: Transect 1-2 cross section, looking upstream

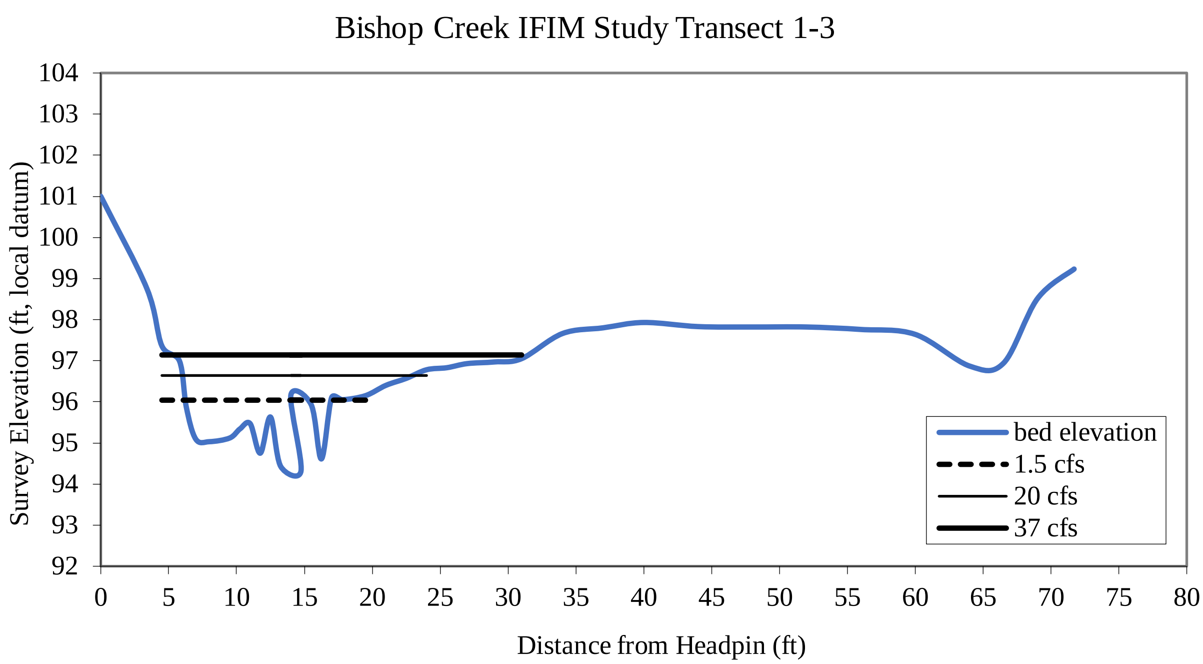


Figure B-3: Transect 1-3 cross section, looking upstream

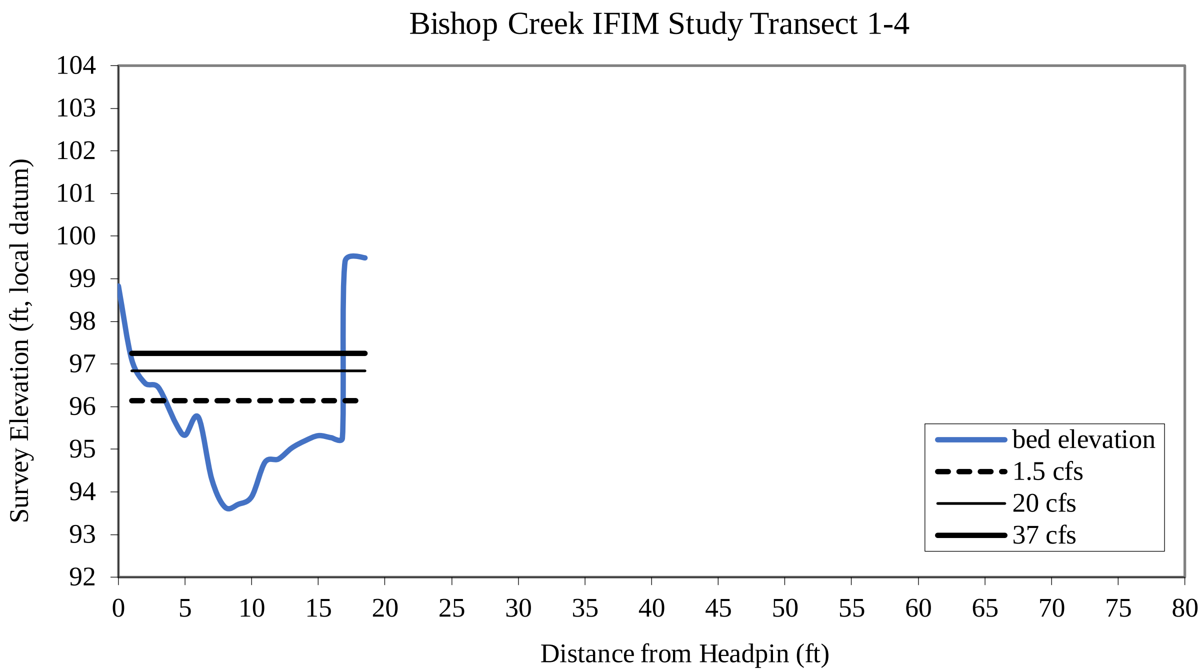


Figure B-4: Transect 1-4 cross section, looking upstream.

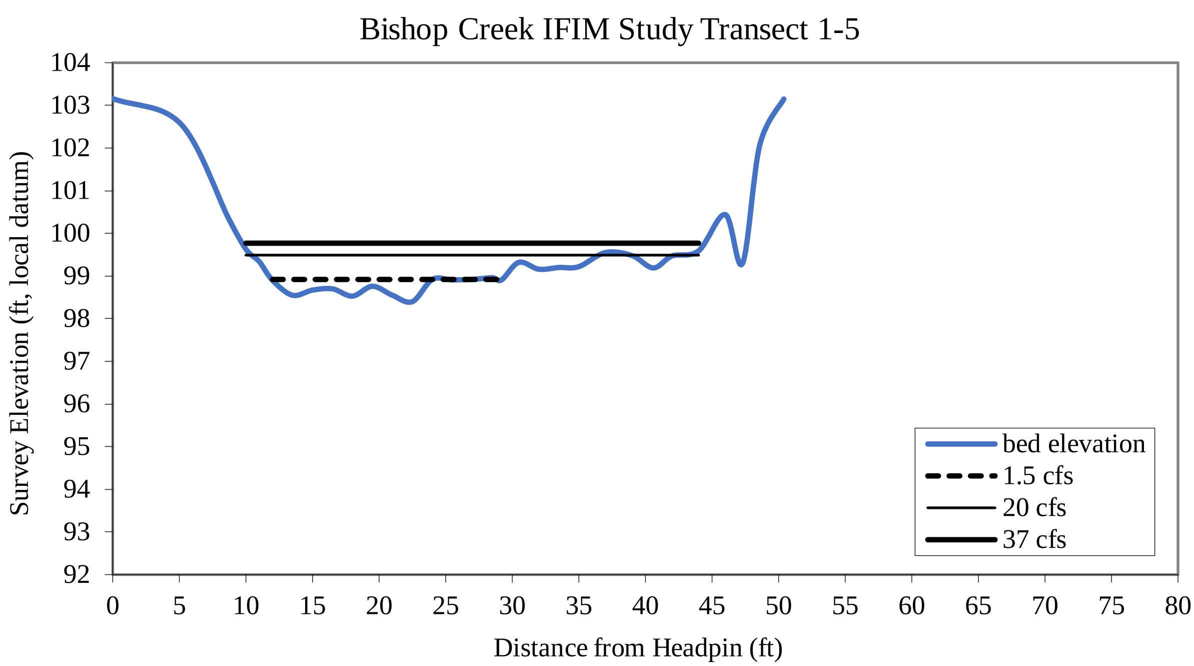


Figure B-5: Transect 1-5 cross section, looking upstream

Reach 2

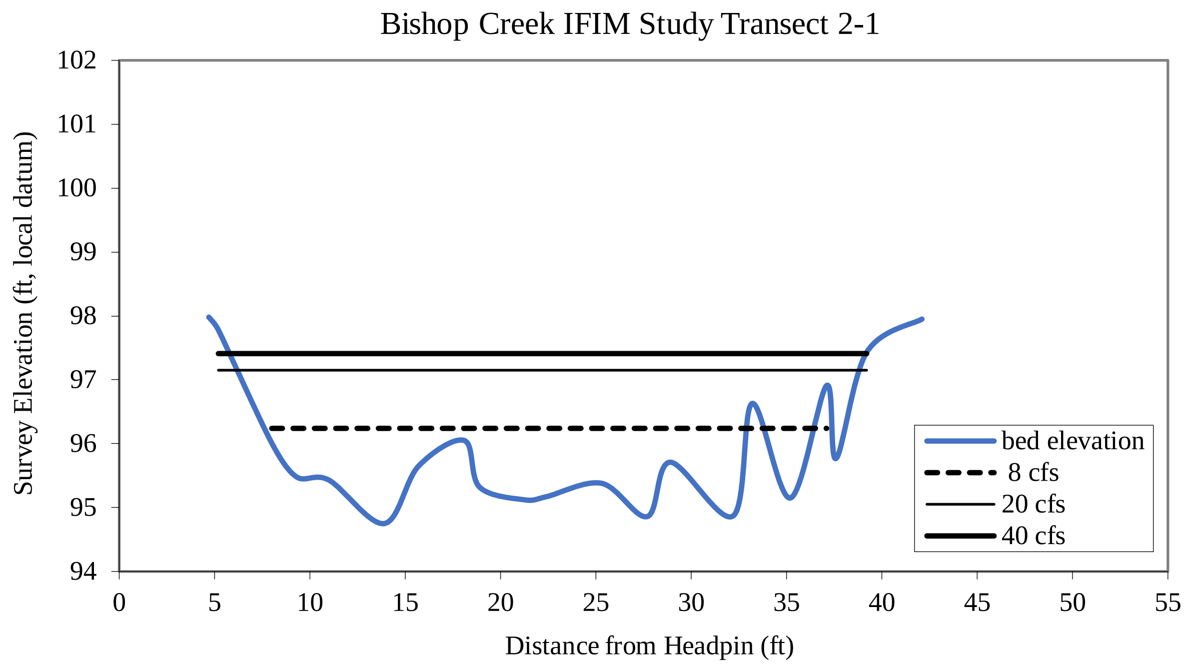


Figure B-6: Transect 2-1 cross section, looking upstream.

