Evaluation of Thermal Refugia and Habitat Restoration Opportunities of the Klamath River between J.C. Boyle Dam and Copco Reservoir

Final Report

May 17, 2023

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1 INTRODUCTION

1.1 Background

The Lower Klamath Project (FERC No. 14803; "Project") consists of four dams and their associated hydroelectric developments in the Klamath River: J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate. The J.C. Boyle bypass reach is located between J.C. Boyle Dam and J.C. Boyle Powerhouse, and its associated peaking reach begins downstream of the J.C. Boyle Powerhouse and terminates at the Copco Reservoir. The scheduled removal of the Project in 2024 is expected to return the Lower Klamath Project reach (**Figure 1**) to a more natural flow regime.

Figure 1. Map of the Lower Klamath Project reach encompassing the bypass and peaking reach associated with J.C. Boyle Dam, along with other existing hydropower infrastructure.

Recent thermal imagery data collected between J.C. Boyle Dam and Copco Reservoir characterized significant thermal features (STFs) and their specific locations along both the bypass and peaking reaches (McDonnell et al. 2022). STFs represent discrete, spatially limited inputs and complexes of relatively cold water that provide thermal refugia for non-anadromous Redband trout species (*Oncorhynchus mykiss* spp.), anadromous salmonids (following dam removal), and other cold-water species. Thermal refugia range from small features to larger reach-defining thermal habitat features. The extent to which these thermal refugia and habitat features would be affected following dam removal and changed flow regimes is unclear.

Current releases to the bypass reach under normal conditions from J.C. Boyle Dam total 100 cubic feet per second (cfs) to the Klamath River to maintain fish ladder operations and downstream conditions. Springs in the bypass reach add an additional flow of approximately 225 cfs at temperatures of approximately 11 degrees Celsius (°C; PacifiCorp 2005), which stabilizes reach water temperatures year-round under non-spill conditions, resulting in relatively cooler temperatures in summer periods and relatively warmer temperatures during winter periods. This thermal regime is altered during periods of spill from J.C. Boyle Dam, when relatively larger volumes of water released from J.C. Boyle Dam attenuate the temperature impact of spring inputs.

Flows in the peaking reach are more variable than bypass reach conditions as a result of power generation at J.C. Boyle Powerhouse. Releases from the powerhouse to the Klamath River range from 0 cfs to up to about 3,000 cfs during hydropower peaking operations. Powerhouse releases define the downstream end of the bypass reach and contribute to the approximately 325 cfs of flow in the bypass reach at this location. Spring inflows were identified in the peaking reach during the thermal data collection, but a consistent assessment of inflow contribution to the study reach has not been completed.

Post-dam removal flow regimes in the Project area will be regulated at Keno Dam. The specific target flows at Keno Dam following dam removal are not known at this time and will be determined during reconsultation. From late spring through early fall following dam removal, bypass flows will increase severalfold, and peaking reach flows will exhibit far less variability than under the current flow regime. During the wetter periods of the year, flows through the Project area will be augmented by seasonal runoff. Presumably, temporally specific flow regimes based on hydrologic year type, habitat needs, water temperature, and other factors will be developed post-dam removal during consultation between the U.S. Bureau of Reclamation, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service.

Effects on STFs from changes in streamflow following dam removal will vary based on site- and flow-specific conditions of each thermal feature and the magnitude and timing of flow changes. Changed flow regimes post-dam removal could have a variety of effects, some of which may be beneficial; however, increased flows in post-dam removal scenarios are expected to reduce the size of STFs, though the specifics of that change depend on STF location, site-specific riverscape topography, cold-water inflow volume, and magnitude of the flow change. Under increased flows, STFs may get mixed into the main flow or experience a change in shape and form. Some STFs may be located in alcoves, side-channels, or similar areas that may be protected under increased flows.

Deviations from typical flow regimes may include flushing flows for disease mitigation that also enhance habitat (particularly on the receding limb of the hydrograph), enhanced outmigration of juvenile salmonids (base flow augmentation), Native American ceremonial flows, flood control operations, or other events. These flows may span periods of hours, days, or longer and lead to considerable flow increases. Even short duration events can impact STF function, particularly during the warmer periods of the year when cold water thermal refugia plays an important role in salmonid habitat.

1.2 Purpose and Goal

This report identifies and provides recommended management actions in the Project reach following dam removal. The report focuses on habitat assessment and water temperature, but findings can be extended to support short- and long-term anadromous salmonid habitat enhancement and protection, fish monitoring, fish disease considerations, and information that can be used to manage future flow schedules at Keno Dam.

The recommendations in this report are based upon field habitat assessments and temperature modeling, which were informed by analysis of remotely sensed data. Potential salmonid habitat restoration sites that support existing fish populations and post-dam removal repopulation of this area by anadromous fish were also identified. The Klamath Reservoir Reach Restoration Prioritization Plan (K3RP; O'Keefe et al. 2022) listed this effort as a priority study to "utilize the

2021 Thermal Infrared Airborne Imagery captured on the mainstem Klamath River from J.C Boyle to Copco reservoir to identify, prioritize and implement cold water refugia restoration projects."

2 APPROACH

An initial site visit was critical to understanding the remote sensing data and site conditions to support Project work and identify potential restoration prescriptions. The bypass reach is dominated by high-gradient (average 1.9 percent from J.C. Boyle Dam to J.C. Boyle Powerhouse) canyon stream conditions where access for field observations and restoration work present challenges. The downstream peaking reach likewise includes high-gradient sections and only portions are accessible by road, leading to similar challenges. Following the initial site visit, thermal feature prioritization, field habitat assessment, and temperature modeling were completed. Each of these topics is presented below.

2.1 Initial Site Visit

Potential approaches for STF prioritization were considered during an initial site visit that occurred on May 26, 2022. Several locations along the Klamath River, from the wooden bridge just downstream of J.C. Boyle Dam to the Spring Island Recreation site, were viewed during the site visit (**Appendix A**). Participants in this site visit included representatives from Oregon Department of Fish and Wildlife, National Marine Fisheries Service, PacifiCorp, E&S Environmental Chemistry, River Design Group, and Watercourse Engineering. In addition to aspects of STF prioritization, overall project objectives were discussed during the site visit. Schedules and notes from the site visit are also included in **Appendix A**.

2.2 Thermal Feature Prioritization

The 119 individual STFs and three tributaries identified in McDonnell et al. (2022) were grouped into assumed spring complexes or considered as isolated features. Sites were grouped based on distance between features and visualization of the thermal signature in proximity to the features. For example, STFs were grouped at locations where relatively cold water was connected in the thermal image or would be expected to be connected without exposed rocks or with complete visibility of the water surface (e.g., without obstruction by overhanging vegetation). Features located on opposing sides of the river centerline were not grouped, with the exception of three

STFs located in the vicinity of the Spring Island access point. These STF point groupings provided the basis for defining each isolated STF or STF group based on an aerial extent of relatively cold water observed at the river surface in the thermal imagery and are hereafter referred to as "thermal feature areas". Polygons of thermal feature areas associated with each of the original STF points were established in two steps:

<u>Step 1 – Create raster surface of relatively cold water</u>

a) Apparent breaks in the 10-meter (m) longitudinal temperature profile (LTP) data extracted from the thermal imagery were identified and used to divide the overall study reach into four distinct thermal sections (**Figure 2**).

b) River surface temperatures from the 10-m LTP were averaged for each thermal section.

c) A threshold was defined for relatively cold-water areas as locations with temperatures 0.5°C cooler than the average temperatures calculated in Step 1.b (**Table 1**).

d) Deviation between the thermal imagery and the specified relatively cold-water threshold from Step 1.c were mapped as a spatially continuous surface.

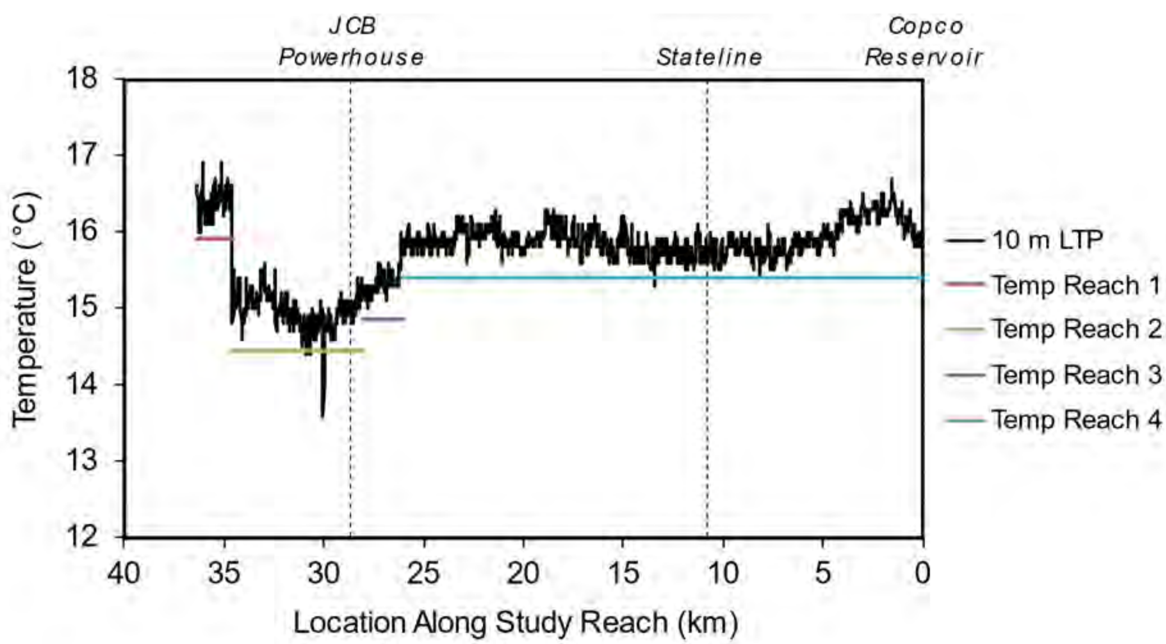


Figure 2. Klamath River surface water temperatures from the 10 m longitudinal temperature profile (LTP) extracted from the thermal imagery (blue line). Threshold temperatures indicative of relatively cold water are shown as variously colored horizonal lines designating the longitudinal extent of each of the four temperature reaches along the overall study reach.

Table 1. Locations of designated thermal reach break designations and associated relatively cold-water temperature thresholds.

Thermal Reach	River Kilometer		Relatively Cold-Water Temperature Threshold (°C)
	Upstream	Downstream	
1	36.33	34.59	15.9
2	34.58	28	14.5
3	27.99	26	14.9
4	25.99	0	15.4

Step 2 – Generate thermal feature areas

a) Grid cells from the output of Step 1.d that met the definition of relatively cold water (i.e., 0.5°C cooler than the LTP thermal section average temperature) were extracted and converted to individual polygons.

b) Individual polygons from Step 2.a less than 1 square meter were removed.

c) Remaining in-channel thermal feature polygons in the vicinity of each STF point/group were aggregated to form multi-part polygons representative of individual thermal feature areas (**Figure 3**).

This process resulted in 54 thermal feature areas, including areas at the confluences of Shovel Creek and Long Prairie Creek. Attributes for prioritization were developed based on input from the Technical Advisory Group (TAG). These attributes were used for prioritization of the 54 thermal feature areas based on several metrics, including:

- Thermal strength
- Proximity
- Habitat enhancement potential
  - Floodplain connectivity
  - Habitat type

Once these metrics were defined, a prioritization matrix was established to reflect the distributions (or classifications) of each attribute across the 54 thermal feature areas, with metrics

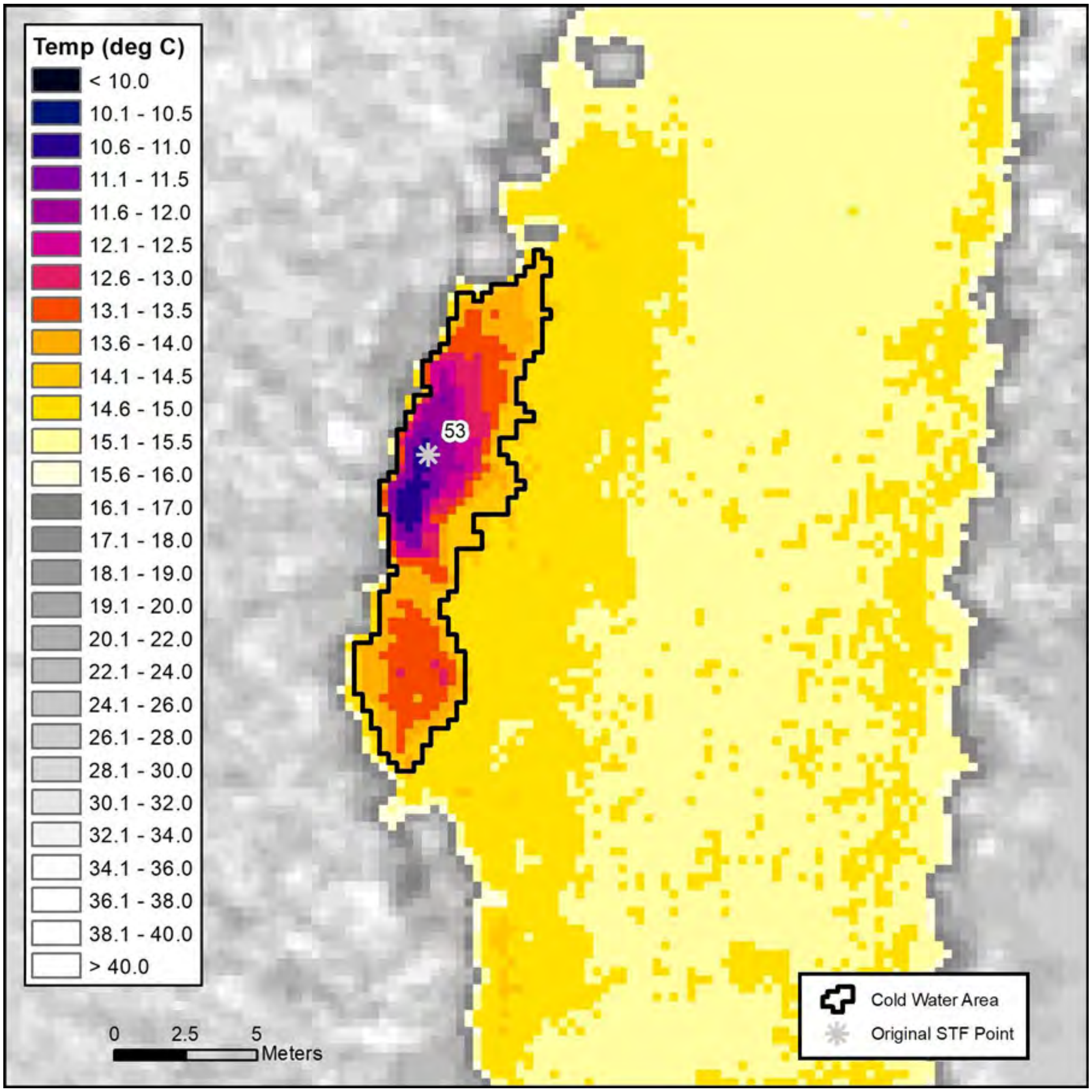


Figure 3. Example relatively cold-water area (RCWA) associated with significant thermal feature (STF) point #53. All grid cells within the RCWA are at least 0.5°C cooler than the average 10 m longitudinal temperature profile (LTP) temperature of the thermal reach in which this STF is located (see text for additional discussion).

grouped into low, moderate, and high potential for habitat enhancement. Each category is defined and described in the following report sections. Information on logistics of river access was also attributed to each thermal feature area.