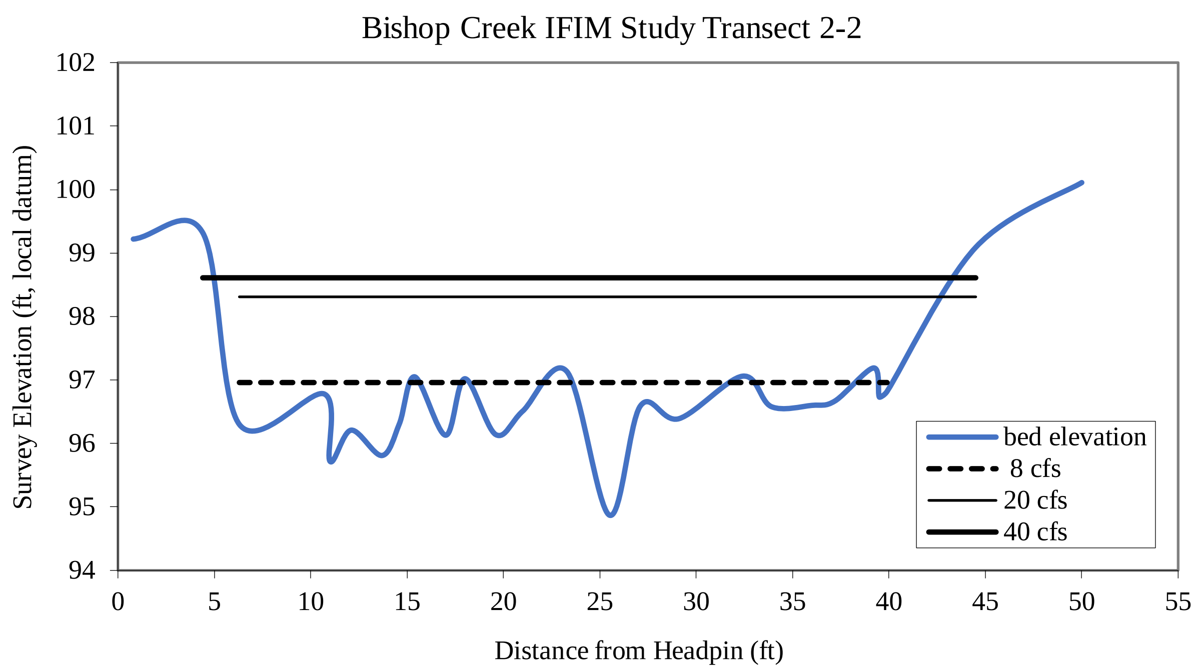


Figure B-7: Transect 2-2 cross section, looking upstream.

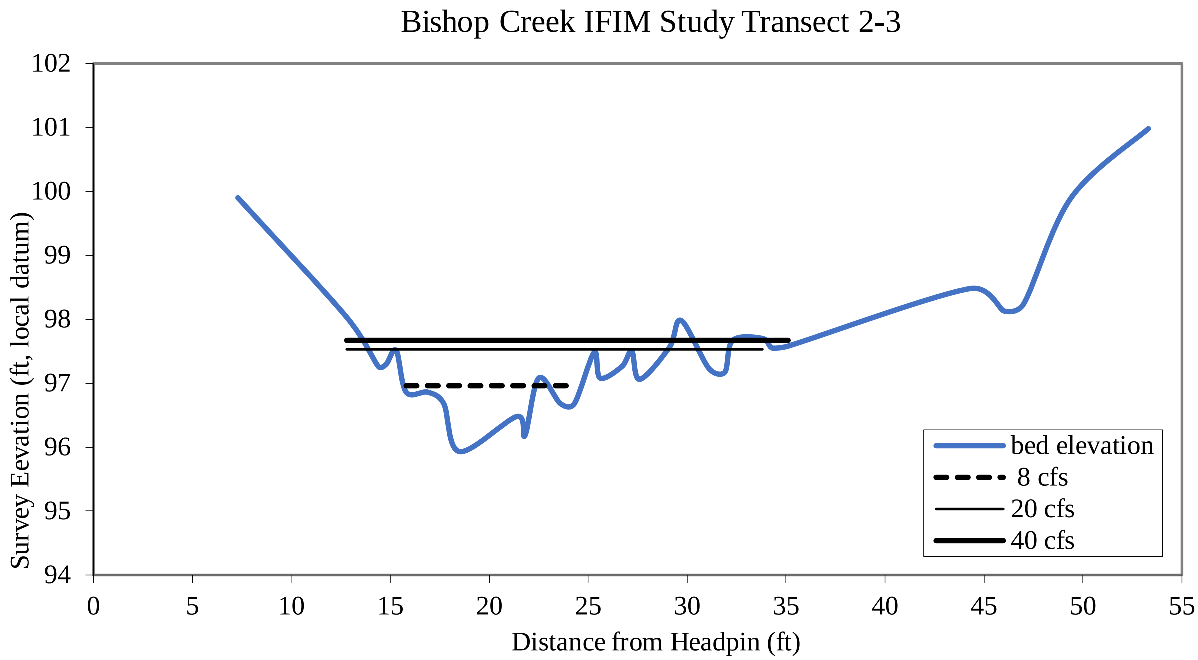


Figure B-8: Transect 2-3 cross section, looking upstream.

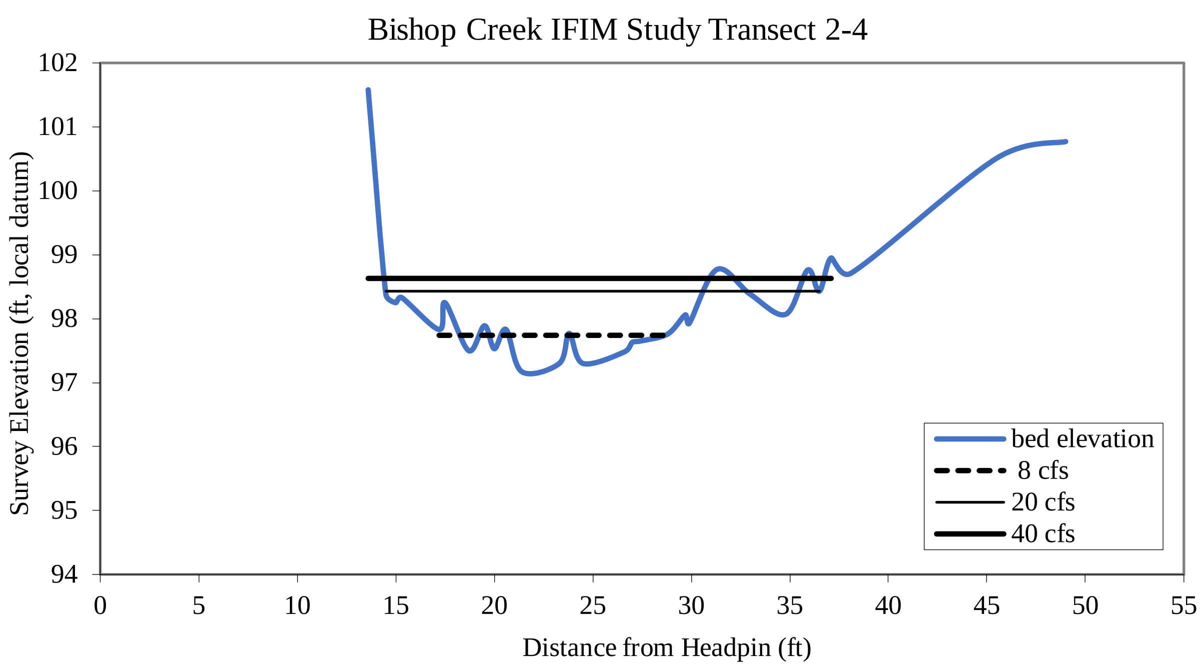


Figure B-9: Transect 2-4 cross section, looking upstream.

Reach 3

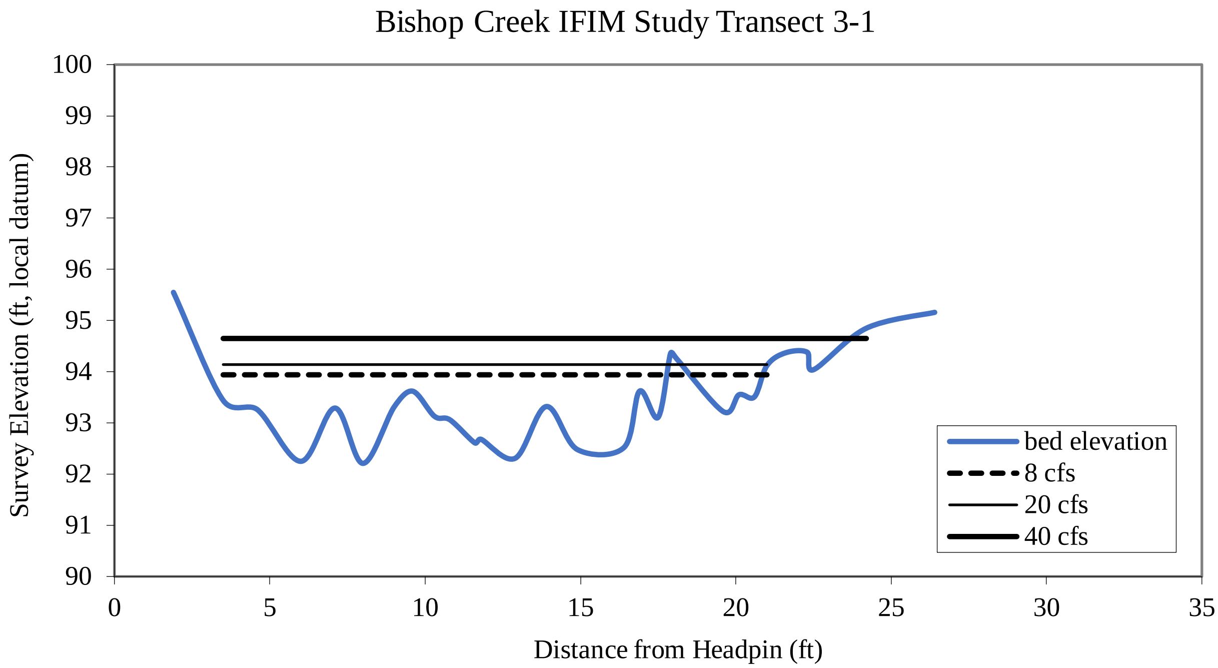


Figure B-10: Transect 3-1 cross section, looking upstream.

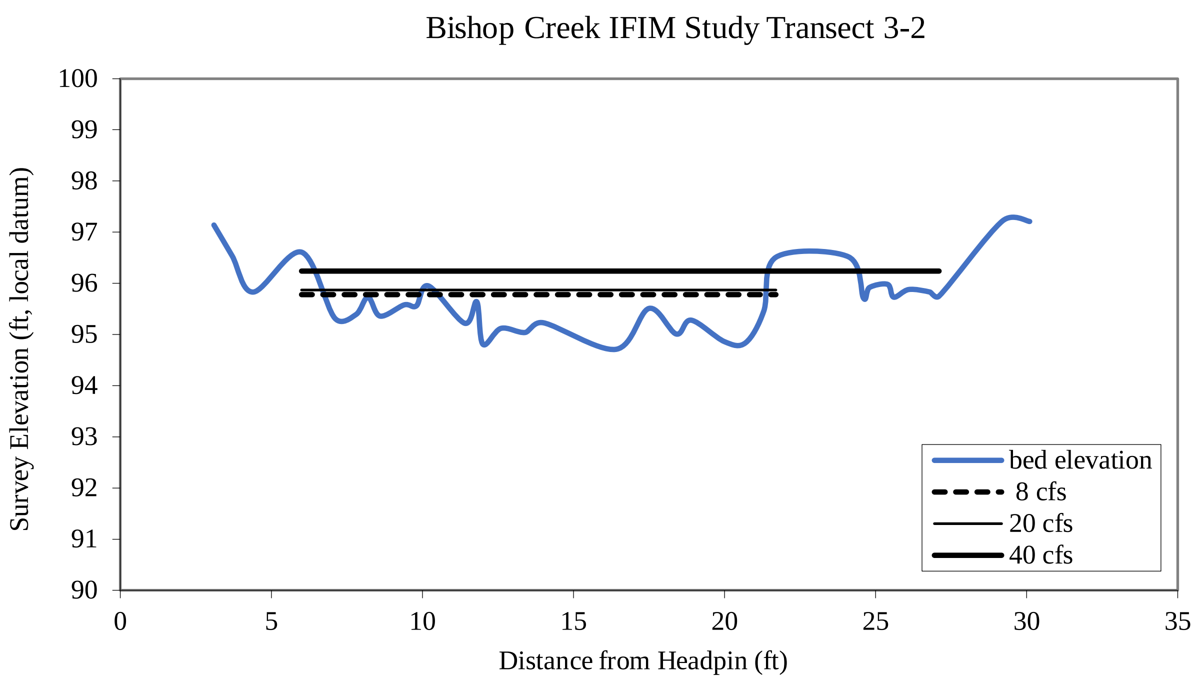


Figure B-11: Transect 3-2 cross section, looking upstream.