2.2.1 Thermal Strength

Water temperature of a thermal feature can represent direct inflow temperatures or a mix of inputs and Klamath River waters. Thus, the thermal signature (temperature) of a feature is a defining metric that represents inflow quantity and temperature, how flows entered the river (e.g., side channel or bank inflow, directly into the bed of the river), where STF flows enter the river (e.g., whether entry point to the channel is deep or shallow), time of year, and other factors. The temperature metric used for thermal feature prioritization was designated as the "thermal strength", which provided a numeric characterization of the apparent magnitude and extent of relatively cold water at each thermal feature (**Figure 3**). Thermal strength of each area was calculated as the sum of the temperature deviation between each 30-cm grid cell of the thermal feature and the associated specified temperature threshold.

2.2.2 Proximity

Proximity of one thermal feature to another thermal feature provides insight into relative connectivity of thermal refugia. Relatively isolated cold-water features may restrict movement of fish, leading to crowding, predation, or other stressors, compared to thermal features that are in close proximity to one another and therefore allow for movement between features, provide opportunity for redistribution, and support a variety of habitats. Both conditions may provide opportunities for habitat protection or enhancement. Proximity of each thermal feature to nearby thermal features was determined according to the sum of the distance (m) to the nearest upstream and downstream thermal feature centroids (**Figure 4**). This determination of proximity to nearby cold-water features was used as one of the four primary metrics for prioritization. Thermal features that exist further from others were considered higher priority relative to features that were in close proximity with others.

2.2.3 Habitat Enhancement Potential

Habitat enhancement potential refers to the relative likelihood that a restoration prescription provides ecological value. Habitat enhancement potential was evaluated based on two metrics: 1) an estimate of floodplain connectivity, and 2) general habitat type designations.

2.2.3.1 Floodplain Connectivity

Floodplains are limited in the high-gradient reaches in the Project area. Nonetheless, identifying those portions of the stream bed that will be inundated over a range of flows is an important consideration for restoration actions. Extent of floodplain connectivity is expected to be directly

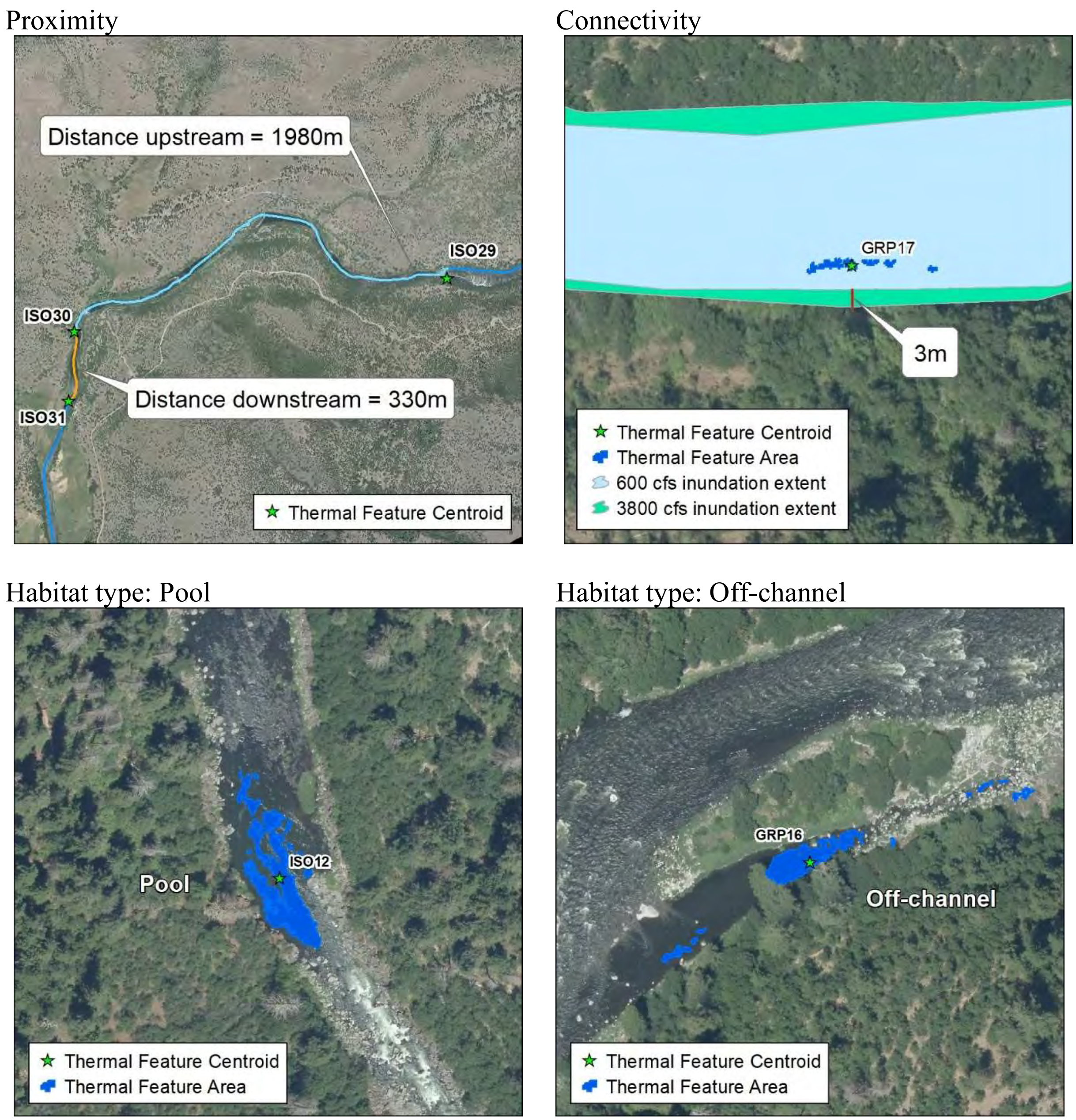


Figure 4. Examples of prioritization metrics used for site selection. (Top left) Example derivation of the proximity metric for thermal feature ISO12. The sum of the distance between of the two nearest (upstream and downstream) features is a total of 2,310 m from ISO30. (Top right) Example illustration of the floodplain connectivity metric derivation for thermal feature GRP17. The floodplain connectivity metric was derived based on the extent of channel expansion with flow (i.e., deviation in inundation extents) at the location of the thermal feature centroid. (Bottom) Example habitat type designations ("Pool" and "Off-channel") based on aerial photo interpretation in the vicinity of thermal features ISO12 and GRP16.

related to the possibilities for habitat protection or enhancement in a given area. Estimates of floodplain connectivity along the study reach were generated by simulating channel inundation extents resulting from flow rates of 600 cfs and 3,800 cfs and calculating the channel width expansion distance (m) between these two flow rates (**Figure 4)**.

Modeled water surface elevations for the chosen flow rates were extracted from an existing Sedimentation and River Hydraulics - One Dimension (SRH-1D) model (Karp 2014) and overlaid with a topo-bathymetric LiDAR dataset to determine the inundation extents (QSI 2019a, b).

2.2.3.2 Habitat Type

Existing habitat type in the vicinity of each thermal feature defines the purpose and duration for which fish are expected to utilize a given portion of river. Based on aerial photo interpretation, each of the 54 thermal feature areas were attributed as predominantly associated with one of these three general habitat types: 1) Rapid, 2) Pool/Riffle, and 3) Off-channel Features (**Figure 4)**. Rapids (e.g., boulder cascade habitats) are expected to be difficult to modify under future flow regimes because of the high gradient, high water velocities, and large substrate. Rapids are often relatively underutilized by fish and therefore offer fewer options for habitat preservation or enhancement that directly benefit fish relative to other portions of a river. Pool and riffle habitats provide a greater potential for habitat enhancement work. Existing off-channel habitat features, such as alcoves or side-channels, generally offer the most potential for protection and enhancement of refuge from warmer water and higher velocity conditions in the mainstem portions of the river. Inflow contribution from the larger thermal features located in the bypass reach represent an additional factor to consider for prioritization (see Section 2.4) because the input of large volumes of cold water has dramatic impacts on local and potentially reach-scale habitat. For inclusion within the prioritization matrix, flow estimates from these transects were attributed to each thermal feature upstream of a given transect, bracketed by the next upstream transect.

Other habitat conditions, such as depth, velocity, cover, and substrate, were assessed during field visits to priority thermal features, as described below in Section 2.3.

2.2.4 Prioritization Matrix Development

Individual thermal features were prioritized for further study according to the previously described attributes associated with thermal strength, proximity to other thermal features, and habitat enhancement potential including floodplain connectivity and existing habitat type. A prioritization matrix was established to reflect the distributions (or classifications) of each attribute across the 54 thermal feature areas. Each metric was grouped into three classes with values of 1, 2, and 3, representative of low, moderate, and high potential for habitat enhancement, respectively (**Table 2**). Class breaks associated with quantitative metrics were established based on natural breaks in the distribution of data using the Jenks method (Jenks 1967), which seeks to minimize the variance within classes and maximize the variance between classes. Habitat types classified as Rapid, Pool/Riffle, and Off-channel were given class values of 1, 2, and 3, respectively. Overall scores were totaled by summing the class values across all four metrics. The lowest and highest total score for an individual thermal feature were 4 and 12, respectively (i.e., all four metrics classified as either 1 or 3).

Table 2. Habitat enhancement scores and their respective site access descriptions and prioritization metric cutoffs.

			Prioritization Metrics			
Rating	**Score**	**Access**	**Thermal Strength**	**Proximity (m)**	**Floodplain Connectivity (m)**	**Habitat Classification**
Low	1	Inflatable boat or walk	0 – 5795	40 – 1140	0 – 3.0	Rapid
Med	2	Equipment access to opposite bank	5796 – 25290	1141 – 3010	3.1 – 8.0	Pool or riffle
High	3	Equipment access to same bank	25291 –56483	3011 – 8080	8.1 – 16.0	Off-channel

Given that some prioritization metrics may be considered more useful than others with respect to restoration prioritization, members of the TAG each proposed metric rankings (ranked from 1 through 4; higher rank indicated a more important metric), which were then used to derive weights to apply to the individual metric classifications (1 through 3). Proposed weights for each metric were averaged, rounded to whole numbers, then re-ranked from 1 through 4 (**Table 3**). Thermal strength was deemed the most relatively important metric and given the highest weight (4), while floodplain connectivity was given the lowest (1). These final weights were then

Table 3. Average prioritization metric ranks based upon TAG submissions, rounded and unrounded weighting factors, and metric score ranges.

Metric	Average Rank (TAG)	Average Weighting Factor (NMFS – Fish)[1]	Rounded Weighting Factor	Metric Score Range
Thermal Strength	1.0	4.0	4	4 – 12
Proximity (m)	1.9	3.3	3	3 – 9
Floodplain Connectivity	3.9	1.2	1	1 – 3
Habitat	2.6	2.3	2	2 – 6

[1] NMFS provided two sets of scores, one based on expected benefits to fish and the other based on expected overall ecosystem benefits. The average rank uses the expected benefits to fish in calculating the average weighting factor.

applied to the total score (from 4 to 12) summed across the four prioritization metrics, resulting in a minimum possible weighted score of 10 and a maximum of 30.

2.2.5 Logistics of River Access

Although access to the river is a key determinant of possibilities for habitat protection or enhancement along the study reach, site access was not incorporated directly into the prioritization scoring process. Rather, the above-described in-channel characteristics were used for prioritization among thermal features, and site access was used to partition the features based on areas of the river accessible by foot or boat (Access Score = 1), a road on the opposite bank of the river (Access Score = 2), or a road on the same bank of the river (Access Score = 3). Site access scoring was initially determined utilizing various remote sensing datasets, including GIS roads layers, a LiDAR derived slope model, and recent aerial imagery of the reach. Sites access scoring was also reviewed and verified by local biologists familiar with the study reach.

2.2.6 Site Selection for Field Assessment

Given that restoration opportunities are limited in areas that are only accessible by foot or boat (Access Score = 1), thermal sites accessible by vehicle and by hiking or kayaking a short distance (Access Score = 2 or 3) were considered in the field habitat assessment. Because of the limitations on types of enhancement activities that could be undertaken, sites only accessible by boat were not considered for field assessment. The 10 highest priority sites accessible by vehicle were selected for field assessment.

2.3 Field Habitat Assessment

Field assessments at the priority locations were conducted on October 12th and 13th, 2022. These assessments were focused on describing existing habitat conditions and evaluating the potential to create, enhance, or protect cold-water refuge areas at each of the top 10 priority thermal features with an Access Score of 2 or 3 identified in the prioritization matrix. Klamath River flow conditions in the reach downstream of J.C. Boyle Powerhouse experience daily fluctuations in flows from hydropower generation. In general, the priority thermal sites were evaluated at low to moderate flows and conditions were sufficient for describing the existing habitat characteristics. Dates of each thermal site visit and flow conditions at 8:00 A.M. and 4:00 P.M. at the USGS Klamath River below John C. Boyle Powerplant gage, near Keno, OR (#11510700) are shown in **Table 4**. Flows ranged from 354 to 680 cfs on October 12, 2022, and from 349 to 1,680 cfs on October 13, 2022.

Table 4. Dates and flow conditions (cfs) associated with field assessment activities at priority sites. Data were collected from USGS gage #11510700; Klamath River below John C. Boyle Powerplant, near Keno, OR.

Date	Flow, 08:00	Flow, 16:00	Sites Visited
October 12, 2022	354	680	GRP 15, GRP 16, ISO 16
October 13, 2022	349	1680	GRP 19, GRP 20, ISO 30, ISO 31

Field assessments were conducted by experienced water resource professionals with backgrounds in fish biology, fluvial geomorphology, and hydrology. While some quantitative physical measurements were taken within the thermal features, the assessments were primarily qualitative in nature. Existing habitat features evaluated at each priority location included:

- General habitat type (pool, riffle, etc.)
- Channel slope and morphology
- Approximate width of flood prone area
- Substrate composition
- Cover type and distribution (large wood, overhanging vegetation, etc.)
- Water temperature within and in the vicinity of each thermal feature
- Typical water velocity at each thermal feature
- Typical water depth at each thermal feature

- Riparian vegetation type and condition
- Accessibility to fish (connected off-channel, main channel, etc.)
- Presence of aquatic macrophytes

Three sites were not visited because of access constraints, but observations made from adjacent roadways and remote sensing review were included in the individual site descriptions. Two sites were accessed by inflatable kayak, which was used to ferry across the Klamath River to the opposite bank. The other sites were accessed by vehicle and then hiking. Much of the assessment reach is in a steep canyon, and direct access to the river with vehicles or heavy equipment is difficult, if not impossible, in many areas. Site access was evaluated at each priority site to help determine the types of restoration or enhancement activities that could potentially be undertaken.

2.4 Temperature Modeling

Existing flow and water quality models (PacifiCorp 2005, NCRWQB 2010, ODEQ 2010, 2019) were used to assess water temperature conditions in the Klamath River between J.C. Boyle Dam and Shovel Creek. These models were updated with new information on spring locations in the bypass reach and were used to provide insight into the bypass reach (and downstream) temperature regime after the removal of J.C. Boyle Dam.

2.4.1 Model Description

The Resource Management Associates (RMA) suite of finite-element hydrodynamic and water quality models are capable of accurate simulation of flow and transport in steep river reaches that experience dynamic flow conditions (e.g., hydropower peaking), reproduction of longitudinal stream temperature gradients, and simulation at a sub-daily time step (e.g., hourly). These models have been historically used on the Klamath River (PacifiCorp 2005, NCRWQB 2010, ODEQ 2010, 2019), among other river systems (Deas and Orlob 1999, PCWA 2010, Watercourse 2017).

The RMA suite includes RMA-2 and RMA-11, along with various utility programs (King 2013a, b, 2014). Hydrodynamic simulations are performed using the finite element model RMA-2, which solves the equations of momentum and mass conservation to provide estimates of velocities and water surface elevations at specified locations (nodes) throughout a system. Output from RMA-2 is passed to the water quality model RMA-11. RMA-11 solves the advection-diffusion equation to simulate water quality constituents, including water temperature, at specified locations (nodes) throughout a system. RMA-11 calculates the full energy budget and can simulate sub-daily (e.g., hourly) changes in water temperature. Model output is in the form of synoptic longitudinal profiles of temperature and water quality along the river at all computational locations, or a time series of values at fixed locations. Details of model development and implementation are addressed in PacifiCorp (2005) and Deas et al. (2019).

2.4.2 Inflow Estimates

Inflow contribution from thermal features located in the bypass reach were represented in the model. Field work completed in the summer of 2022 included instream flow measurement of the Klamath River between J.C. Boyle Dam and the J.C. Boyle Powerhouse (bypass reach) to identify general inflow locations and inflow rates of springs located in the bypass reach. Flow measurements within the bypass reach were taken using a Sontek RS-5 acoustic doppler current profiling (ADCP; **Appendix B**) system at four transects (**Figure 5**).

Data from these measurements were subjected to an on-site quality assurance protocol in addition to post-processing quality assurance steps. These flow measurements were used to re-locate the spring flow inputs specified in the water quality modeling effort.

2.4.3 Model Scenarios

The RMA model developed for the purposes of this study consists of 388 nodes, with approximately 75 m spacing, between J.C Boyle Dam and Shovel Creek. The model was implemented at 15-minute intervals and with output reported hourly and was applied using historical hydrology, water temperature boundary conditions, and meteorology from the year 2004, which was a "normal" hydrologic year. Three model runs were developed. One run was conducted to update the spring flow contributions from the original characterization (PacifiCorp 2005) based on the flow transect data collected during the summer of 2022 to represent "existing conditions". Two additional runs were conducted to investigate expected future scenarios relative to post-dam conditions (**Table 5)**. The two expected future scenarios were based on the new spring locations and were specified to examine the potential implications of two constant flow conditions without the presence of J.C. Boyle Dam, using 800 cfs and 1,800 cfs as steady-state flow rates at the current J.C. Boyle Dam location. The 800 cfs flow scenario was intended to

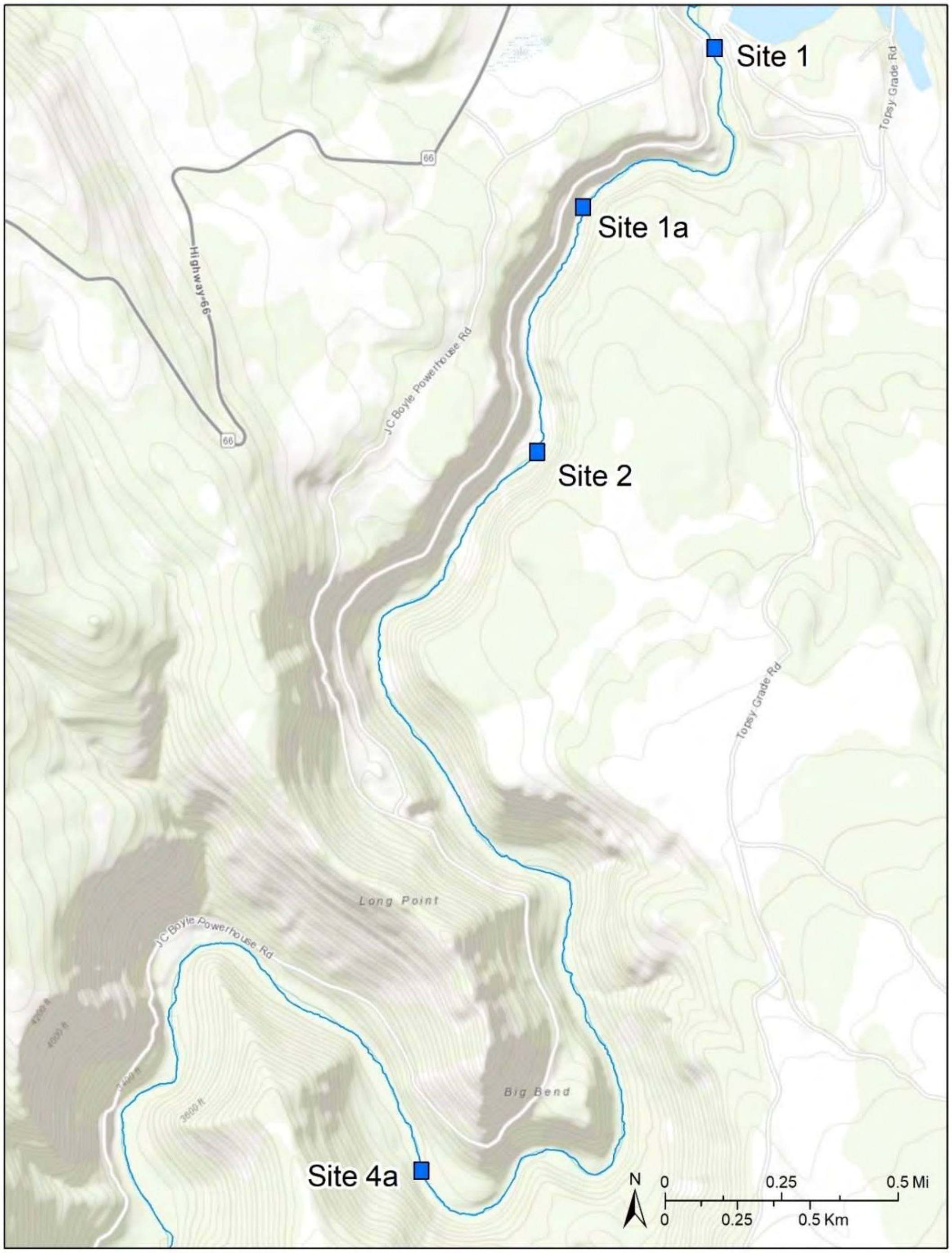


Figure 5. Locations of flow measurement transects (dark blue boxes) used for estimating flow rates for three sections of the Klamath River bypass reach.

represent the approximate flow regime at the J.C. Boyle Dam location to support downstream summer flows at the USGS gage (11516530) Klamath River below Iron Gate Dam. The 1,800 cfs flow scenario was intended to represent the approximate flow regime at the J.C. Boyle Dam location to support cultural flows for Native American Tribes in the middle and lower Klamath River, which are typically provided for a short period (less than 24 hours). For both the 800 cfs and 1,800 cfs cases, accretions downstream of the J.C. Boyle Dam location would provide the additional flow to achieve downstream objectives.

Table 5. Summary of RMA model scenarios implemented, and the data sources or values used for selected parameters.

Scenario	Spring Information	Flow Rate from J.C. Boyle Dam	Flow Rate from J.C. Boyle Powerhouse	Upstream Water Temperature
Historical	Historical	Historical	Historical	Historical
Existing Conditions (Baseline)	Updated	Historical	Historical	Historical
Constant 800 cfs (No dam)	Updated	800 cfs	1 cfs	Modeled results from Keno reach
Constant 1,800 cfs (No dam)	Updated	1,800 cfs	1 cfs	Modeled results from Keno reach

For the 800 cfs and 1,800 cfs scenarios, J.C. Boyle Powerhouse flows were set in the model to 1 cfs and 11°C to essentially remove them as a significant source of flow or temperature. Model output from five specific model nodes within the Klamath River study reach (**Table 6**) was used to evaluate each scenario, in additional to consideration of full longitudinal profile data. Klamath River flow rates and water temperatures at the Keno gage are lowest and warmest in July and August, with historical average (2006 – 2021) monthly streamflow for the last 15 years at the Keno gage of 703 cfs and 687 cfs in July and August, respectively (USGS 2022). The 800 and 1,800 cfs scenarios were only modeled in summer months when potentially adverse water temperatures may occur in the Klamath River. The model was applied for a 2-week period in mid-August that would typically include seasonal high-water temperatures.

This period is also in the proximity of typical ceremonial flows in the Klamath River. Scenario results focused on the hottest seven days within the simulations according to the maximum 7-day average of the daily maximum temperature metric.

Table 6. Selected model output locations along the study reach, node numbers, and nearest Klamath River mile for comparison.

Location	Node Number	River Kilometer from Thermal Imaging Study	Nearest Klamath River Mile
Below J.C. Boyle Dam	1	36.2	225
Above J.C. Boyle Powerhouse	92	29.1	221
Below J.C. Boyle Powerhouse	102	28.3	220
OR-CA Stateline	331	10.8	209
Above Shovel Creek Confluence	388	6.4	207

2.4.4 Model Validation

Model validation for the bypass and peaking reaches is addressed in PacifiCorp (2005). To develop temperature boundary conditions for the two expected future scenarios (i.e., 800 cfs and 1,800 cfs), the upstream Klamath River model between Keno Dam and J.C. Boyle Reservoir was used to simulate the 800 cfs and 1,800 cfs flow releases from Keno Dam, respectively. This approach provided a means to approximate a more representative diurnal signal at J.C. Boyle Dam location under no-dam conditions and account for the conveyance of different release quantities from Keno Reservoir.

The Klamath River model from Keno Dam to J.C. Boyle Reservoir was reviewed to ensure representativeness for this exercise. Limited field data were available but were sufficient to indicate the model effectively simulated water temperatures through the reach. Simulated and measured water temperature are compared for the Klamath River immediately upstream of J.C. Boyle Reservoir in **Figure 6**.

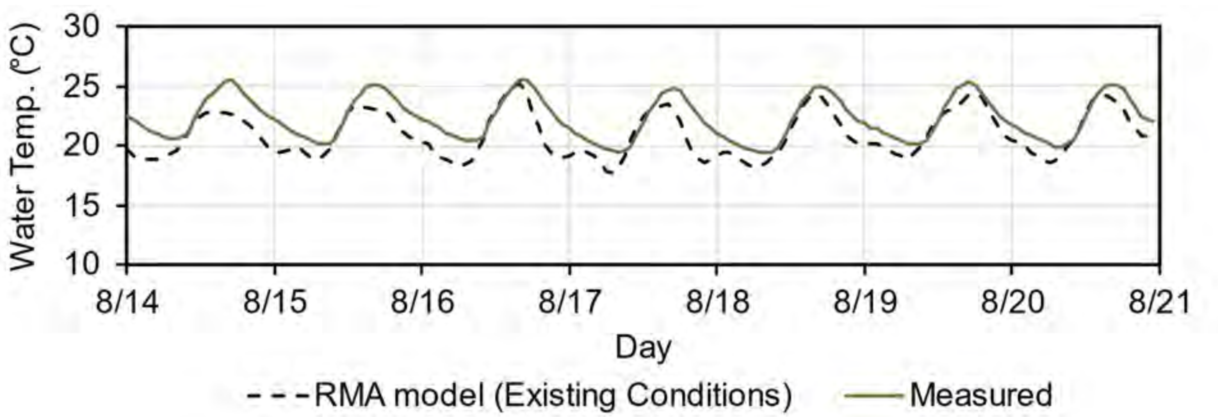


Figure 6. Comparison between simulated and measured Klamath River water temperature upstream of J.C. Boyle Reservoir (08/09/2004 – 08/23/2004) using the RMA2 and RMA 11 Keno Dam to J.C. Boyle Reservoir model.

3 RESULTS AND DISCUSSION

3.1 Prioritization Matrix

Thermal sites with the greatest areal extent and magnitude of relatively cold water were accessible by foot/boat or by road on the same bank (**Figure 7**), indicating both limited and good potential for habitat enhancement activities in areas with the coldest inputs. Given that relatively large numbers of thermal sites were identified in the bypass reach, sites accessible by foot were in closest proximity to another site. Sites readily accessible by vehicle (Access Score = 3) were generally located furthest from another thermal site, increasing the enhancement value of these areas. Only six thermal sites were associated with off-channel habitat (two sites per access type), which was the highest valued habitat type from a habitat enhancement perspective. Taken together, these distributions of prioritization metric values indicate good potential for habitat enhancement in areas that are readily accessible by vehicle, with the important caveat that relatively few of these areas were identified.