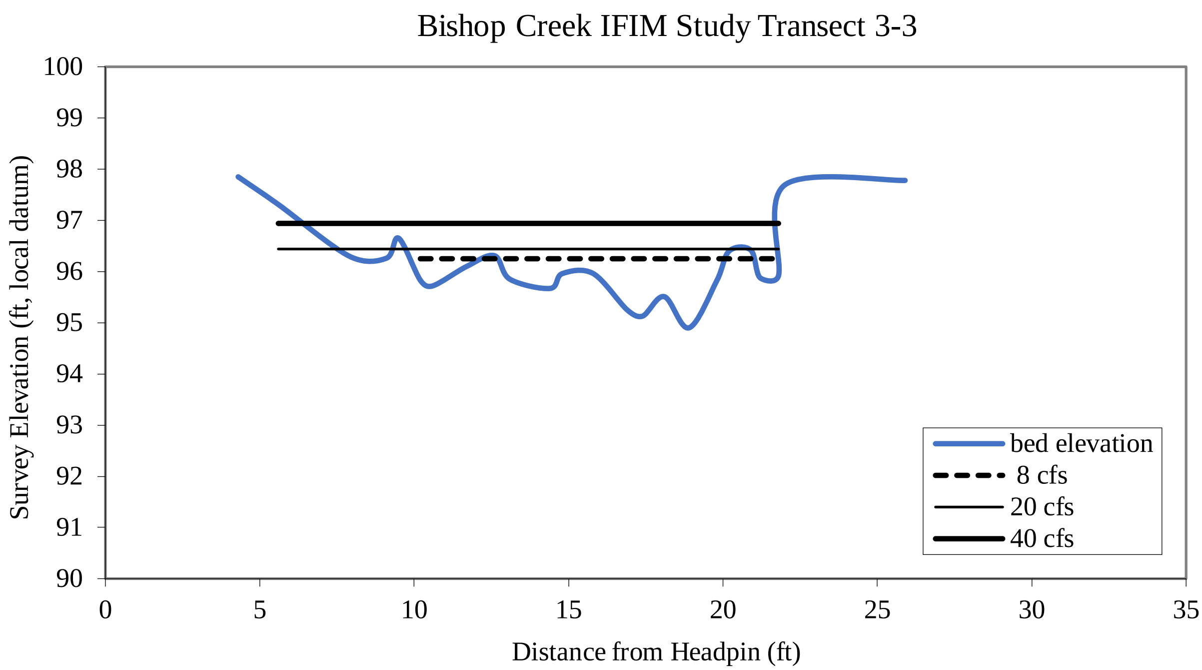


Figure B-12: Transect 3-3 cross section, looking upstream.

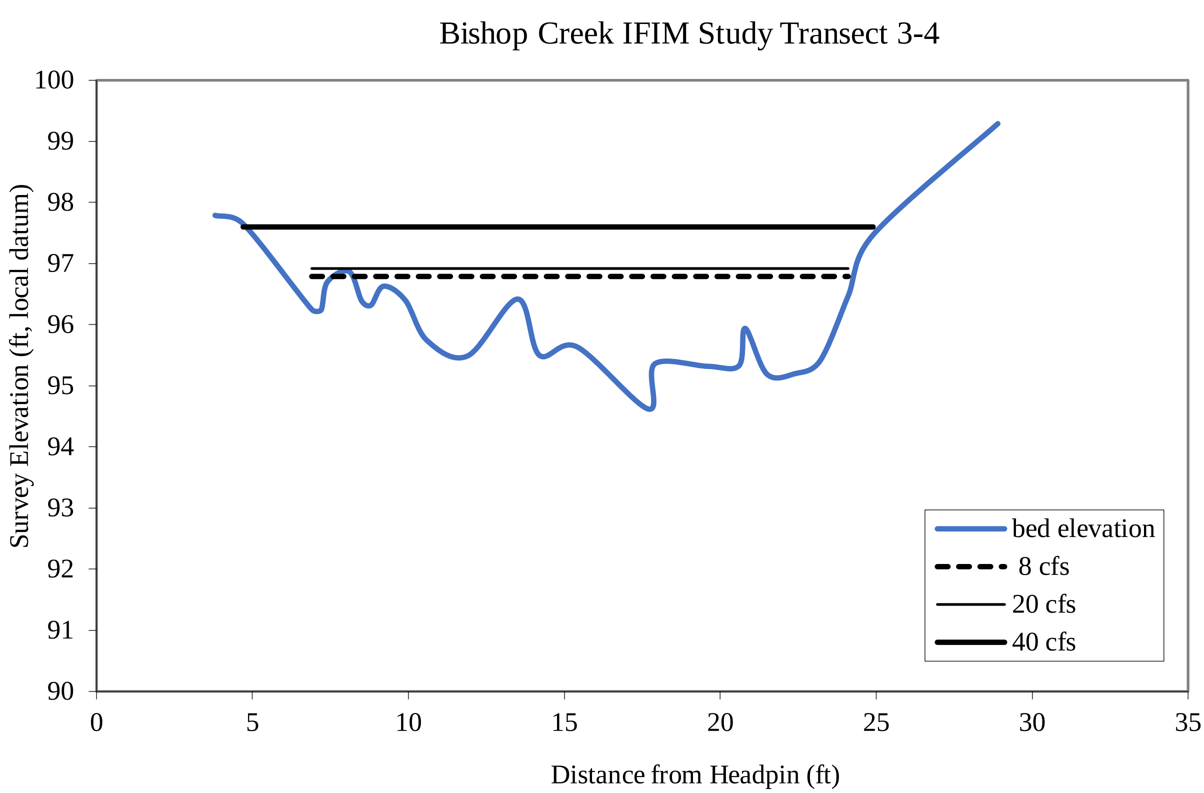


Figure B-13: Transect 3-4 cross section, looking upstream.

Reach 5

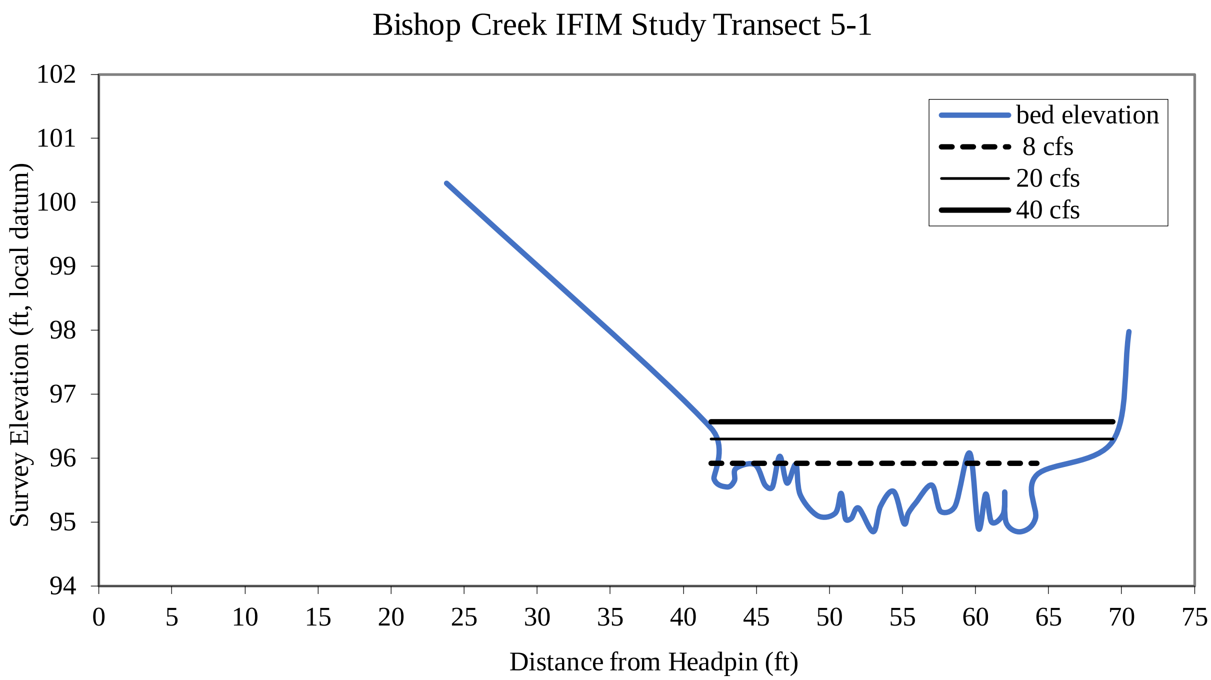


Figure B-14: Transect 5-1 cross section, looking upstream.

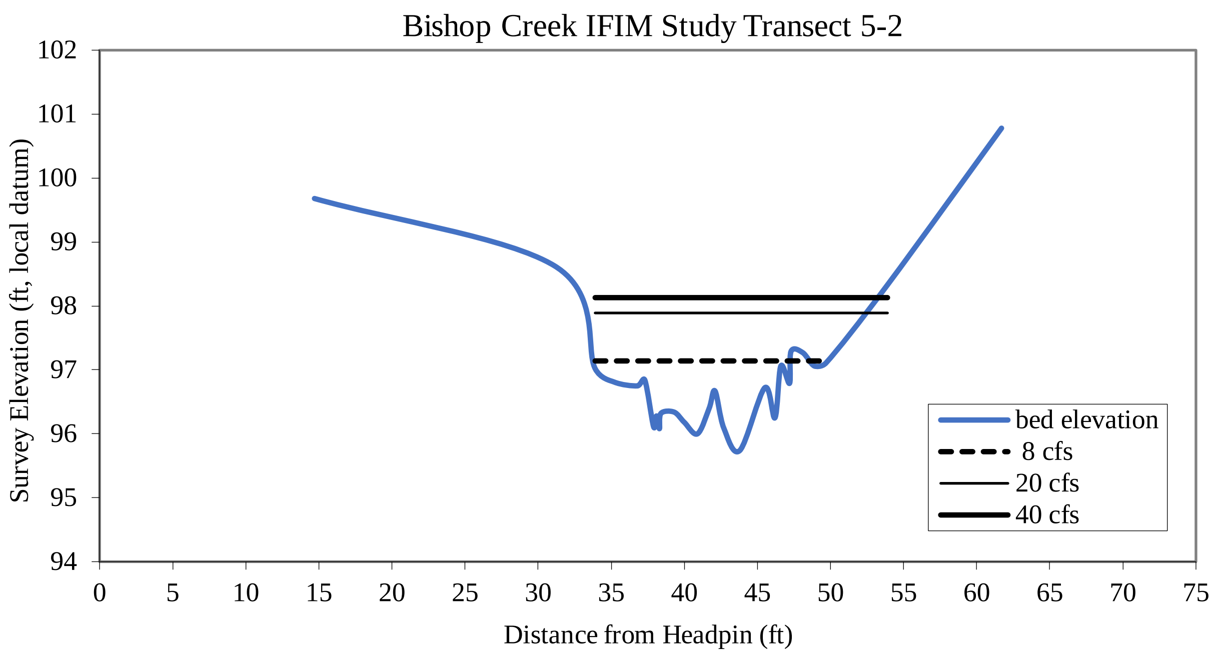


Figure B-15: Transect 5-2 cross section, looking upstream.