Scores across individual prioritization metrics varied longitudinally among thermal sites along the study reach (**Figure 8**). Many of the sites with the highest thermal strength and floodplain connectivity (i.e., scores of 2 and 3) occurred upstream of J.C. Boyle Powerhouse, where access is constrained to by foot/boat. Moderate to high scores for proximity and habitat type were relatively well distributed longitudinally across access types. The prioritization data matrix,

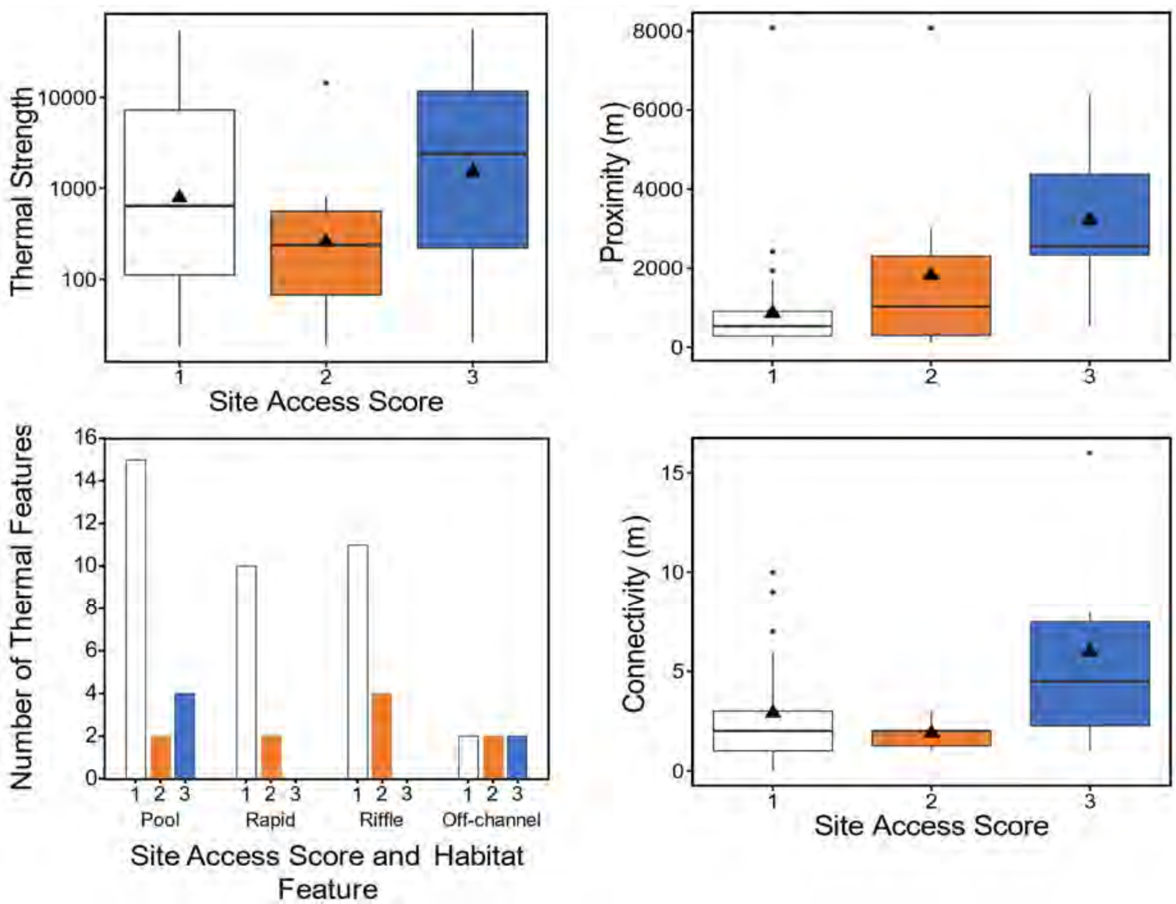


Figure 7. Boxplots of metric results vs. site access score and histogram of the number of thermal features by site access score and habitat feature. Triangles on the boxplots represent the mean of each distribution.

along with descriptive statistics of the three quantitative prioritization metrics for the 54 candidate thermal sites, is shown in **Appendix C.**

Weighted total priority scores were closely related to total (unweighted) scores (**Figure 9**). Although the weighting did not have substantial effects on overall priority ranking among sites, the weighted scores were used to select priority sites for field assessment. The two most highly ranked sites occur between Stateline and Copco Reservoir (**Figure 10**), at the confluences of Shovel and Long Prairie creeks with the Klamath River. Other relatively highly ranked sites with nearby vehicle access occurred within a few kilometers of the J.C. Boyle Powerhouse.

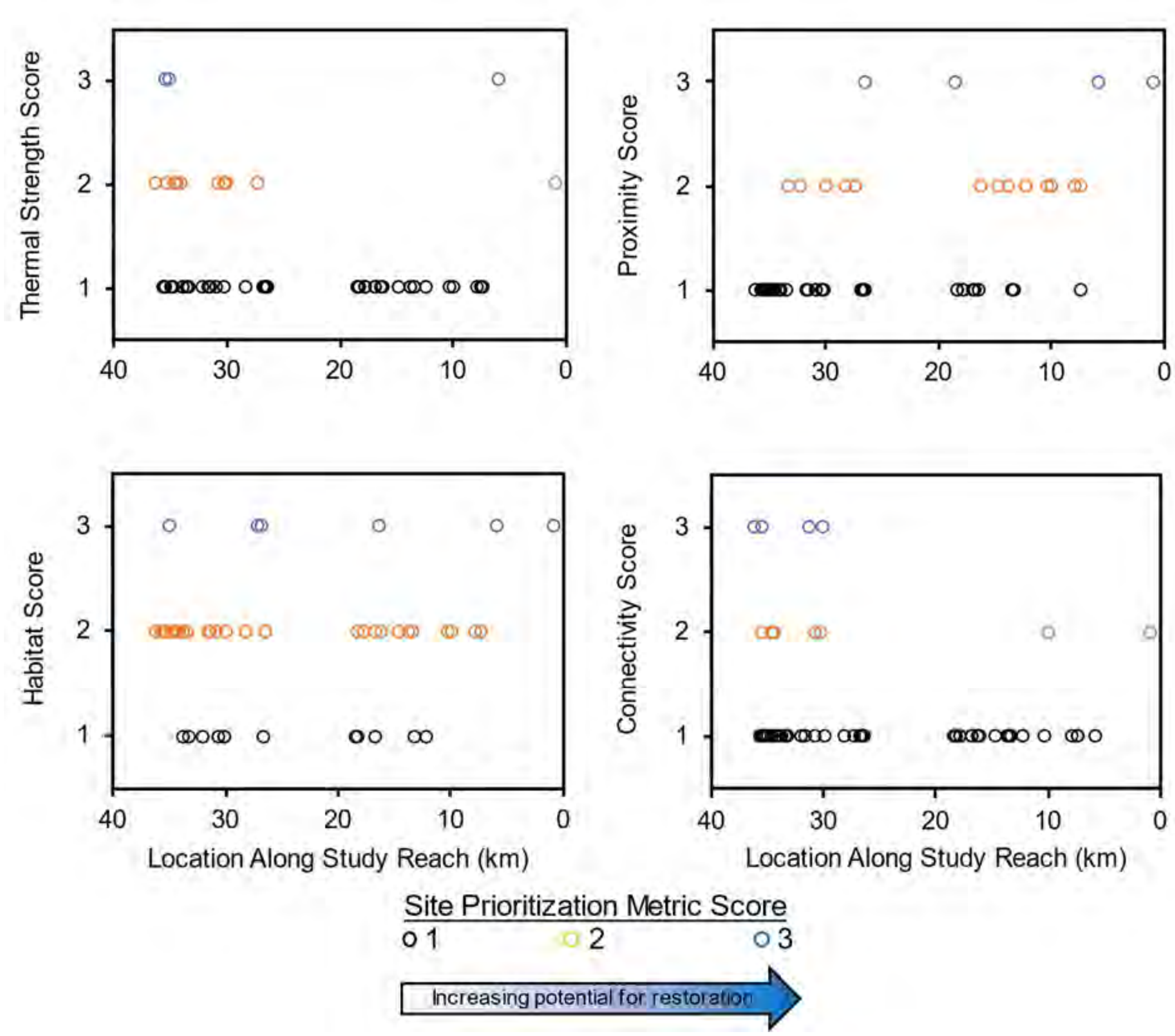


Figure 8. Longitudinal profiles of prioritization metric scores. The J.C. Boyle Powerhouse is located at river km 28.8, the CA-OR border is at river km 10.8, and river km 0 is the upstream end of Copco Reservoir.

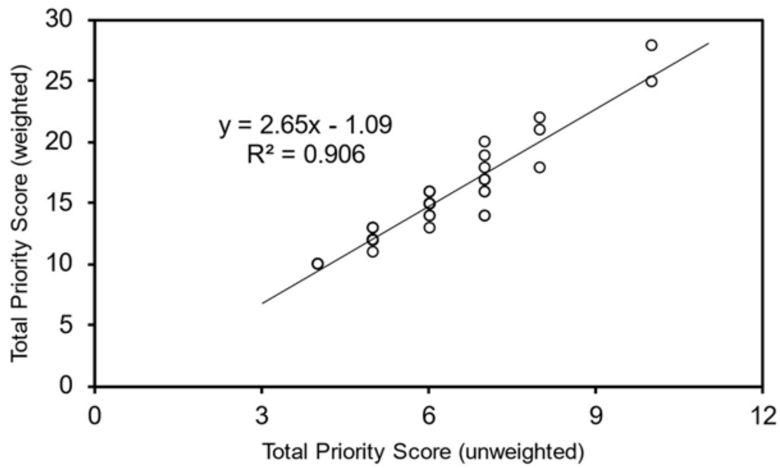


Figure 9. Comparison of weighted and unweighted priority score totals among the 54 candidate thermal sites.

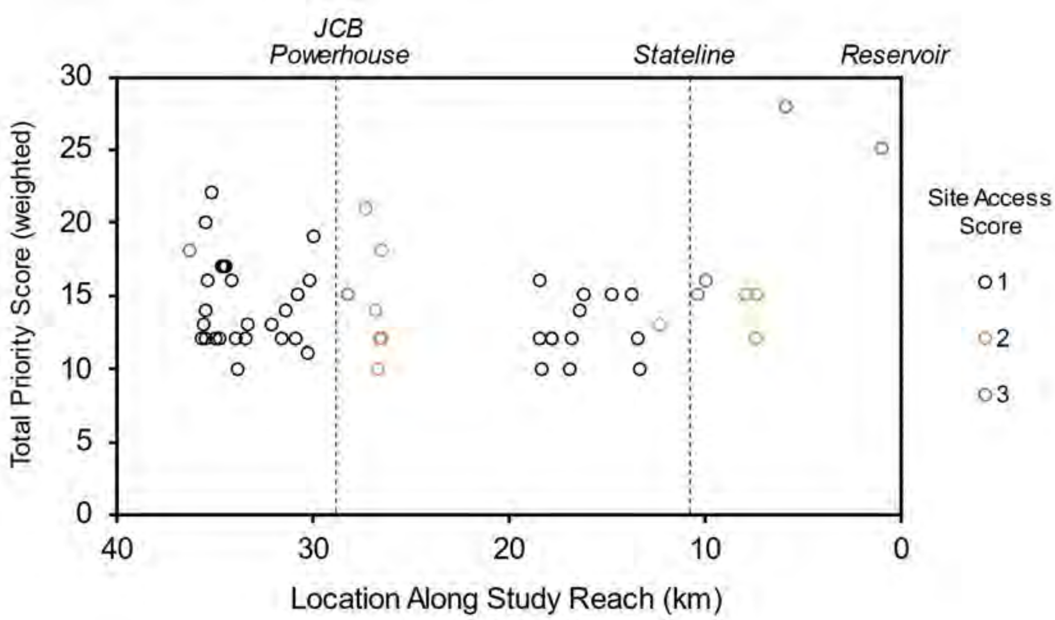


Figure 10. Longitudinal profile of prioritization metric scores ranked by site access. The J.C. Boyle (JCB) Powerhouse is located at river km 28.8, the CA-OR border ("Stateline") is at river km 10.8, and river km 0 is the upstream end of Copco Reservoir.

3.2 Flow Transects and Updated Spring Locations

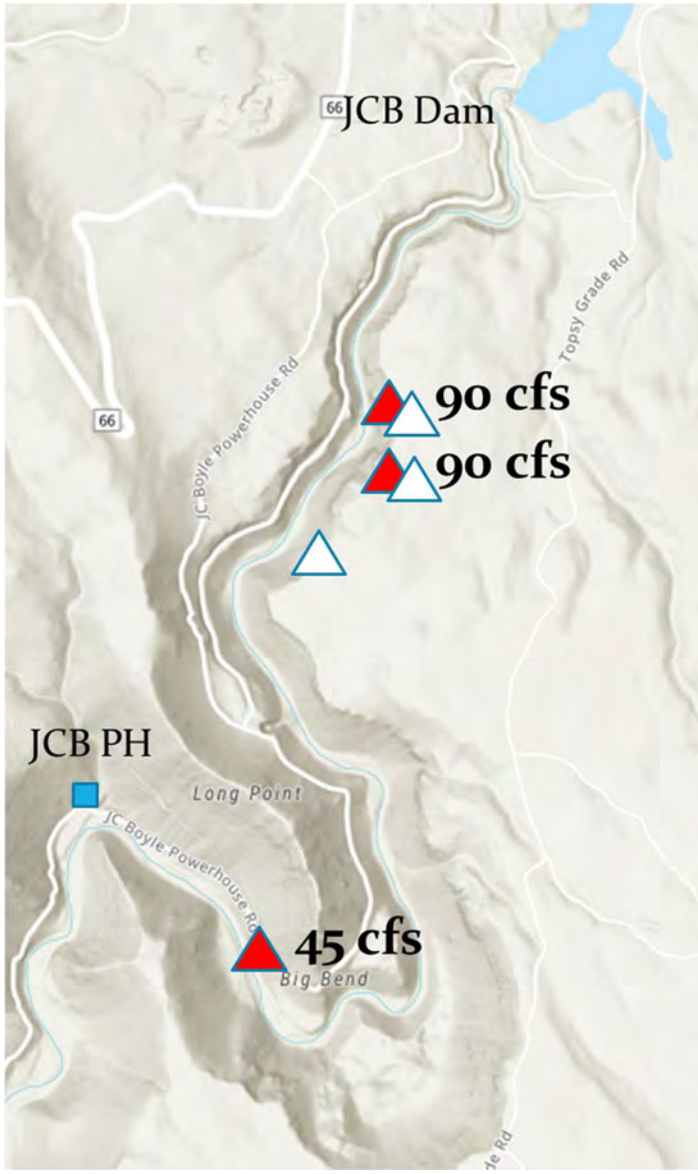
Flow transect data provided additional context to the extent of cold-water contribution from sets of isolated and grouped thermal features along the bypass reach. These results provided further insight into the relative importance of the thermal features identified in the September 2021 thermal imagery within this reach, as well as the likelihood of cold-water persistence under higher and warmer flows following dam removal. For example, the combined thermal strength metric for thermal sites between flow transects 1 and 1a was more than 130,000, which was more than twice the combined thermal strength of the thermal features located between transects 1a and 2 (**Table 7**). However, inflow rates associated with the latter set of thermal sites was 183 cfs, relative to < 1 cfs for the upstream sites. This indicates that relatively cold-water conditions between transects 1a and 2 would be expected to persist to a greater extent under expected increased flow conditions post-dam removal (see Section 3.5), relative to conditions between transects 1 and 1a. Acoustic doppler current profile data generated at the four transect sites are shown in **Appendix D**.

Locations and flow rates of the bypass reach spring inputs were updated in the RMA model based on flow transect results (**Figure 11; Table 8**). The first two springs were moved slightly downstream from their original locations and the third spring was moved towards the J.C. Boyle Powerhouse. The original total spring flow estimate of 225 cfs was re-allocated across the three locations with additional flow provided at the springs located at nodes 26 and 32, and a flow reduction for the spring located at node 84.

These changes in spring location had little influence on modeled flow and water temperatures at selected sites along the study reach (**Appendix E**). Although these springs have direct local thermal impacts on Klamath River temperatures and associated habitat suitability for salmonids, these model results indicate negligible differences downstream with the updated spring locations and flow rates. These minimal differences at the reach scale extended throughout the year: in the summer when the springs are a relatively cool water source to a warm river and in the winter when the springs are a relatively warm water source to a cold river.