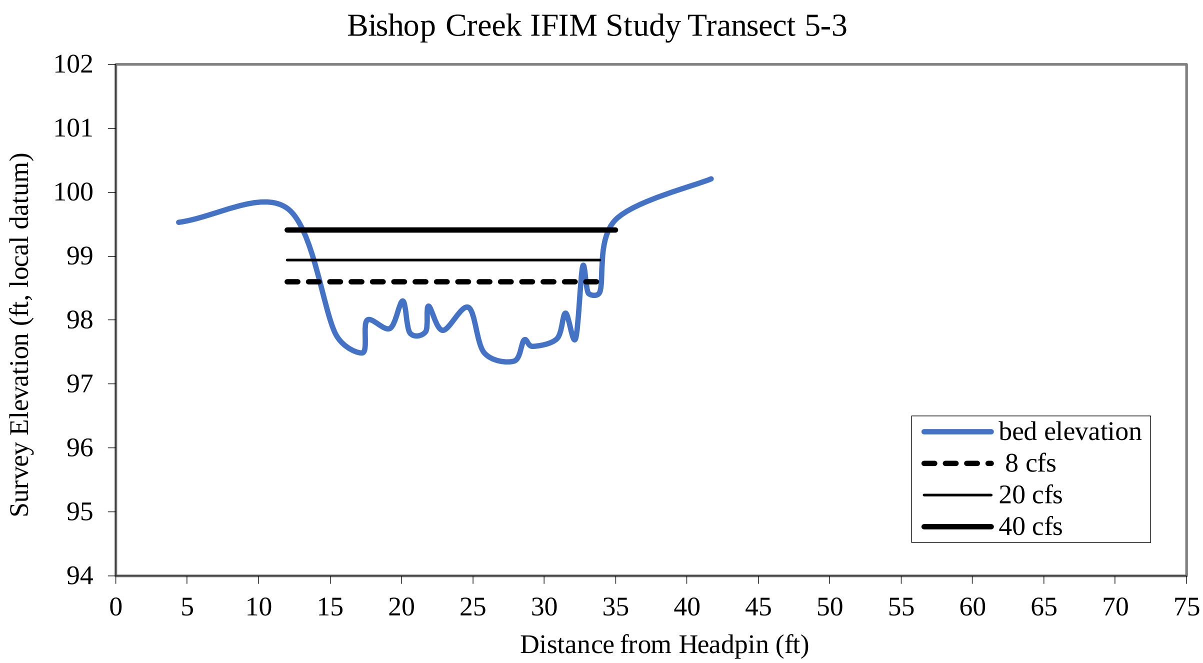


Figure B-16: Transect 5-3 cross section, looking upstream.

Reach 7

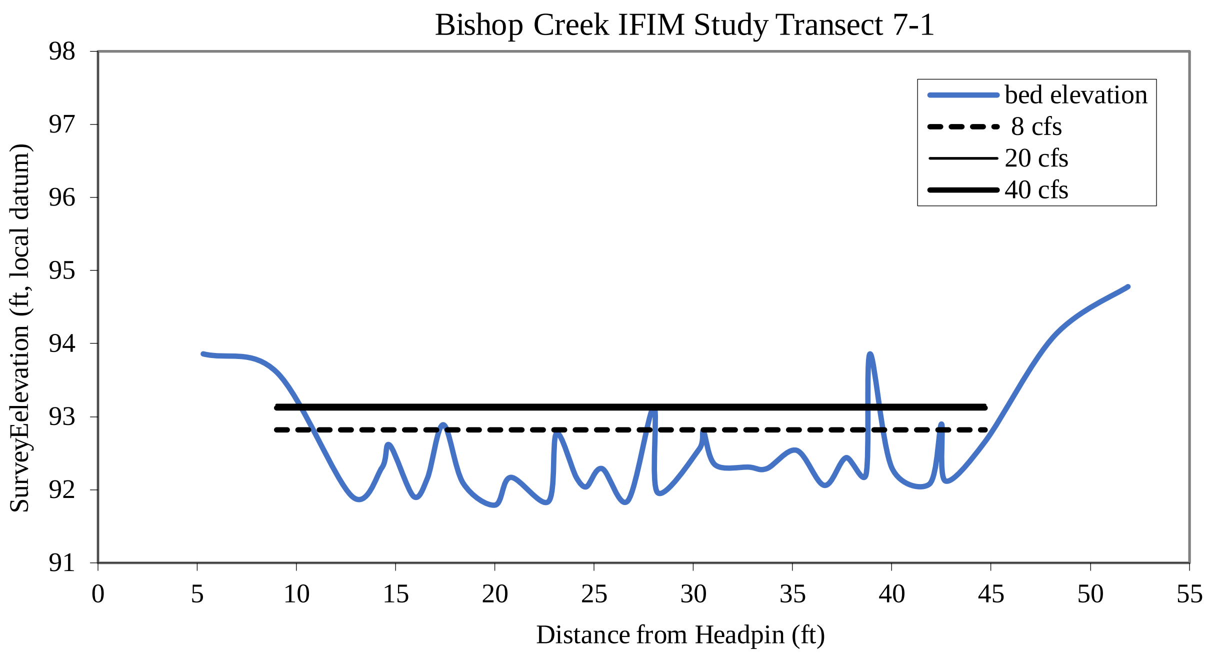


Figure B-17: Transect 7-1 cross section, looking upstream.

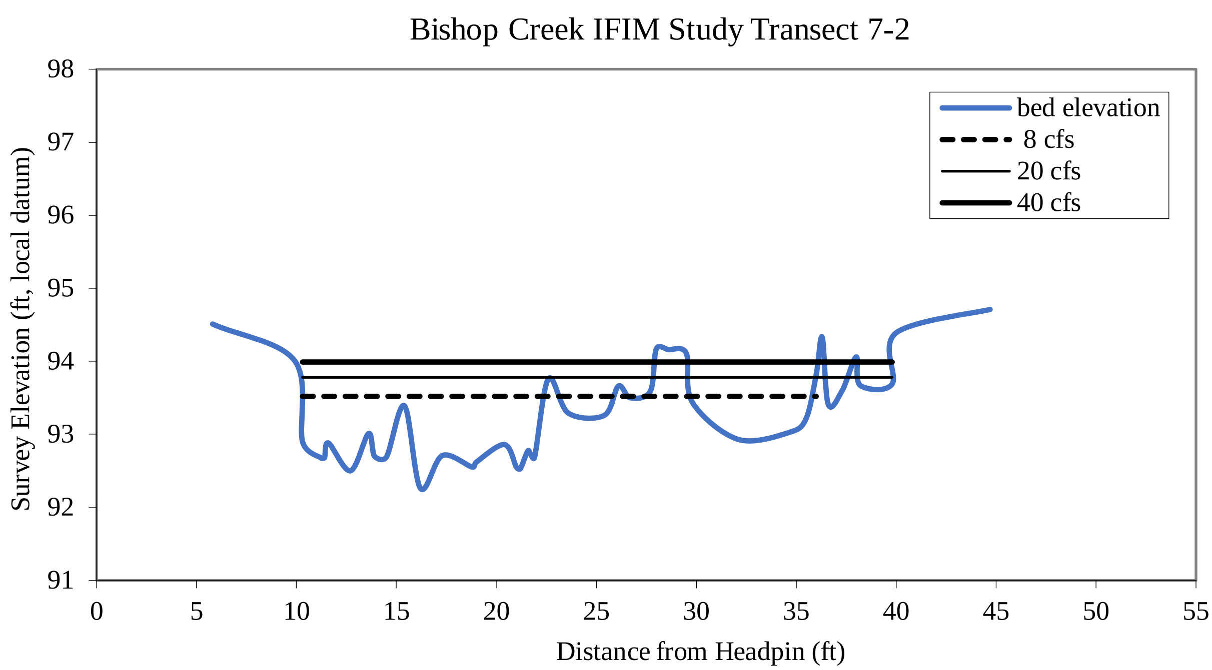


Figure B-18: Transect 7-2 cross section, looking upstream.

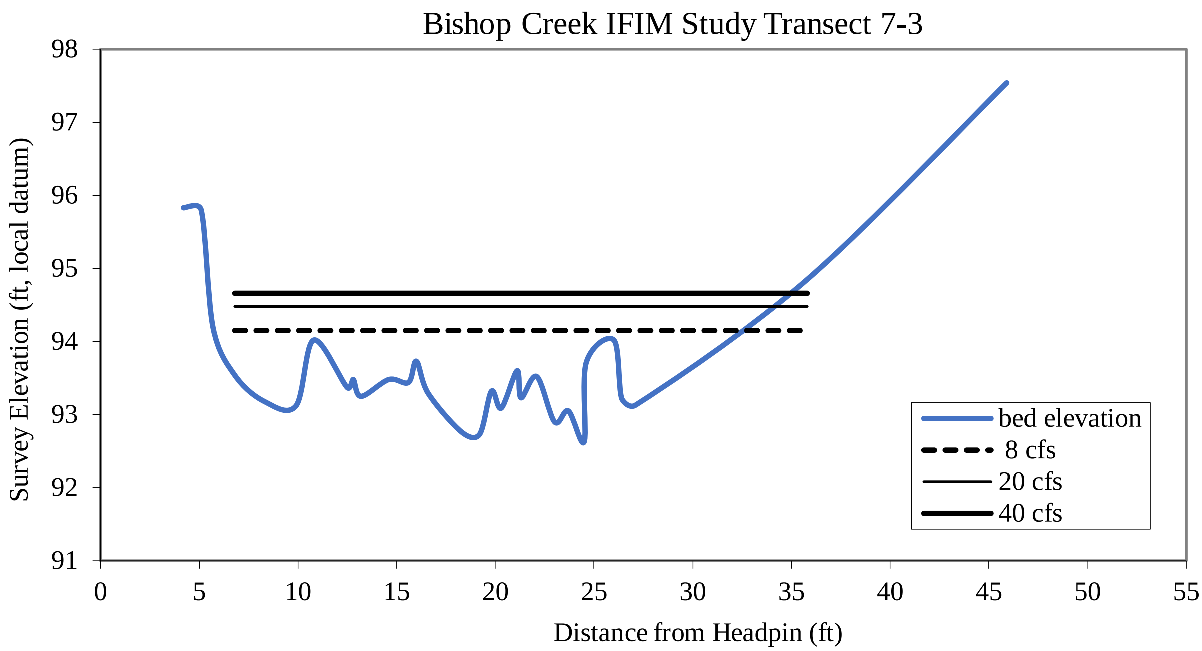


Figure B-19: Transect 7-3 cross section, looking upstream.