Table 7. Flow rates assigned to thermal sites located in the bypass reach and associated thermal strength metric values.

Name	River Bank	Thermal Strength	Flow Rate (cfs)
GRP01	R	12995	Not rated
GRP02	L	1197	< 1
ISO01	L	110	< 1
GRP03	R	54828	< 1
ISO02	L	66	< 1
ISO03	R	75	< 1
GRP04	R	18210	< 1
GRP05	R	50183	< 1
ISO04	L	146	< 181
GRP06	R	2635	< 181
GRP07	R	12322	< 181
GRP08	R	25290	< 181
ISO05	L	7808	< 181
GRP09	L	8593	< 181
GRP10	R	3453	< 53
ISO06	L	153	< 53
ISO07	R	61	< 53
GRP11	R	162	< 53
ISO08	L	971	< 53
ISO09	R	422	< 53
ISO10	R	152	< 53
GRP12	R	5795	< 53
GRP13	R	8106	< 53
ISO11	R	311	< 53
GRP14	R	9777	< 53
ISO12	R	17619	< 53



Spring locations employed in original modeling scenario; input flow rates of 75 cfs

Spring locations employed in updated modeling scenario; variable input flow rates based upon flow transect measurements

Figure 11. Approximate locations of spring inputs to the bypass reach used in the original and updated modeling scenarios. Red triangles indicate input locations and magnitude of input used for the “Existing Conditions” model scenario.

Table 8. Spring node numbers and associated flow rates used in the original and updated modeling scenarios.

Scenario	Node Numbers	Flow Rate (cfs)[1]
Original Spring (Historical)	22, 24, 36	75, 75, 75
Existing Conditions	26, 32, 84	90, 90, 45

[1] The order of flow rates corresponds to the order in node number. Node numbers represent the most downstream node associated with the spring inflow element used for modeling.

3.3 Selected Priority Areas

Among the 16 thermal sites with nearby road access, the top 10 (ranked by weighted total score) were selected for field assessment (**Table 9**). These 10 road-accessible sites are located between J.C. Boyle Dam and Copco Reservoir (**Figure 12**), with notable gaps in the bypass reach and between ISO16 and ISO30.

3.4 Existing Conditions at Priority Thermal Sites with Habitat Enhancement Potential

Relatively cold water inflows may provide important refuge habitat for anadromous fish following dam removal. These same inflows can also provide important relatively warm water inflows during the winter months when upstream river flows are relatively cooler. Post-dam removal, the bypass reach will be subject to higher flow rates that are expected to dilute these cold-water inflows. Habitat assessments at priority locations revealed a range of opportunities for the protection and/or enhancement of relatively cold-water conditions in these areas.

Priority thermal sites at the Shovel Creek and Long Prairie Creek confluences with the Klamath River have the most restoration opportunity, followed by two areas within one mile downstream of the Spring Island Boat Access point (**Table 10**). Existing conditions of the four sites with proposed habitat enhancement activities are described in the sections just below, with descriptions of the remaining six sites provided in **Appendix F**.

Table 9. The 10 thermal sites selected for field assessment, associated prioritization results, and corresponding weighted scores from the priority matrix.

Name	Thermal Strength	Thermal Strength Score (weighted)	Proximity	Proximity Score (weighted)	Habitat Description	Habitat Score (weighted)	Connectivity (m)	Connectivity Score (weighted)	Access Score	Total Score (weighted)	Site Rank
GRP19	56483	12	6390	9	Off-channel	6	3	1	3	28	1
GRP20	8480	8	4930	9	Off-channel	6	6	2	3	25	2
GRP16	14320	8	1450	6	Off-channel	6	1	1	2	21	3
ISO16	48	4	8070	9	Pool	4	1	1	2	18	4
GRP01	12995	8	550	3	Pool	4	16	3	3	18	5
ISO31	20	4	2390	6	Pool	4	8	2	3	16	6
ISO32	19	4	2570	6	Riffle	4	2	1	2	15	7
ISO34	568	4	1520	6	Pool	4	2	1	2	15	8
GRP15	672	4	2720	6	Pool	4	2	1	3	15	9
ISO30	152	4	2310	6	Pool	4	1	1	3	15	10

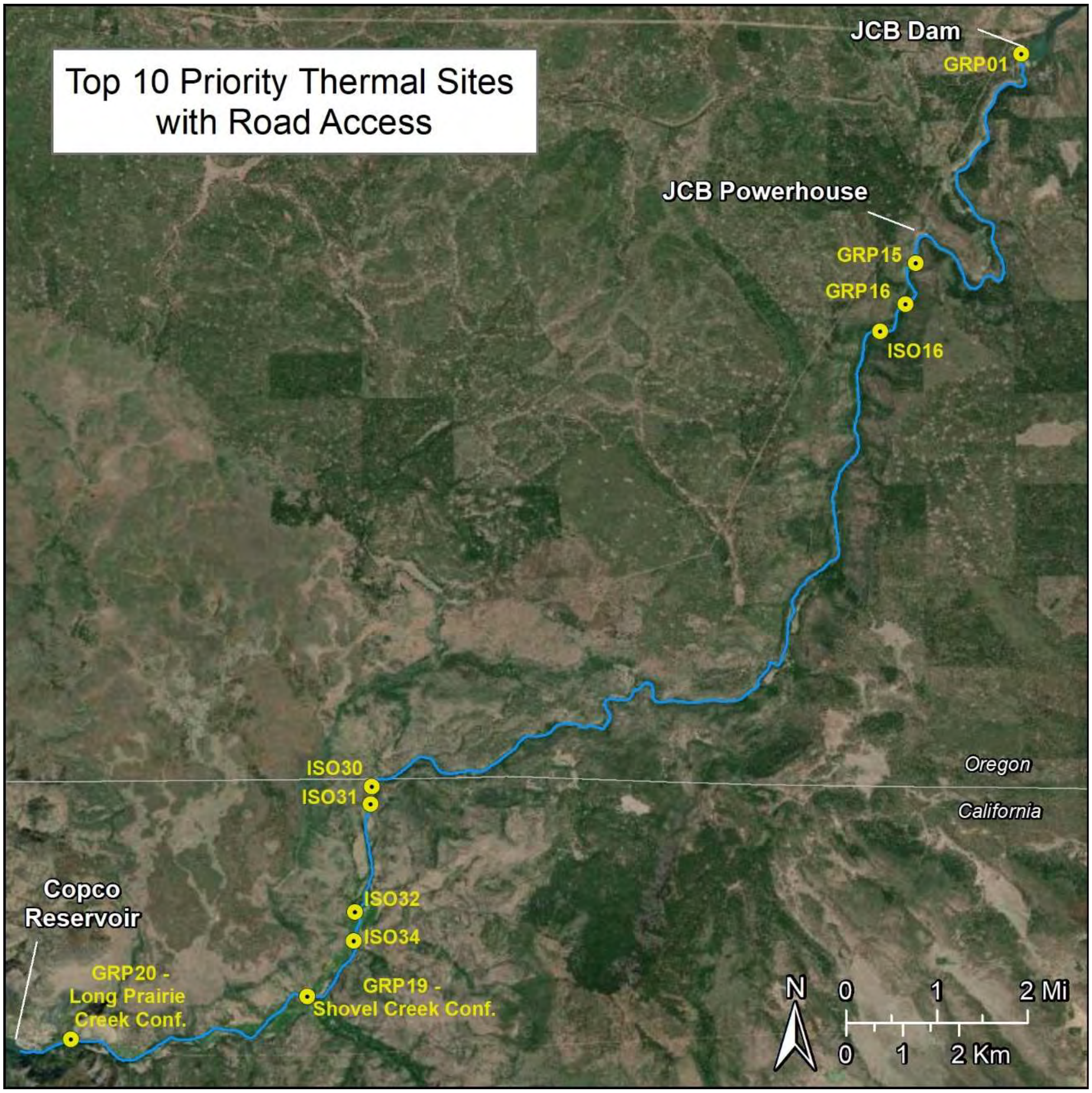


Figure 12. Locations of top ten priority thermal features, with nearby road access, selected for field assessment.

Table 10. Selected attributes of sites selected for field assessment.

Site #	Site Score Rank	Field Recon	Ownership	Feature	Location	Proposed Enhancement	Priority
GRP 19	1	Y	PacifiCorp	Tributary Confluence	Shovel Creek confluence	Protection / Cover / Riparian / Wetland	High
GRP 20	2	Y	KRRC	Tributary Confluence	Long Prairie Creek confluence	Protection / Cover / Riparian /	High
GRP 16	3	Y	US BLM	Spring Alcove	0.6 miles downstream of Spring Island	Cover	Med
ISO 16	4	Y	US BLM	Hydraulic Upwelling / Seep	1.0 miles downstream of Spring Island	Cover / Riparian	Low
GRP 01	5	N	KRRC	Seep / Spring	J.C. Boyle Dam	TBD	TBD
ISO 31	6	Y	PacifiCorp	Hydraulic Upwelling	1,500 ft downstream of Hayden Cr confluence	None	Low
ISO 32	7	N	PacifiCorp	Hydraulic Upwelling	1.1 miles upstream of Shovel Cr confluence	None	Low
ISO 34	8	N	PacifiCorp	Hydraulic Upwelling	0.8 miles upstream of Shovel Cr confluence	None	Low
GRP 15	9	Y	US BLM	Hydraulic Upwelling	Spring Island Boat Access	None	Low
ISO 30	10	Y	PacifiCorp	Hydraulic Upwelling	500 ft downstream of Hayden Cr confluence	None	Low

3.4.1 Group 16 (GRP16, Rank 3)

The spring/hyporheic feature designated as GRP16 is located in an alcove approximately 500 ft to 1,000 ft downstream of USGS gage #11510700 on land managed by the U.S. Bureau of Land Management (BLM; **Figure 13**). The alcove, which functions as a side channel under high flow conditions, is well-connected to the main channel at the downstream end and provides some habitat for rearing of juvenile salmonids under existing conditions. The thermal feature and alcove are located on river-left as the Klamath River transitions from a right-turning to a left-turning bend. The island separating the alcove from the mainstem functions as a point bar, and grade-controlling rapids are adjacent to both the upstream and downstream ends of the island. The river-left hillslope adjacent to the side channel is steep with high relief, which has resulted in significant rockfall and the formation of a boulder scree slope. A 400-ft-long, 100-ft-wide scree field forms the upstream portion of the side-channel and connects the island to the hillslope. The scree field consists of material ranging from 1 ft cobble to boulders over 10 ft in diameter. Tall grasses and large boulders in the scree field limit direct observation of the bottom of the channel, but the interstices between the largest boulders appear to be filled with large gravel, cobbles, and small boulders.

The 40- to 60-ft-wide alcove located in the downstream portion of the 400 ft of the side channel is fully connected to the Klamath River at the downstream end and provides ingress and egress for fish from the river. Substrate in the alcove is coarse grained with localized 1- to 2-ft thick silt-clay deposits between larger clasts and on alcove margins. Average substrate size tends to fine with distance downstream, starting with 1- to 2-ft-diameter boulders dominating at the upstream end and large gravel and small cobble dominating downstream within the alcove. Boulders and large cobble substrate are again dominant at the downstream connection in the mainstem Klamath River. Macrophyte coverage was over 90 percent of the wetted channel in much of the alcove during the field visit.

Site hydrology was observed on October 12, 2022, with discharge of approximately 350 cfs at USGS gage# 11510700. Surface flow was not observed through the scree field during the assessment. However, a small trickle (<0.1 cfs) of flow was observed entering through the boulders at the upstream end of the alcove. The presence of this flow and its 14.2°C measured temperature, which was similar to values measured in the mainstem, indicate minor hydraulic

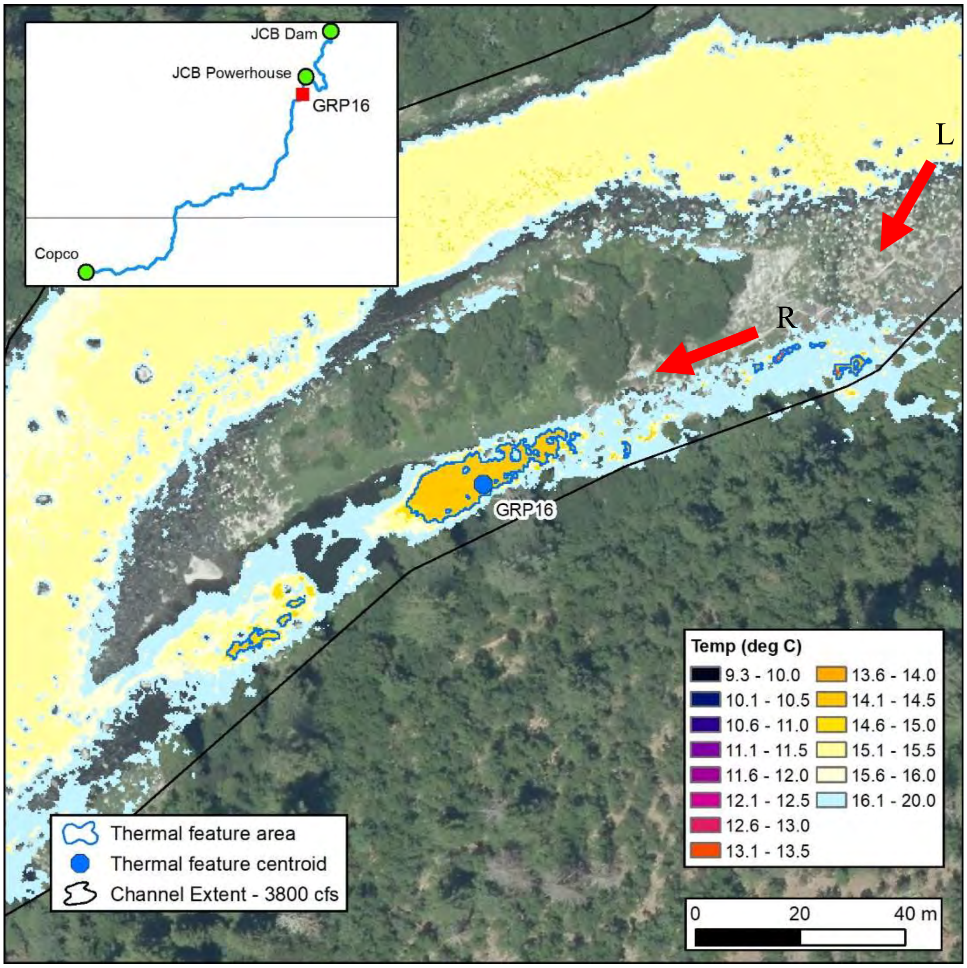


Figure 13. Imagery and photographs of site Group 16. Top: Thermal infrared imagery in the vicinity of the site. "L" and "R" arrows on the uppermost image indicate approximate vantage points for the below left and right site photos, respectively. L: View looking downstream at scree field at upstream entrance to side channel. For scale, boulders in foreground and middle ground are 5 to 15 ft in diameter. R: View looking downstream at the alcove. Photos taken October 12, 2022.

connection to the mainstem at lower mainstem flows via the scree field at the upstream portion of the side channel. At the assessment flow, average depths in the alcove were approximately 1 to 1.5 feet, and water surface elevations were approximately 1 to 2 ft lower than the mainstem. The high-water line on boulders in the alcove was 2 to 2.5 ft higher than the observed water surface. This high-water line corresponds to daily releases from J.C. Boyle Dam, which typically increase discharge to almost 1,700 cfs. Increased hydraulic connection through the scree field at the upstream end of the alcove is expected during daily flow releases. Water temperatures measured on the bed at a depth of 1.5 ft at 100 ft upstream from the downstream end of the alcove were 12.7°C, and cooler water temperatures were observed qualitatively but not measured near the centroid of the alcove. A point source for the cool water was not identified. Under the current flow regime, the cooler temperatures in the alcove are likely diluted during high flow releases that increase hydraulic connection to the mainstem through the scree field.