Reach 8

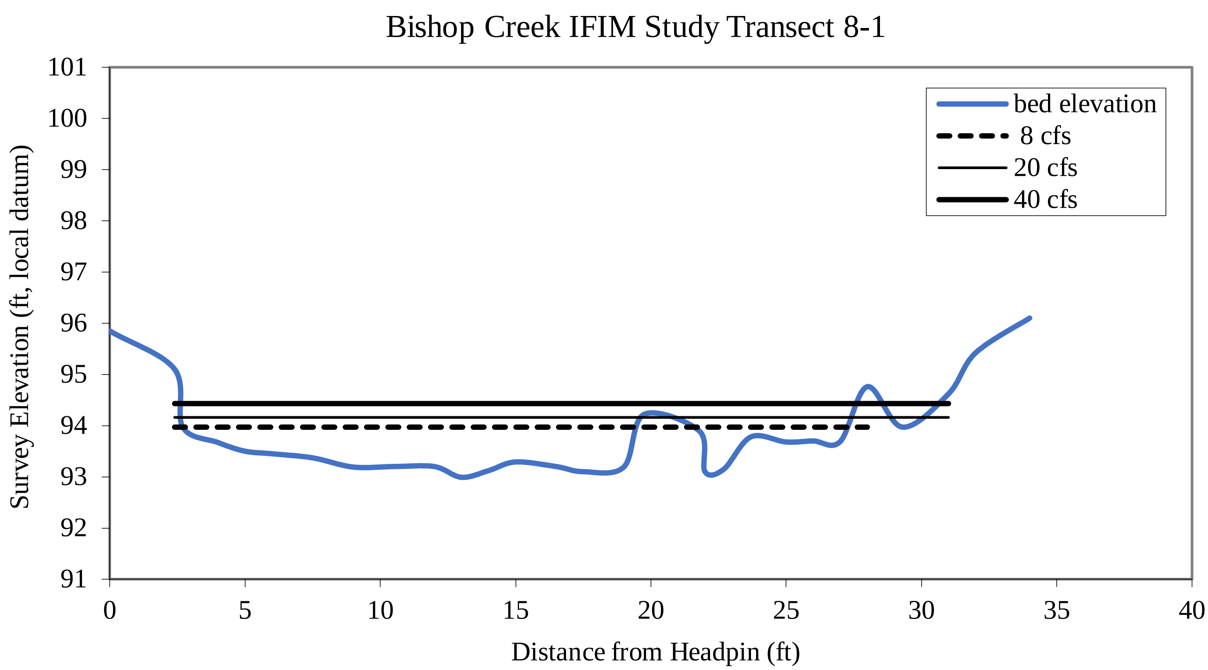


Figure B-20: Transect 8-1 cross section, looking upstream.

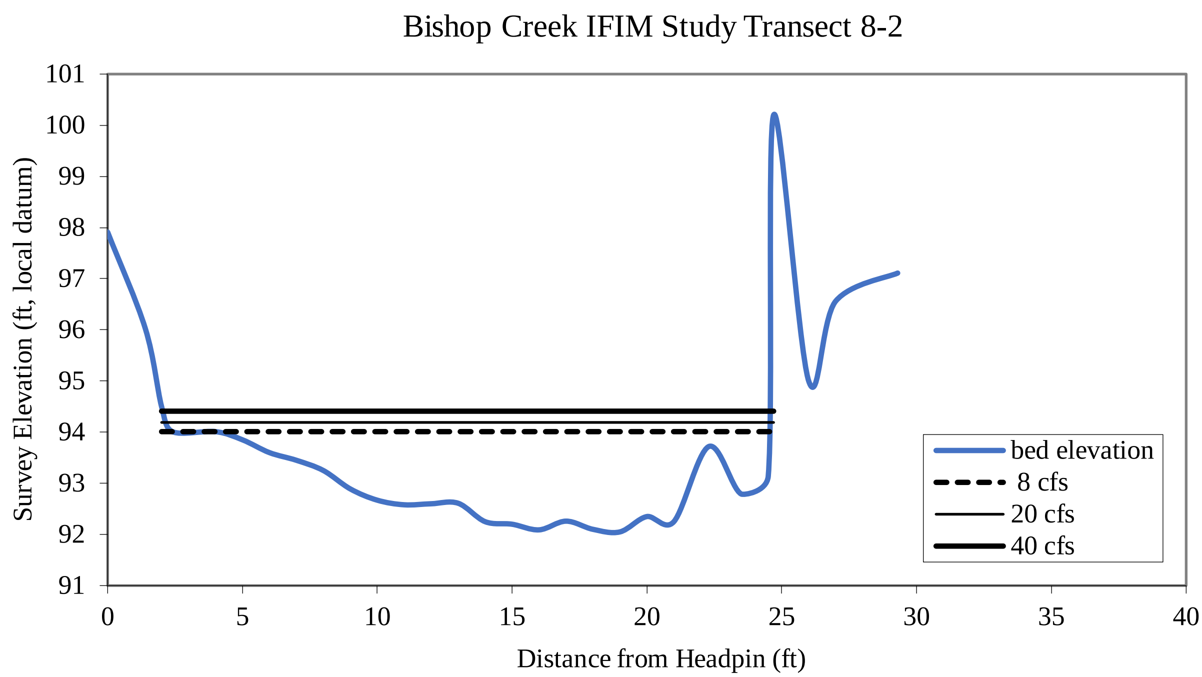


Figure B-21: Transect 8-2 cross section, looking upstream.

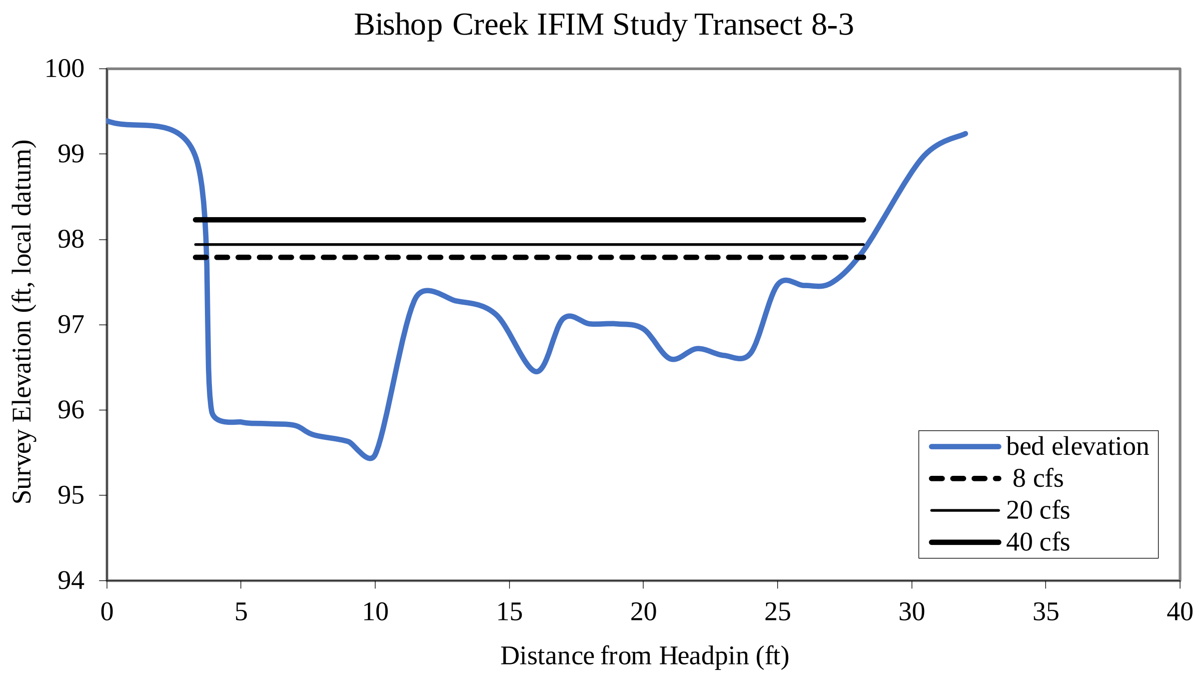


Figure B-22: Transect 8-3 cross section, looking upstream.

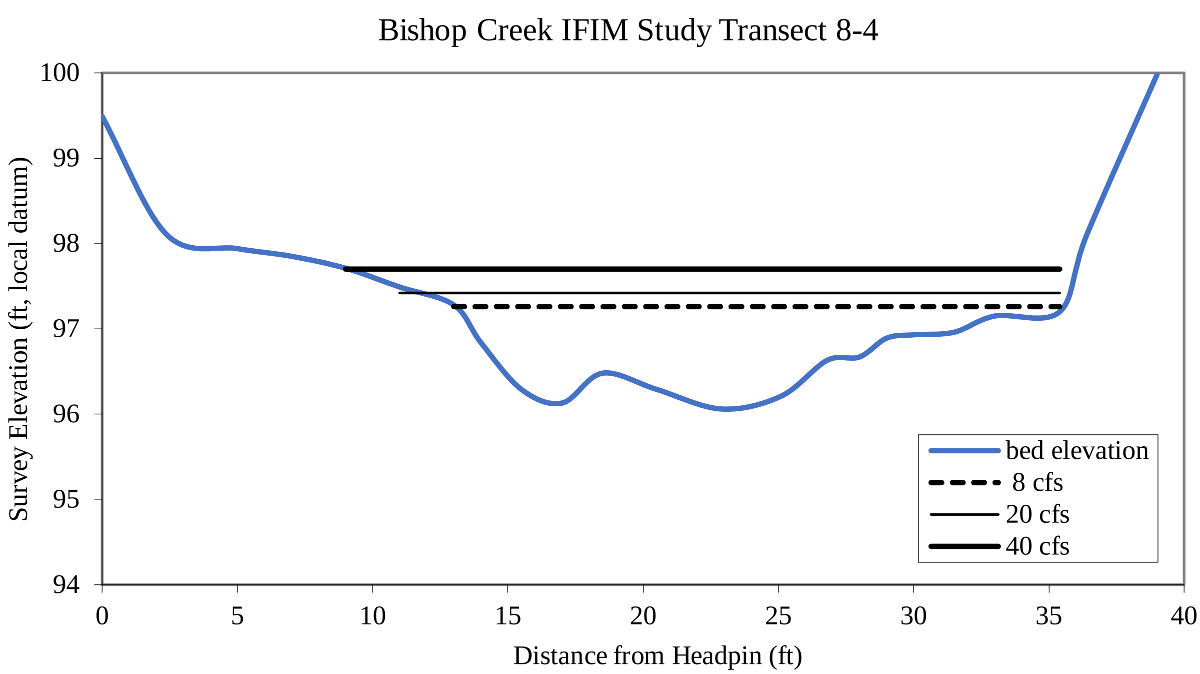


Figure B-23: Transect 8-4 cross section, looking upstream.