Access to the site is difficult. The river-left hillslope consists of a steep scree field with a basalt cliff band located along the top. This structure precludes any vehicle access to the site from the plateau surface. Foot access from the river-right bank required ferrying across the river near the gage site upstream of rapids and traversing boulder deposits along the river’s edge downstream to access the scree field. Vehicle access from river right would require traversing down a steep forested hillslope from the road and crossing a fast flowing, boulder-covered stretch of the mainstem to the island.

3.4.2 Isolate 16 (ISO16, Rank 4)

The spring/seep designated as ISO16 is a small single feature located along the river-left bank at the head of a long pool (Lat: 42.078219, Long: -122.080117) on land managed by the BLM (**Figure 14**). The feature is located on the eddy line adjacent to the thalweg and across the channel from the outlet of an 800-ft long side channel. Relatively cool-water conditions observed at the river surface may be caused by upwelling associated with this eddy. The side channel is perched above the low-flow water surface and was dry at the survey flow of approximately 350 cfs. The side channel is well-connected at higher flows closer to daily peak flow values. Based on visual inspection, depths within the cold-water feature are expected to be 2-4 ft at low to moderate flows, with velocities of approximately 2-4 ft/s in the thalweg and approximately 0-1 ft/s within the recirculating eddy.

The eddy at ISO16 is approximately 15-20 ft wide with the cold water mapped at the outermost 5 ft adjacent to the thalweg. Substrate is dominated by 1 to 4 ft diameter boulders mixed with large cobbles. No macrophytes were observed and the combination of large substrate and high velocities during high flows will likely preclude the proliferation of macrophytes under future conditions. Cover is limited to existing boulders with no large wood or other overhanging cover objects nearby. Riparian conditions consist of shrubs and grasses, with sparse trees on the hillslope well away from the active channel. The pool provides some resting and holding habitat for migrating adult salmonids and is located just downstream of a series of high-gradient rapids and shallow riffles with limited resting habitat. Additionally, the slow water boulder habitat along the bank margins of the pool provides some rearing habitat. Small trout were observed feeding on the surface along both river-right and river-left eddies near the pool head.

Potential enhancement activities are limited by access, bank configuration, and velocities at high flows. Survey access to the site was via foot from river-right canyon road, then walking down the hillslope and along the island that separates the main channel and side channel. Old logging roads may provide access from river-left but are decommissioned and overgrown at the present time and may require costly improvements and rehabilitation to facilitate equipment access. Primary enhancement activities could include the placement of large wood from the river-left bank extending out to ISO16 and improving riparian vegetation conditions. Because of the location of ISO16 in a narrow channel at the head of a pool and the lack of stable features to tie into along the river-left scree slope, it's unlikely that cover objects placed by hand crews would remain stable at high flows.

While conducting the assessment of ISO16, habitat conditions of several other small features along the river-left bank of the mainstem river channel just upstream of ISO16 were also documented. These features are located along a boulder scree slope and appear to have small amounts of water cascading into the mainstem through a porous boulder matrix above the low flow water surface elevation. A common observation at these features was a lack of vegetation at the interface of the seep and river (**Figure 14**). These features are also located adjacent to high-gradient riffles and rapids and provide minimal slow-velocity edge habitat. Little adult holding or juvenile rearing habitat exists within proximity to these features.

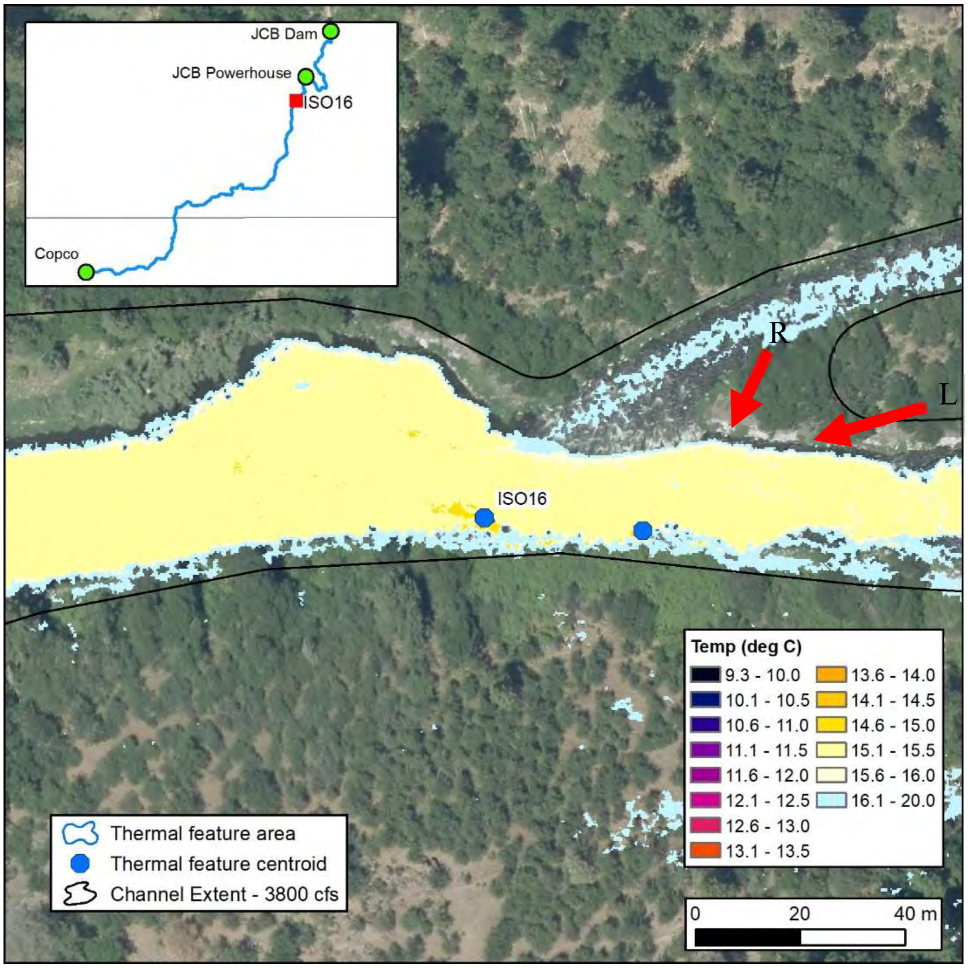


Figure 14. Imagery and photographs of site Isolate 16. Top: Thermal infrared imagery in the vicinity of the site. "L" and "R" arrows on the uppermost image indicate approximate vantage points for the below left and right site photos, respectively. L: Looking downstream at large pool from river-right side channel outlet. ISO 16 is located on the river-left eddy line along the boulder scree slope. R: Looking across the channel to a seep located upstream of ISO 16. Note lack of vegetation at the seep location. Photos taken October 12, 2022.

3.4.3 Group 19 (GRP19, Rank 1)

The thermal feature located at the confluence with Shovel Creek (GRP19; Lat: 41.97264, -122.20450) consists of a continuous cold-water influx along the river-left channel margin as Shovel Creek enters and mixes with the Klamath River (**Figure 15**). During the survey flow of approximately 350 cfs, the thermal feature extended approximately 600 ft downstream from the Shovel Creek confluence and approximately 35 ft out from the left wetted edge of the river channel. Water temperatures within the feature occur as a gradient between Shovel Creek and Klamath River temperatures as the two water bodies become more well-mixed as distance increases in a downstream direction or away from the left channel edge. Shovel Creek water temperature was measured at 9.1°C upstream of the Klamath River influence, and Klamath River water temperature was measured at 13.7°C upstream of the Shovel Creek confluence. Near the centroid of the feature, water temperatures were taken at 15 ft, 30 ft, and 45 ft from the left wetted edge and measured 9.8°C, 11.8°C, and 13.5°C, respectively. At elevated Klamath River flows, the zone of influence of Shovel Creek water is likely reduced and more confined to the confluence area and river-left channel margin.

Substrate within the feature is primarily cobbles with lesser amounts of gravels and boulders. Aquatic macrophytes were sparse. Depths are generally between 0.5 and 1.5 ft. Measured velocities were between 0 and 1.5 ft/s. Cover is predominately provided by boulders and a small amount of overhanging vegetation in portions of the channel margin. No large wood was present within the feature. Riparian vegetation was comprised of grasses, some mature willows, and few mature trees located near the upstream end of the feature.

Approximately 500 ft downstream of the Shovel Creek confluence, a wetland feature is present on the river-left floodplain with small amounts of water draining into the Klamath River. The feature is identified as a freshwater emergent wetland on the National Wetlands Inventory mapper. The wetland vegetation conditions have been impacted by land use activities, including cattle grazing.

A small hot spring was identified on the left bank of the Klamath River approximately 600 ft downstream of the Shovel Creek confluence (**Figure 16**). The hot spring was discharging a small

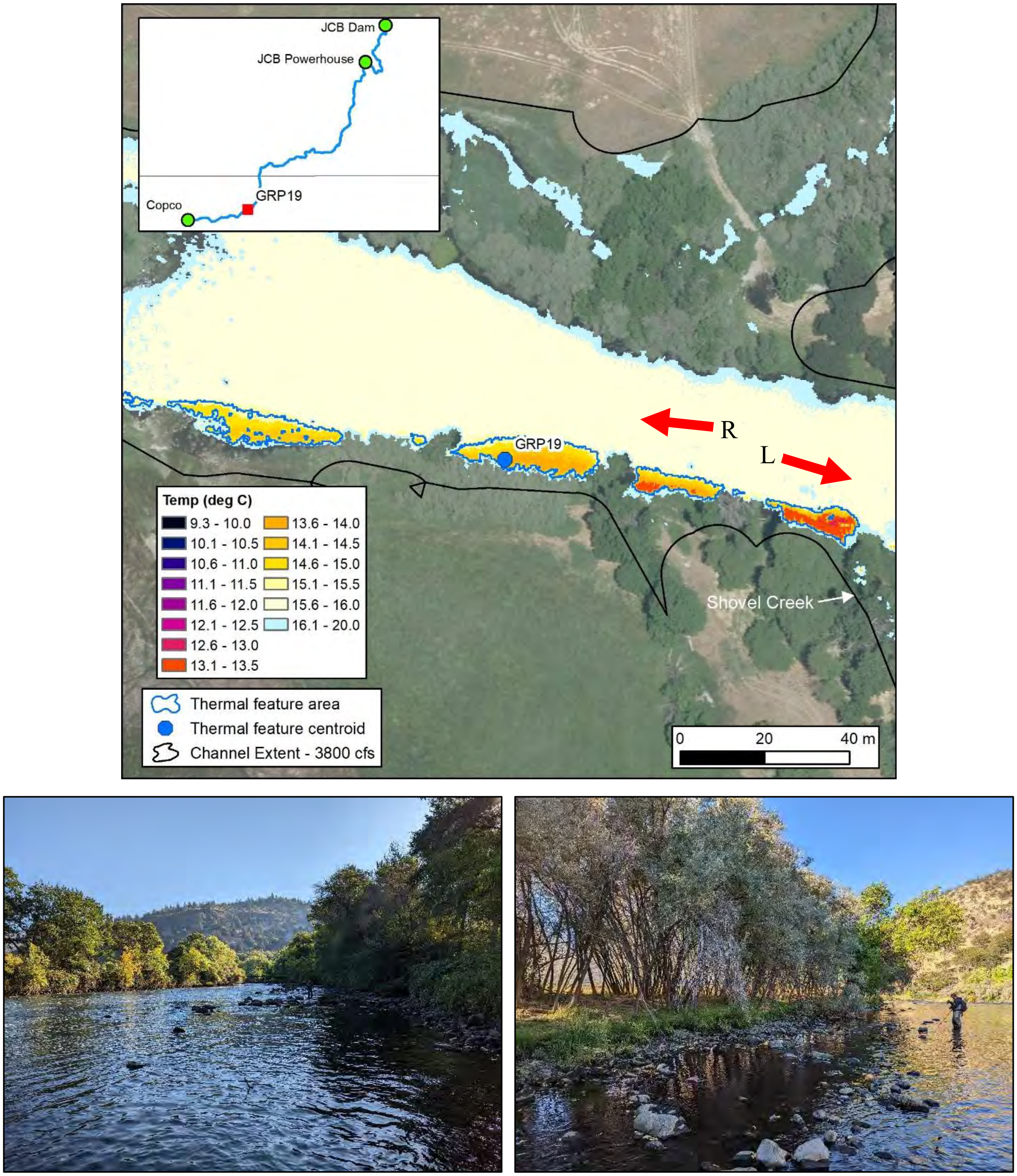


Figure 15. Imagery and photographs of site Group 19. Top: Thermal infrared imagery in the vicinity of the site. "L" and "R" arrows on the uppermost image indicate approximate vantage points for the below left and right site photos, respectively. L: View looking upstream towards Shovel Creek confluence, at river left in treeline shadow R: View looking downstream near centroid of Group 19 thermal feature. The riparian community includes mature willows, but lacks shrubs or other tree species. Photos taken October 13, 2022**.**

Figure 16. Photographs of wetland and thermal spring features near Shovel Creek confluence. Left photo: Freshwater emergent wetland present on river-left floodplain approximately 500 ft downstream of Shovel Creek confluence. Right photo: Small hot spring located on river-left bank approximately 600 ft downstream of Shovel Creek confluence. Water temperature measured near the spring source was 35.5°C. Photos taken October 13, 2022.

amount of water (<0.5 cfs) directly to the Klamath River and the temperature was measured at 35.5°C near its source. Within the thermal feature, habitat conditions are generally adequate for rearing of juvenile salmonids. The site may act as summer temperature refugia and may also provide warmer conditions that help optimize feeding and growth in the winter.