Reach 9

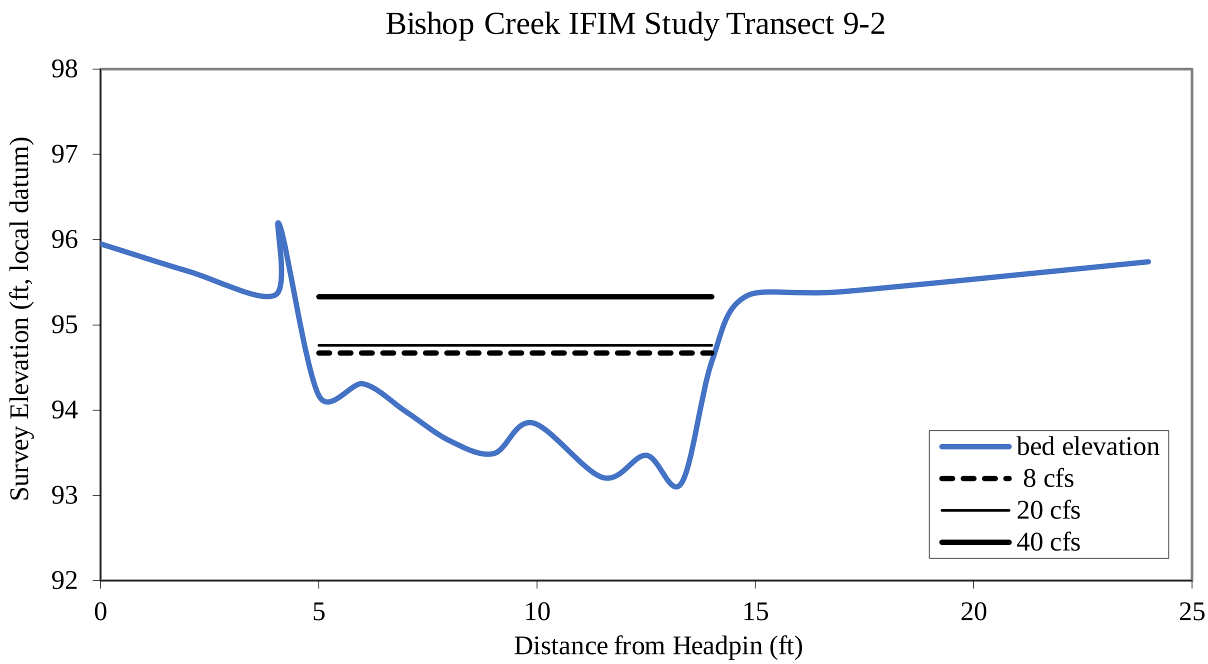


Figure B-24: Transect 9-2 cross section, looking upstream.

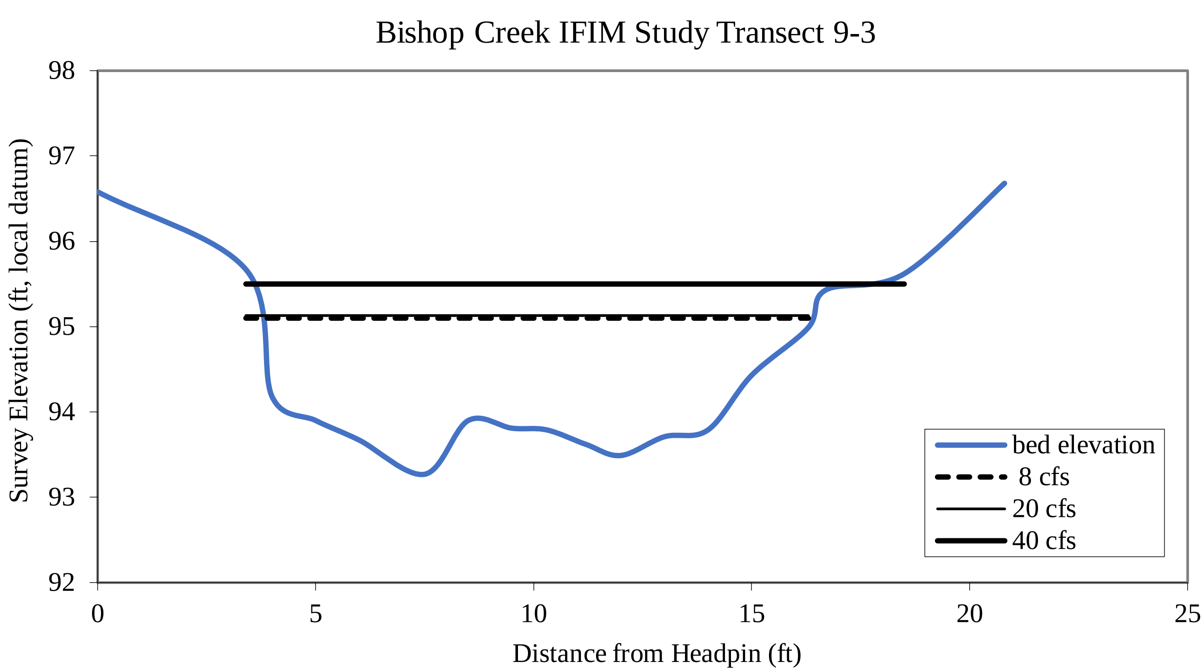


Figure B-25: Transect 9-3 cross section, looking upstream.

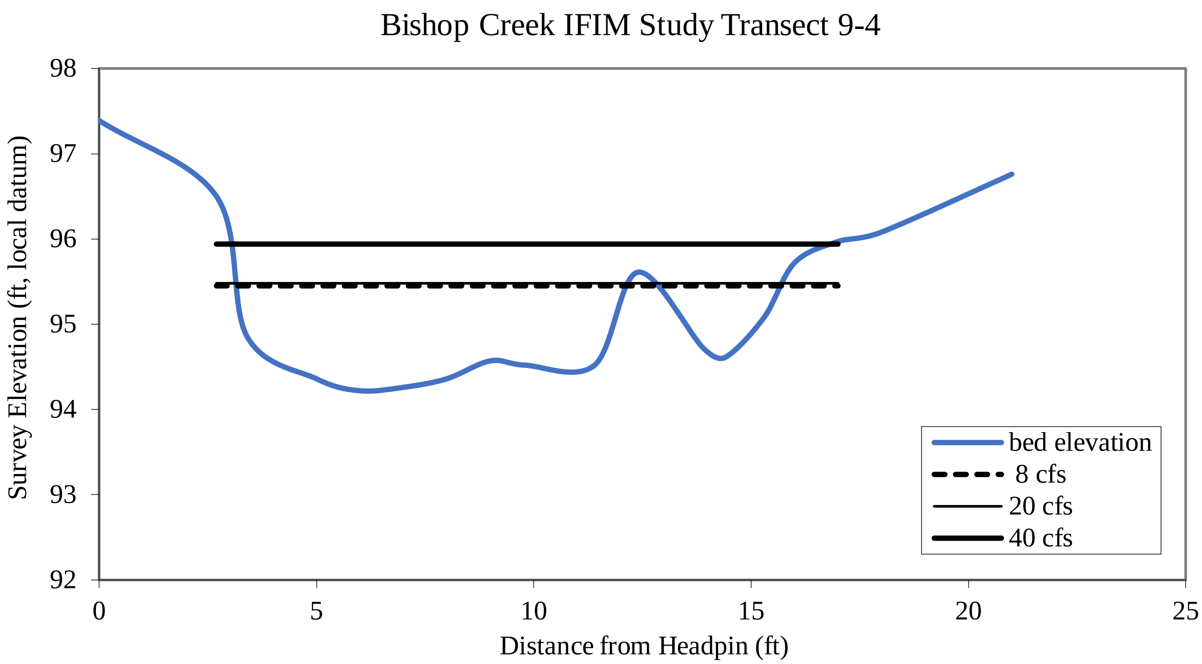


Figure B-26: Transect 9-4 cross section, looking upstream.

Reach 10

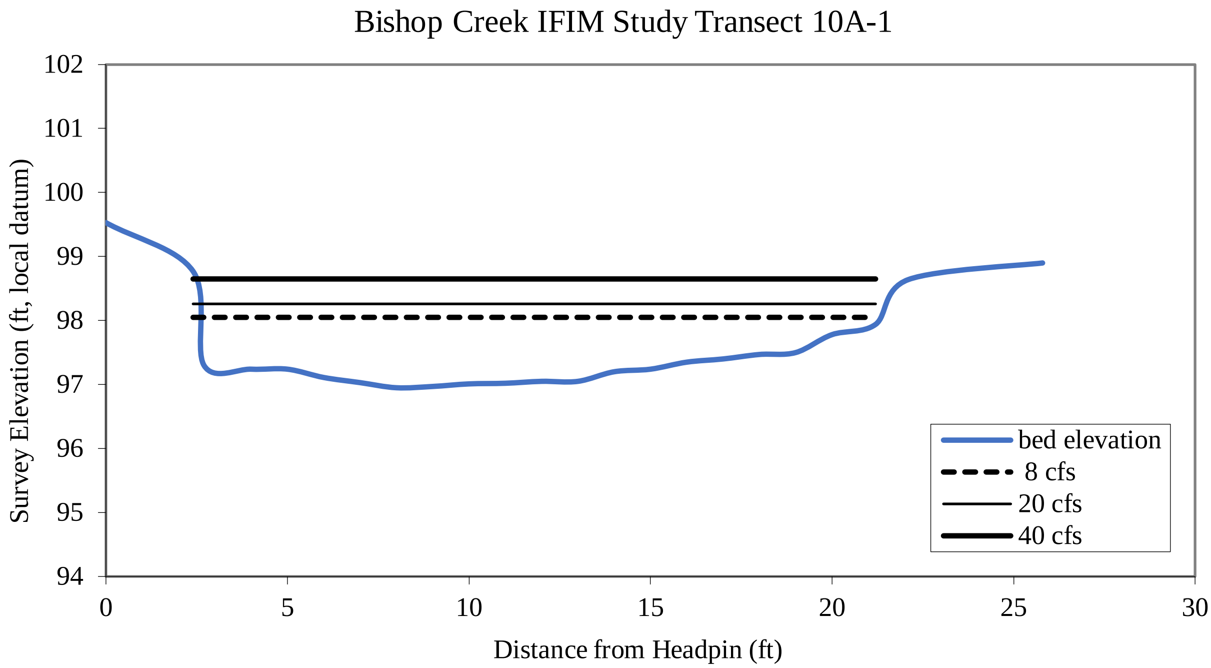


Figure B-27: Transect 10A-1 cross section, looking upstream.