3.4.4 Group 20 (GRP20, Rank 2)

The thermal feature located at the confluence with Long Prairie Creek (GRP20; Lat: 41.96610, Long: -122.25527) currently consists of a 60 ft long, 10-25 ft wide, connected alcove where Long Prairie Creek meets the backwater of Copco Reservoir (**Figure 17**). Just upstream of the confluence, approximately 3 cfs of Long Prairie Creek flow was documented at 12.8°C. Water temperatures in the surrounding reservoir backwater were measured at 15°C. Outside of the reservoir backwater, substrate in Long Prairie Creek consisted of small cobbles and large gravels with lesser amounts of large cobbles and boulders. Downstream in the alcove and reservoir footprint, substrate was primarily cobbles and gravels covered by a layer of fines. Macrophytes were present over approximately 80 percent of the cold-water plume within the reservoir backwater. Water depths were typically 1.5-3 ft with a maximum depth of

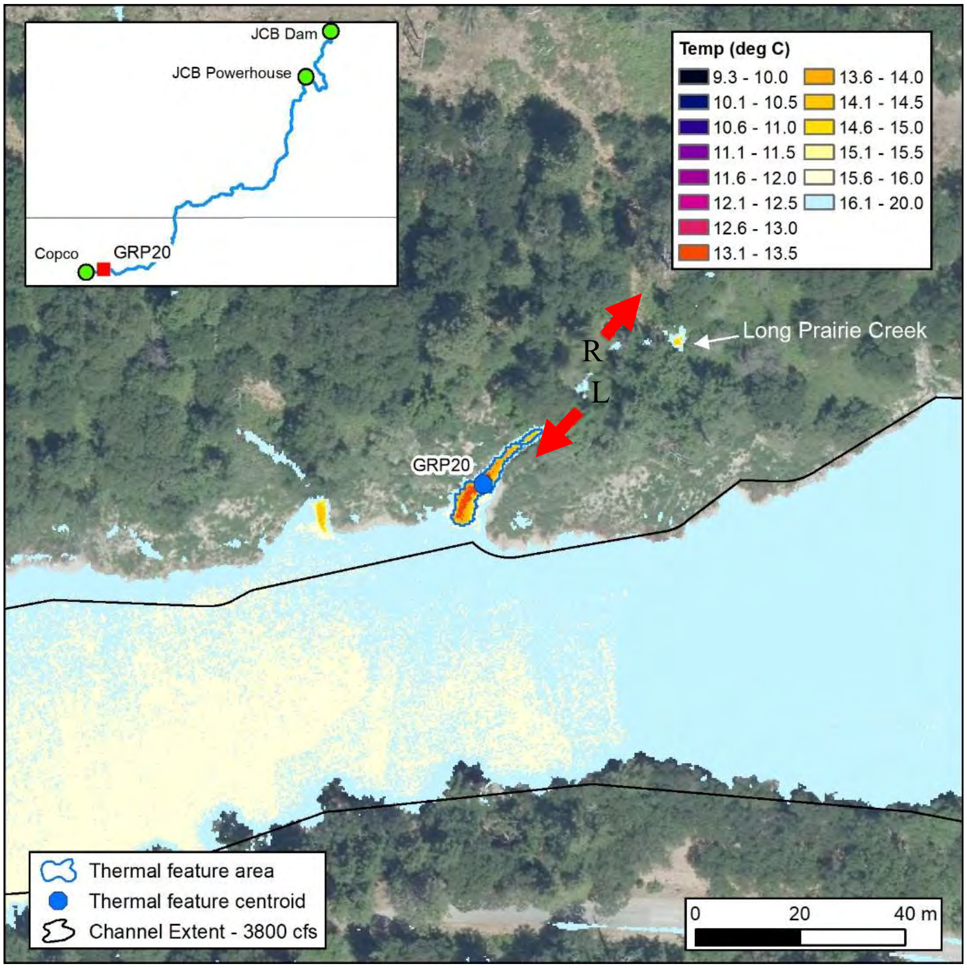


Figure 17. Imagery and photographs of site Group 20. Top: Thermal infrared imagery in the vicinity of the site. "L" and "R" arrows on the uppermost image indicate approximate vantage points for below left and right site photos, respectively. L: View looking downstream near the centroid of Group 20 at the backwater alcove feature at the Long Prairie Creek confluence within Copco Reservoir. R: View looking upstream from near Group 20 centroid at existing stream channel conditions in lower Long Prairie Creek. Photos taken October 13, 2022.

approximately 4 ft. Velocity was measured at 0.8 ft/s where Long Prairie Creek entered the reservoir backwater and then slowed as it entered the reservoir. Besides aquatic macrophytes, cattails and sedges on the bank margins provide some cover for juvenile fish. No large wood was documented within the cold-water plume in the reservoir. Riparian conditions were variable with large amounts of Himalayan blackberry and other invasive species present. Some large western red cedar and ponderosa pine were also noted in the stream corridor.

Although the site currently contains adequate depths, velocities, and some aquatic vegetation to provide quality rearing habitat in the connected alcove, the site should be re-assessed following reservoir drawdown and dam removal activities prior to re-consideration of habitat enhancement potential.

3.5 Existing and Expected Future Water Temperature Conditions

The hottest 7 days were determined to be August 14 – 20, 2004, based on the maximum 7-day average of the daily maximum temperature (7DADM) of existing conditions among the simulated two-week August period across all scenarios. Hourly upstream water temperature inflow boundary conditions at J.C. Boyle Dam (node 1) under existing conditions during this period was approximately 22.5°C, with little diurnal range due to the impoundment located just upstream (**Figure 18**). Expected future water temperatures in the 800 cfs and 1,800 cfs post-dam removal scenarios mostly bracketed existing conditions during the same timeframe with diurnal fluctuations between approximately 20 to 25°C. Water temperatures associated with the 800 cfs scenario were slightly cooler than the 1,800 cfs scenario, suggesting that the heat load to the wide and shallow Keno Reservoir cools slightly faster at the lower flow than at the higher flow as the water travels towards J.C. Boyle Reservoir.

Meteorological conditions impose a diurnal signal on water temperatures upstream of J.C. Boyle Powerhouse (node 92) under existing conditions as water is conveyed through the bypass reach. Downstream of the J.C. Boyle Powerhouse (node 102), these maximums are warmer (relative to upstream of the powerhouse (node 92) and offset from the future scenarios by the early daily onset of hydropower peaking flows that bring relatively warm water from J.C. Boyle Reservoir

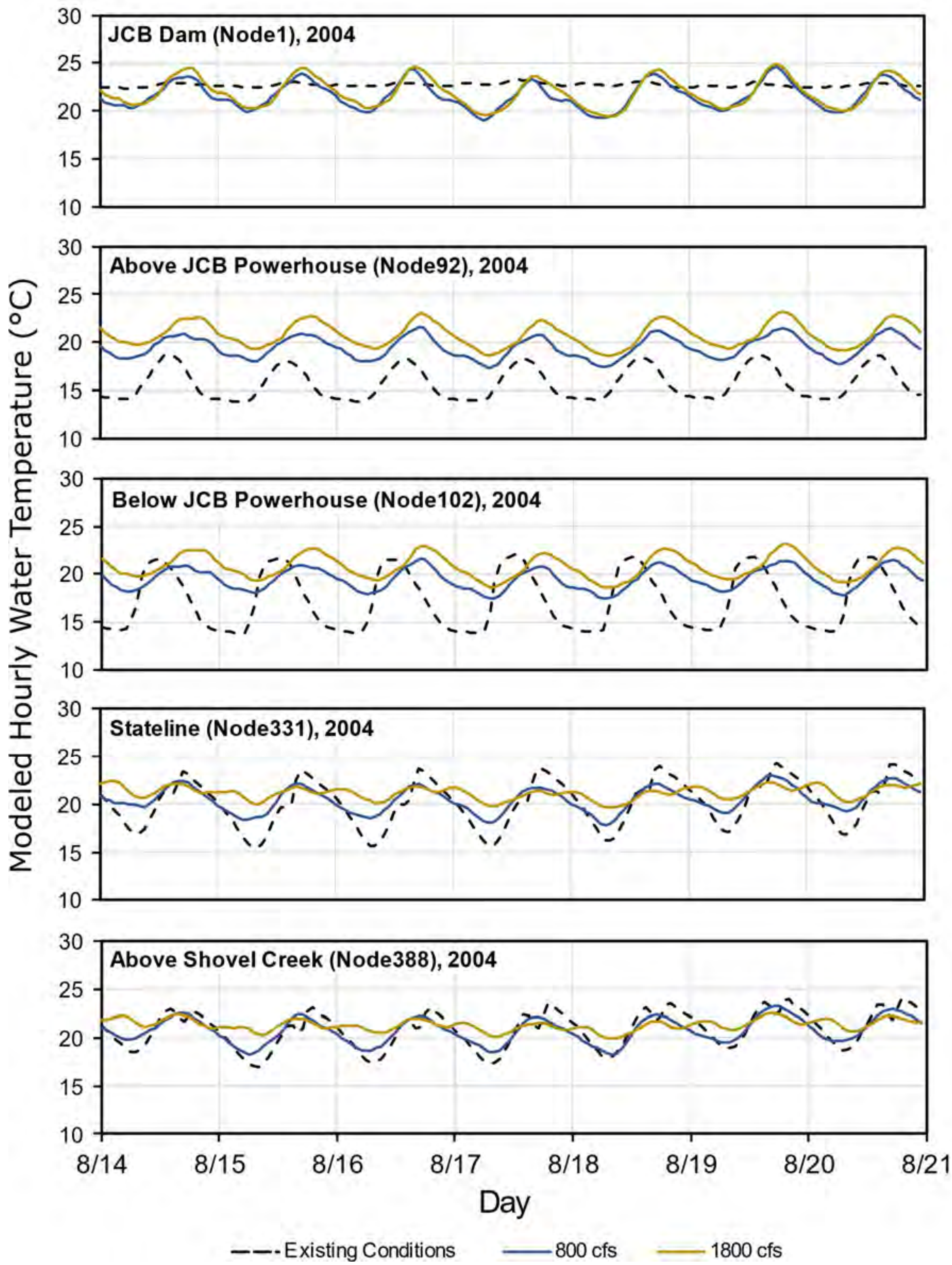


Figure 18. Hourly time series from 08/14/04 to 08/21/04 of RMA-modeled water temperatures at selected model nodes. Landmarks pertaining to each model node's location are shown.

(via the canal) into the Klamath River mainstem at the J.C. Boyle Powerhouse at a different timing than the diurnal signal imposed on the river by ambient meteorology.

Although the cold-water spring inflows of the bypass reach cool water temperatures across all scenarios upstream of the J.C. Boyle Powerhouse (node 92; **Figure 18**), the 800 and 1,800 cfs scenarios show less of an effect from the springs because of the higher volume of upstream Klamath River water flowing into the bypass reach under these simulated post-dam removal conditions, relative to the 100 cfs of water released from J.C. Boyle Dam under existing conditions. As the water travels downstream from the J.C. Boyle Powerhouse and across Stateline (node 331), temperatures warm under existing conditions and cool under expected future flows as the diurnal signals become more coincident, fluctuating above and below approximately 21°C upstream of Shovel Creek (node 388).

The longitudinal profile of the maximum 7DADM temperature provides the full extent of variation in maximum water temperatures along the study reach (**Figure 19**; **Figure 20**), which generally shows warmer expected future (post-dam) conditions in the bypass reach and similar conditions in the peaking reach across all scenarios.

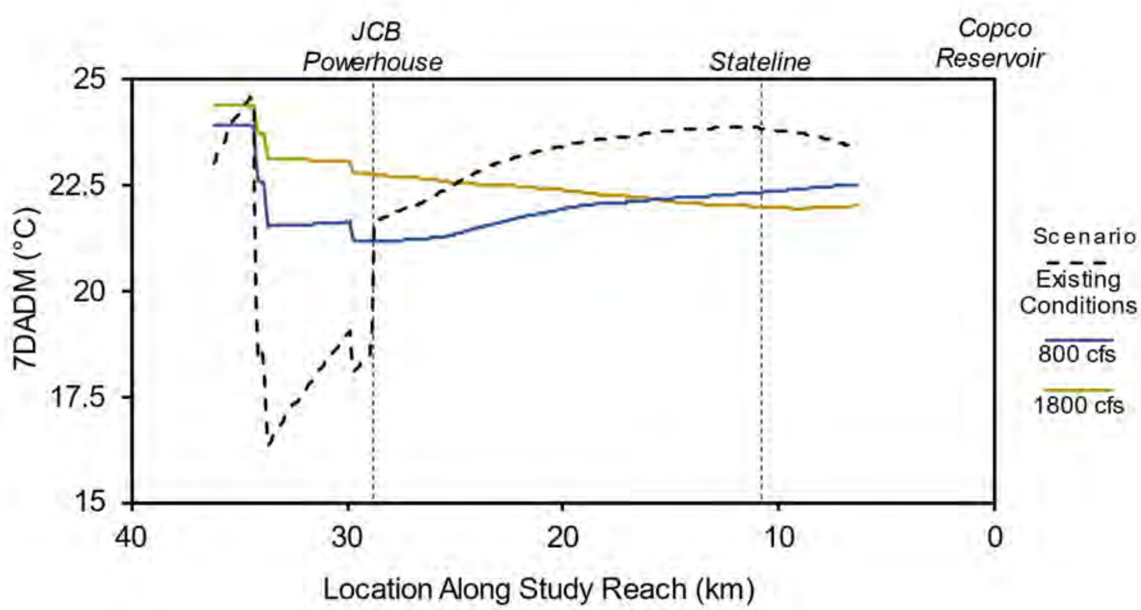


Figure 19. Longitudinal profile of 7-day average of the daily maximum (7DADM) water temperature for the modeled scenarios.