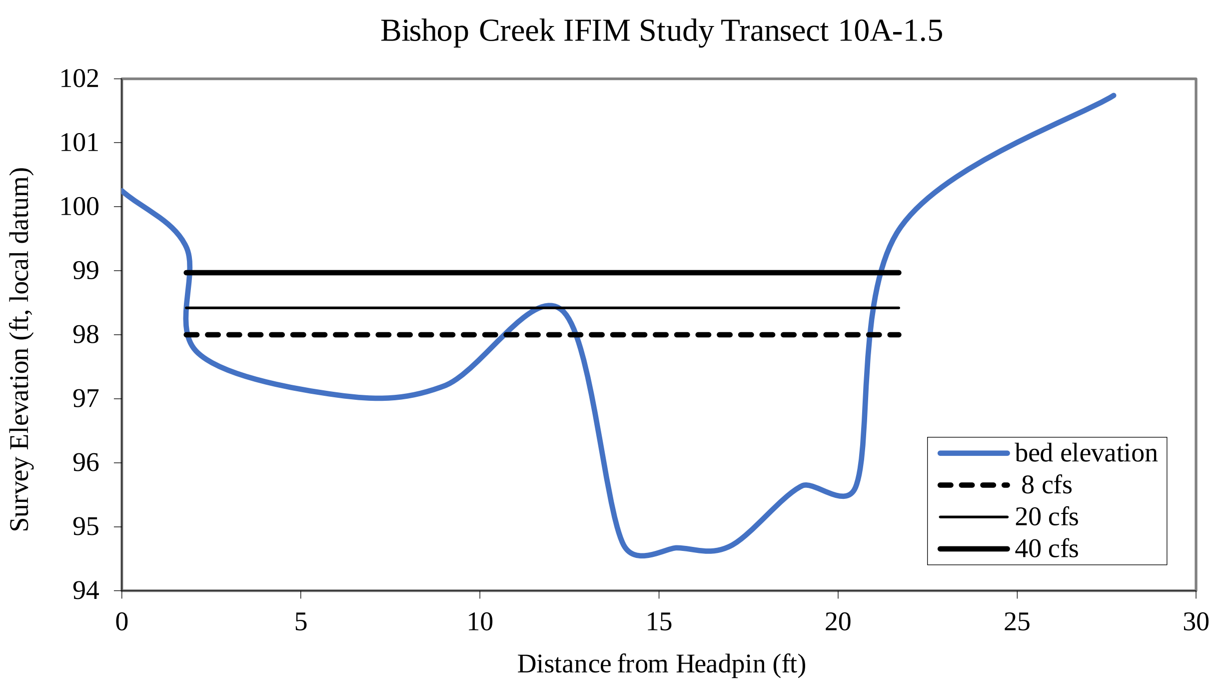


Figure B-28: Transect 10A-1.5 cross section, looking upstream.

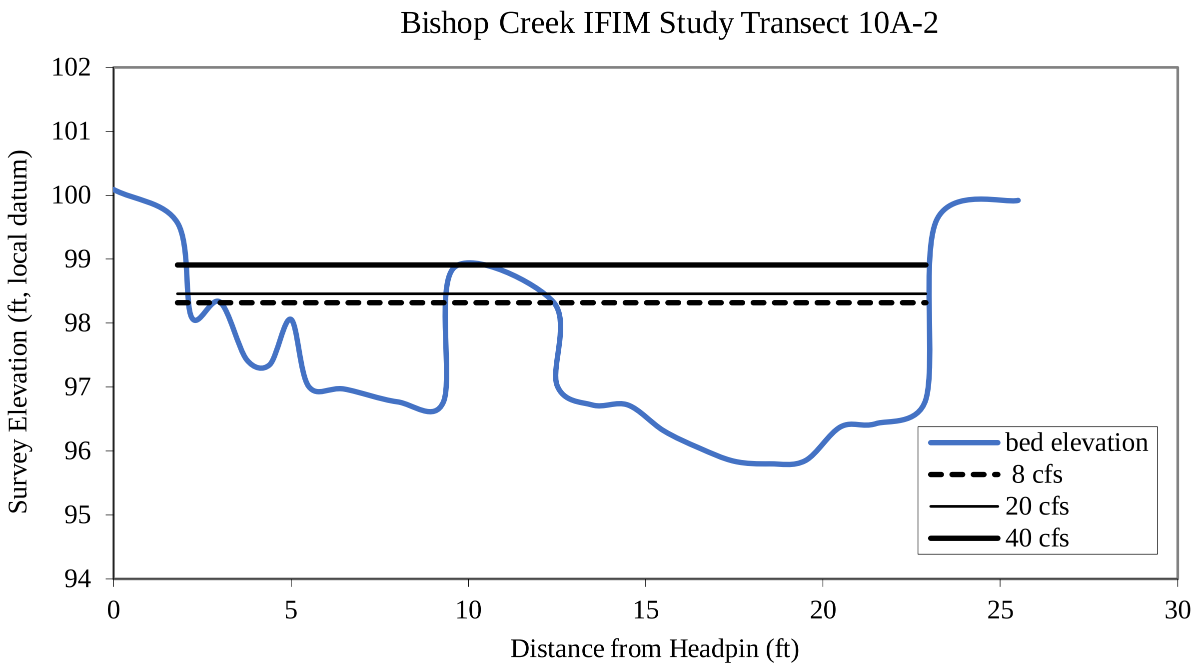


Figure B-29: Transect 10A-2 cross section, looking upstream.

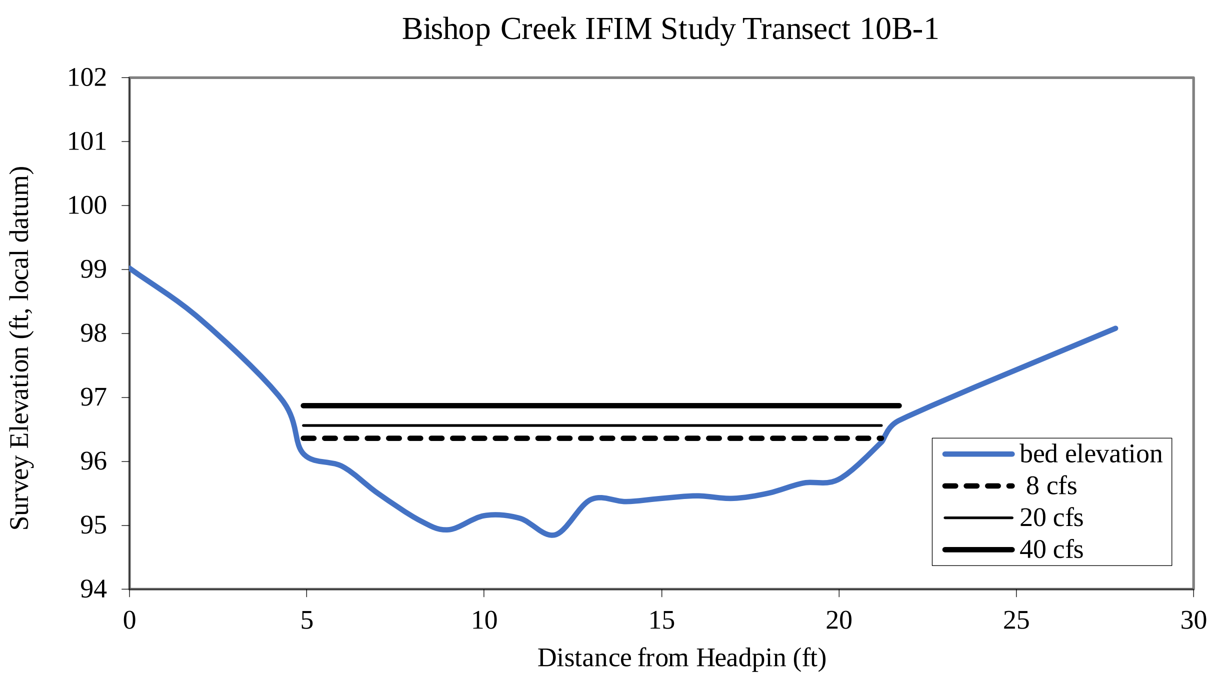


Figure B-30: Transect 10B-1 cross section, looking upstream.

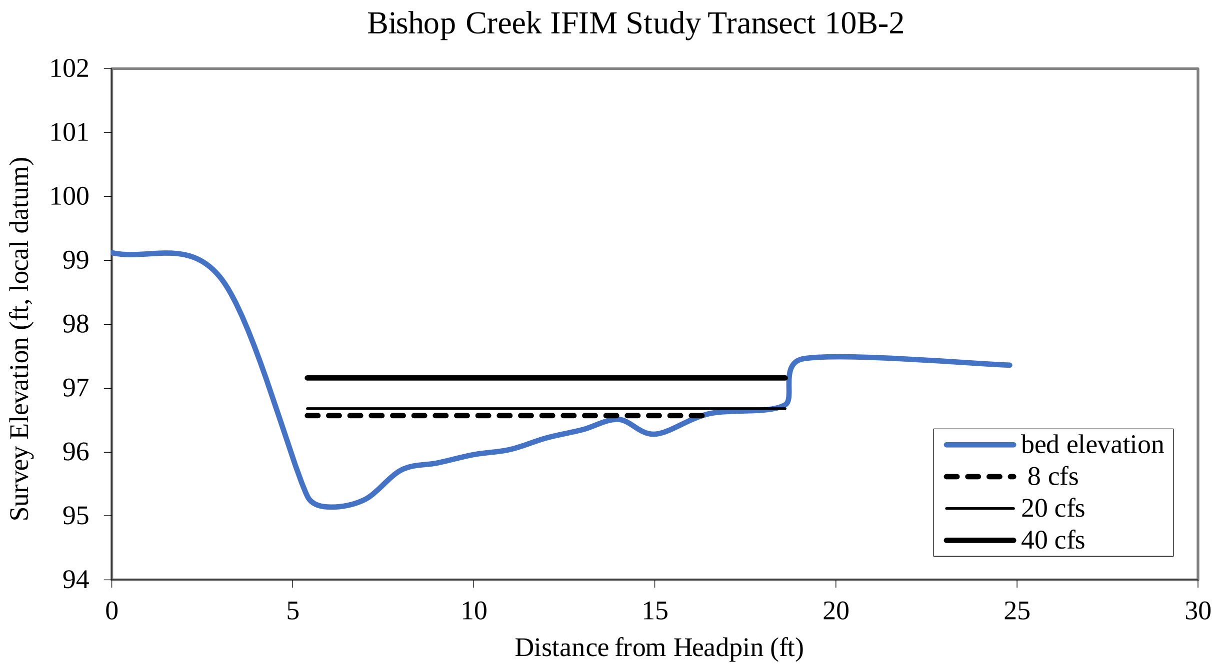


Figure B-31: Transect 10B-2 cross section, looking upstream.

APPENDIX C

STUDY SITE PHOTOS

REACH 1

PHOTO C- 1 TRANSECT 1-1 AT LOW FLOW CONDITIONS, 1.5 CFS (LEFT), MID-FLOW CONDITIONS, 20 CFS (RIGHT),AND HIGH FLOW (37 CFS) CONDITIONS (BOTTOM). ORIENTED DOWNSTREAM.

PHOTO C- 2 TRANSECT 1-2 AT LOW FLOW, 1.5 CFS (LEFT), MID-FLOW, 20 CFS (RIGHT) CONDITIONS, AND HIGH FLOW (37 CFS) CONDITIONS (BOTTOM). ORIENTED UPSTREAM.

PHOTO C- 3 TRANSECT 1-3 AT LOW FLOW, 1.5 CFS (LEFT), MID-FLOW, 20 CFS (RIGHT) CONDITIONS, AND HIGH FLOW, 37 CFS CONDITIONS (BOTTOM). ORIENTED DOWNSTREAM

PHOTO C- 4 **TRANSECT 1-4 AT LOW FLOW, 1.5 CFS (LEFT), MID-FLOW, 20 CFS (RIGHT), AND HIGH FLOW, 37 CFS (BOTTOM) CONDITIONS. LOW AND MID FLOW ORIENTED DOWNSTREAM (HIGH FLOW PHOTO ORIENTED UPSTREAM.**

PHOTO C- 5 TRANSECT 1-5 AT LOW FLOW, 1.5 CFS (LEFT), MID-FLOW, 20 CFS (RIGHT), AND HIGH FLOW, 37 CFS (BOTTOM) CONDITIONS. ORIENTED UPSTREAM.

REACH 2

PHOTO C- 6 TRANSECT 2-1 AND 2-2 AT LOW FLOW (LEFT), MID-FLOW, (RIGHT), AND HIGH FLOW (BOTTOM), CONDITIONS. ORIENTED LOOKING FROM RIVER-LEFT

PHOTO C- 7 **TRANSECT 2-3 AND 2-4 AT LOW FLOW, (LEFT), MID-FLOW (RIGHT), AND HIGH FLOW, (BOTTOM), CONDITIONS. ORIENTED LOOKING FROM RIVER LEFT.**

PHOTO C- 8 **TRANSECT 3-3 AND 3-4 AT LOW FLOW CONDITIONS. ORIENTED LOOKING FROM RIVER LEFT.**

REACH 3

PHOTO C- 9 **STUDY SITE 3 AT LOW FLOW, (LEFT), MID-FLOW (RIGHT), AND HIGH FLOW, (BOTTOM), CONDITIONS. ORIENTED LOOKING DOWNSTREAM FROM RIVER LEFT.**

REACH 5

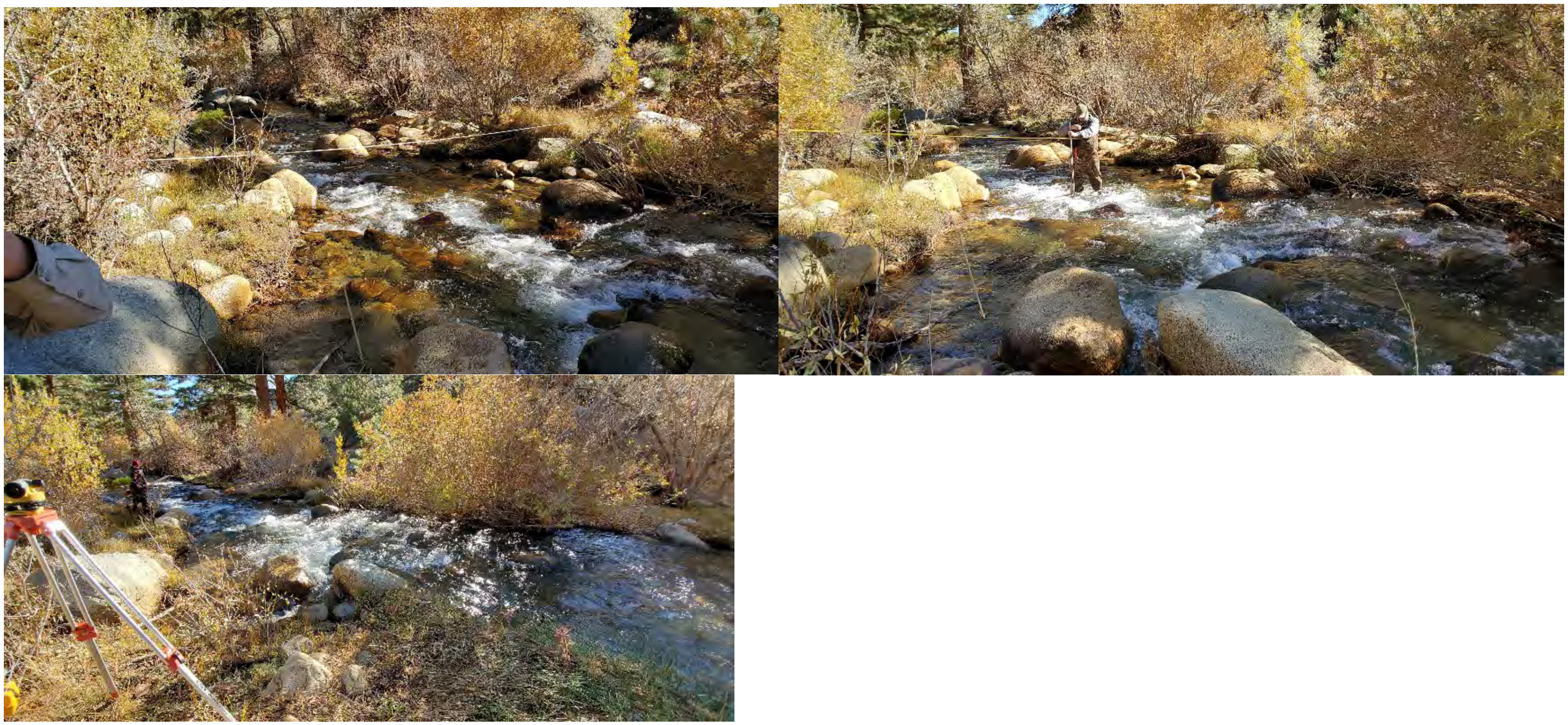


PHOTO C- 10 STUDY SITE 5 TRANSECTS 5-1 AND 5-2 AT LOW FLOW, (LEFT), MID-FLOW (RIGHT), AND HIGH FLOW (BOTTOM), CONDITIONS. ORIENTED LOOKING DOWNSTREAM FROM RIVER LEFT.

PHOTO C- 11 STUDY SITE 5 TRANSECTS 5-3 AT LOW FLOW, (LEFT), MID FLOW (RIGHT) AND HIGH FLOW (BOTTOM). ORIENTED LOOKING FROM RIVER LEFT.

REACH 7

PHOTO C- 12 STUDY SITE 7 AT LOW FLOW (LEFT), MID-FLOW (RIGHT) AND HIGH FLOW (BOTTOM), CONDITIONS. ORIENTED LOOKING DOWNSTREAM FROM RIVER LEFT.

REACH 8

PHOTO C- 13 TRANSECT 8-1 AT LOW FLOW, 8 CFS (LEFT), MID-FLOW, 20 CFS (RIGHT), AND HIGH FLOW, 40 CFS (BOTTOM), CONDITIONS. ORIENTED DOWNSTREAM.

PHOTO C- 14 TRANSECT 8-2 AT LOW FLOW, 8 CFS (LEFT), MID-FLOW, 20 CFS (RIGHT), AND HIGH FLOW, 40 CFS (BOTTOM), CONDITIONS. ORIENTED UPSTREAM.

PHOTO C- 15 TRANSECT 8-3 AT LOW FLOW, 8 CFS (LEFT), MID-FLOW, 20 CFS (RIGHT), AND HIGH FLOW, 40 CFS (BOTTOM), CONDITIONS. ORIENTED TOWARD RIVER RIGHT LOOKING DOWNSTREAM.

PHOTO C- 16 **TRANSECT 8-4 AT LOW FLOW, 8 CFS (LEFT), MID-FLOW, 20 CFS (RIGHT), AND HIGH FLOW, 40 CFS (BOTTOM), CONDITIONS, ORIENTED UPSTREAM.**

REACH 9

PHOTO C- 17 TRANSECT 9-2 AT LOW FLOW, 8 CFS (LEFT), MID-FLOW, 20 CFS (RIGHT), AND HIGH FLOW, 40 CFS (BOTTOM), CONDITIONS. ORIENTED DOWNSTREAM.

PHOTO C- 18 TRANSECT 9-3 AT LOW FLOW, 8 CFS (LEFT), MID-FLOW, 20 CFS (RIGHT), AND HIGH FLOW, 40 CFS (BOTTOM), CONDITIONS. ORIENTED UPSTREAM.

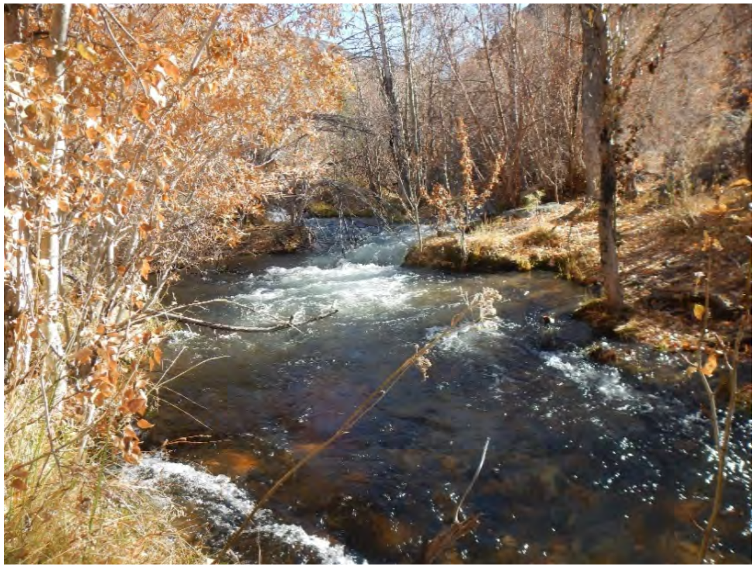


PHOTO C- 19 TRANSECT 9-4 AT LOW FLOW, 8 CFS (LEFT), MID-FLOW, 20 CFS (RIGHT), AND HIGH FLOW, 40 CFS (BOTTOM), CONDITIONS. ORIENTED UPSTREAM.

REACH 10

PHOTO C- 20 TRANSECT 10A-1 AT LOW FLOW, 8 CFS (LEFT), MID-FLOW, 20 CFS (RIGHT), AND HIGH FLOW, 40 CFS (BOTTOM), CONDITIONS. ORIENTED UPSTREAM.

PHOTO C- 21 TRANSECT 10A-1.5 AT LOW FLOW, 8 CFS (LEFT) AND MID-FLOW, 20 CFS (RIGHT), CONDITIONS. ORIENTED TOWARD RIVER LEFT, LOOKING UPSTREAM (NO PHOTO TAKEN AT HIGH FLOW RELEASE).

PHOTO C- 22 **TRANSECT 10A-2 AT LOW FLOW, 8 CFS (LEFT), MID-FLOW, 20 CFS, AND HIGH FLOW, 40 CFS (BOTTOM), CONDITIONS. ORIENTED DOWNSTREAM.**

PHOTO C- 23 TRANSECT 10B-1 AT LOW FLOW, 8 CFS (LEFT), MID-FLOW, 20 CFS (RIGHT), AND HIGH FLOW, 40 CFS (BOTTOM), CONDITIONS. ORIENTED UPSTREAM.

PHOTO C- 24 TRANSECT 10B-2 AT LOW FLOW, 8 CFS (LEFT), MID-FLOW, 20 CFS (RIGHT), AND HIGH FLOW, 40 CFS (BOTTOM), CONDITIONS. ORIENTED UPSTREAM.