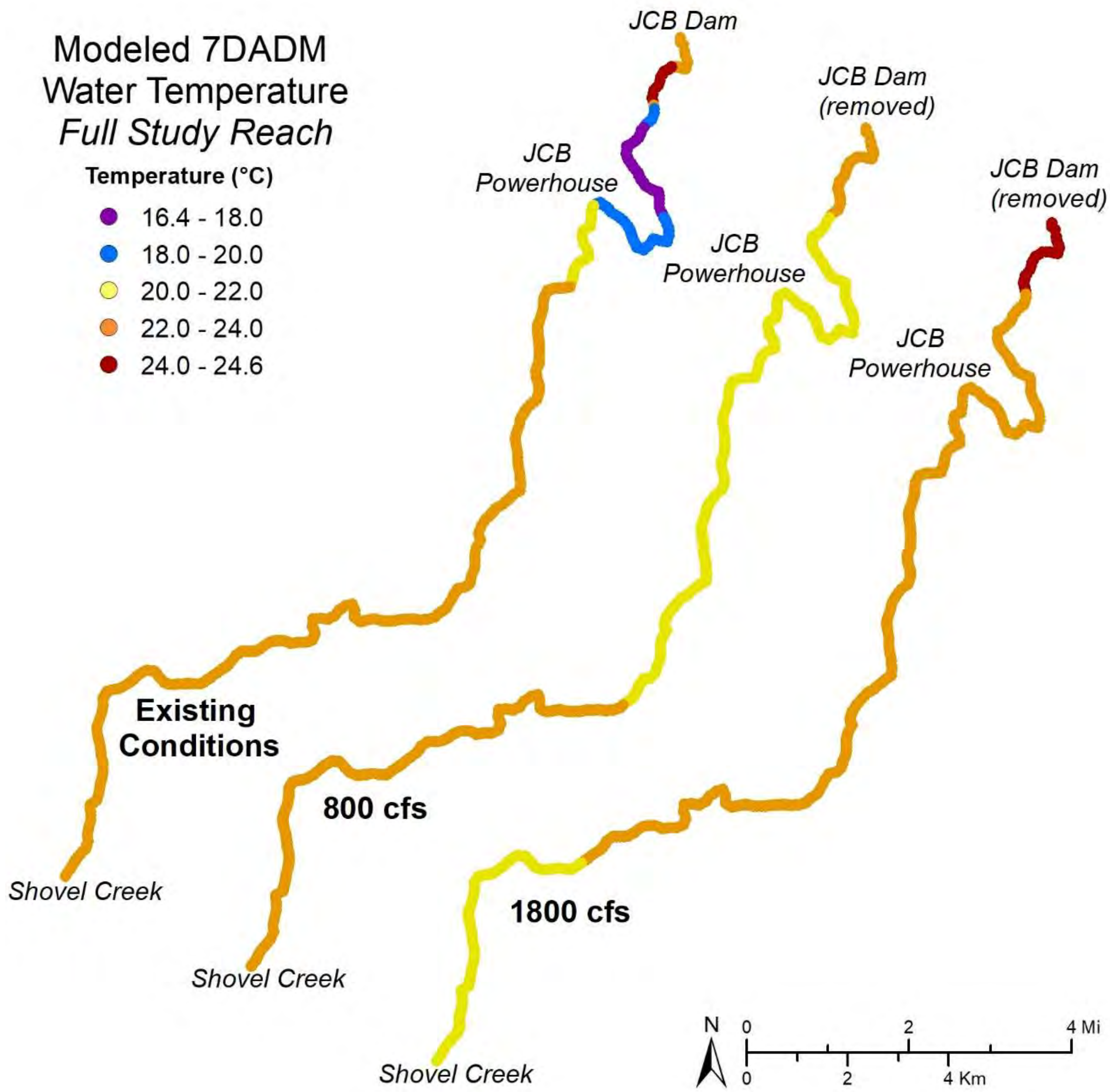


Figure 20. Spatial representation of modeled 7-day average of the daily maximum (7DADM; August 14 – 20, 2004) water temperature results comparing existing conditions with expected future post-dam removal scenarios (800 cfs and 1,800 cfs) along the modeled study reach.

Given that the most ecologically relevant differences in temperature occurred in the bypass reach (**Figure 21**), these results were summarized separately from those of the full study reach (**Table 11**). Nearly 75 percent of the bypass reach length (approximately 5 km) was expected to reflect 7DADM water temperatures (August 14 – 20, 2004) cooler than 20°C under existing conditions. Under flows between 800 and 1,800 cfs following removal of J.C. Boyle Dam, none of the bypass reach is expected to reflect 7DADM water temperatures cooler than 20°C during the same time frame (August 14 – 20). At flows as high as 1,800 cfs, the entire bypass reach is expected to reflect 7DADM water temperatures warmer than 22°C. Results among these scenarios should be used for comparative purposes only. There may be years (other than 2004) during which water temperatures may be warmer based on meteorological conditions and upstream circumstances.

These modeled longitudinal temperature distributions do not represent local thermal refugia at spring input locations that would persist under increased flows through the bypass reach. Specifically, following removal of J.C. Boyle Dam, although daily maximum temperatures are expected to increase in both the bypass and peaking reaches under the simulated flow conditions, several opportunities for cold water refugia are likely to remain.

Table 11. RMA-11 node count percentages incremented by 7DADM temperature values and corresponding approximate lengths of stream for across the bypass reach from August 14 - 20, 2004.

	Model Scenario – Bypass Reach Nodes Only					
	Existing Conditions		**800 cfs**		**1800 cfs**	
7DADM Temperature Range (°C)	**Percent of All Nodes**	**Approx. Length of Stream (km)**	**Percent of All Nodes**	**Approx. Length of Stream (km)**	**Percent of All Nodes**	**Approx. Length of Stream (km)**
16.4 - 18	31.5	2.2	0.0	0.0	0.0	0.0
18 - 20	41.3	2.9	0.0	0.0	0.0	0.0
20 - 22	0.0	0.0	66.3	4.6	0.0	0.0
22 - 24	13.0	0.9	33.7	2.3	72.8	5.0
24 - 24.6	14.1	1.0	0.0	0.0	27.2	1.9
SUM	***100***	***6.9***	***100***	***6.9***	***100***	***6.9***

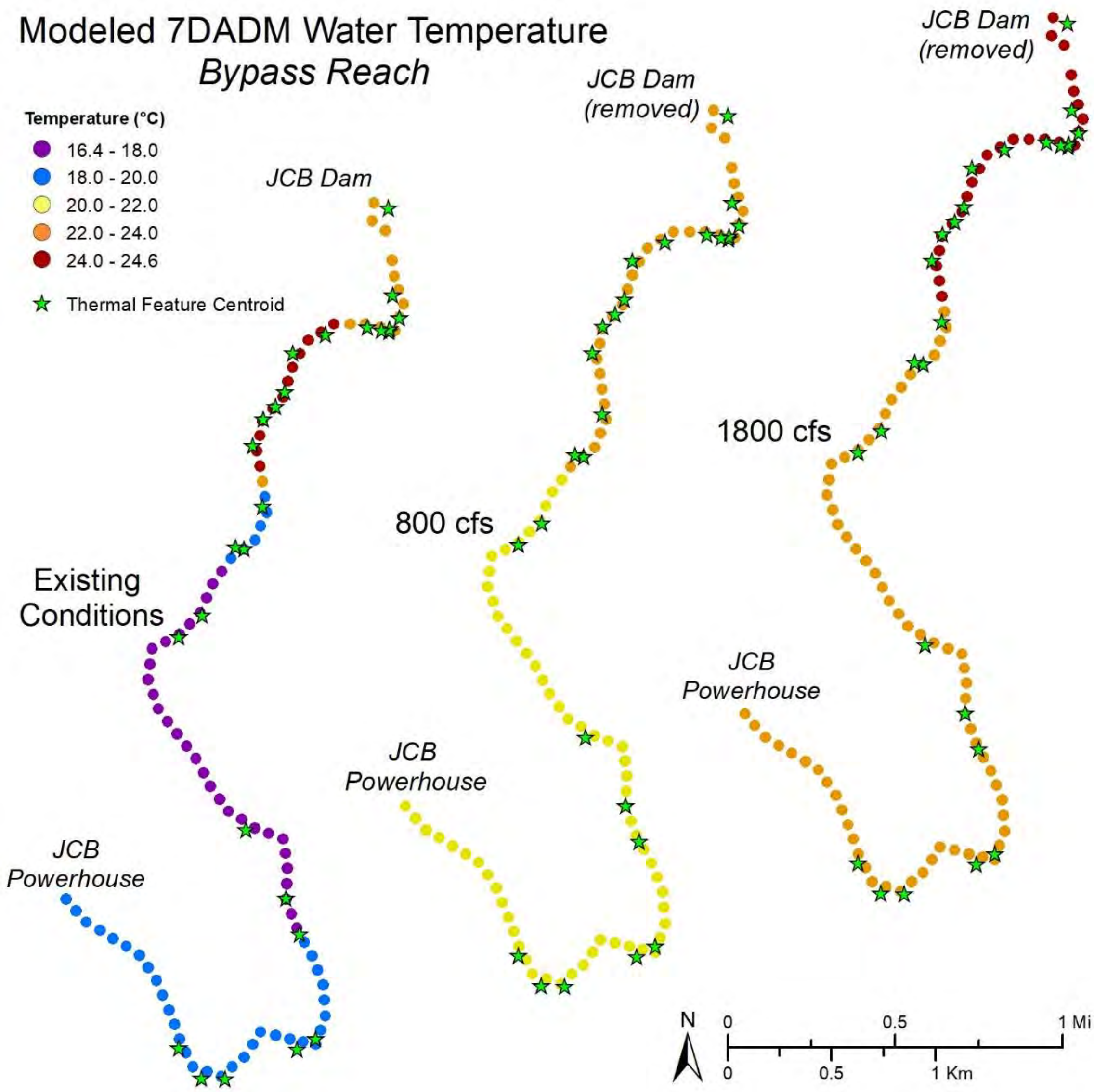


Figure 21. Spatial representation of modeled 7-day average of the daily maximum (7DADM; August 14 – 20, 2004) water temperature results at 75-m intervals comparing existing conditions with expected future post-dam removal scenarios (800 cfs and 1,800 cfs) within the J.C. Boyle bypass reach. Thermal feature centroids are also shown.

Modeled 7-day average of the daily ***minimum*** temperatures under simulated future flows were mostly cooler than 20°C throughout the study reach, with deviations from average daily ***maximum*** temperatures of approximately 4°C in the bypass reach (**Figure 22**). Salmonids may be able to transition between areas of discrete, persistent cold water refugia during these nighttime hours as a method of avoiding less energetically favorable (i.e., warmer) conditions expected

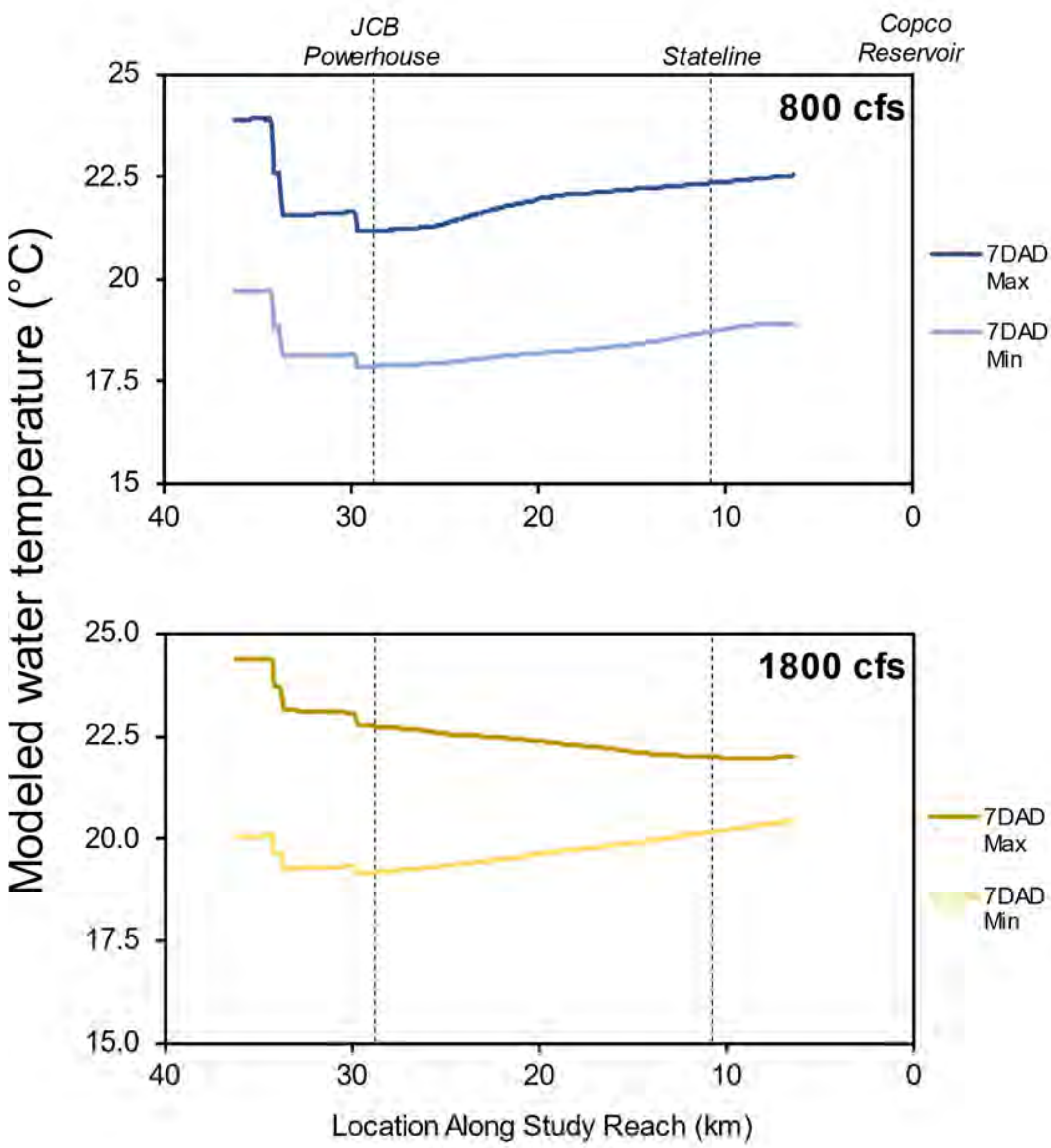


Figure 22. RMA-model produced 7-day average of the daily minimum and maximum temperatures for the week of August 14 – 20 in the study reach under expected future flow rates post-dam removal.

during the day. Examples where salmonids may seek to move among refugia include adult immigration and holding; and juvenile rearing activities such as emigration, seeking appropriate rearing habitats and cover, improved feeding opportunities, avoiding predators or crowding, or other activities. The bypass reach, and associated spring inputs, provides a unique opportunity for salmonids (and potentially other species) to take advantage of multiple refugial areas within relatively close proximity.

Other potential cold water refugia occur throughout the Klamath River mainstem, typically at tributary confluences, or within tributary streams. Potential future refugia in the Project area or vicinity, in addition to the considerable bypass springs, include smaller spring inflow areas, Shovel Creek, Long Prairie Creek, Close Butte springs upstream of Copco Dam (river right), and Fall Creek. Post-dam removal, all potential refugial locations should be assessed for habitat enhancement opportunities to preserve cold-water conditions, or otherwise increase habitat suitability for salmonids.

3.6 Potential Future Habitat Enhancement at Priority Sites

Preliminary proposed habitat enhancement activities associated with priority thermal features range from providing riparian cover to in-stream boulder and/or large wood placement in channel margins. Proposed activities are discussed here for each of the four sites considered to have adequate potential for habitat enhancement (**Figure 23**). Habitat enhancement projects should consider the variety of species and life stages/histories expected to utilize the feature. For example, although maintaining the largest pool of cold water possible may be beneficial for adult fish looking for summer holding opportunities, a feature of this type may not be the most important habitat characteristic for juvenile fish searching for suitable rearing habitat. Consideration of the variety of habitat features to support an array of fish life-stages will be important for maximizing habitat enhancement project benefits. The confluences of Shovel Creek (thermal feature GRP19) and Long Prairie Creek (thermal feature GRP20) appear to provide the most potential for this sort of multi-factor consideration. Other considerations in terms of habitat enhancement include continued gravel augmentation in the bypass reach and downstream of the J.C. Boyle Powerhouse (**Figure 24**).

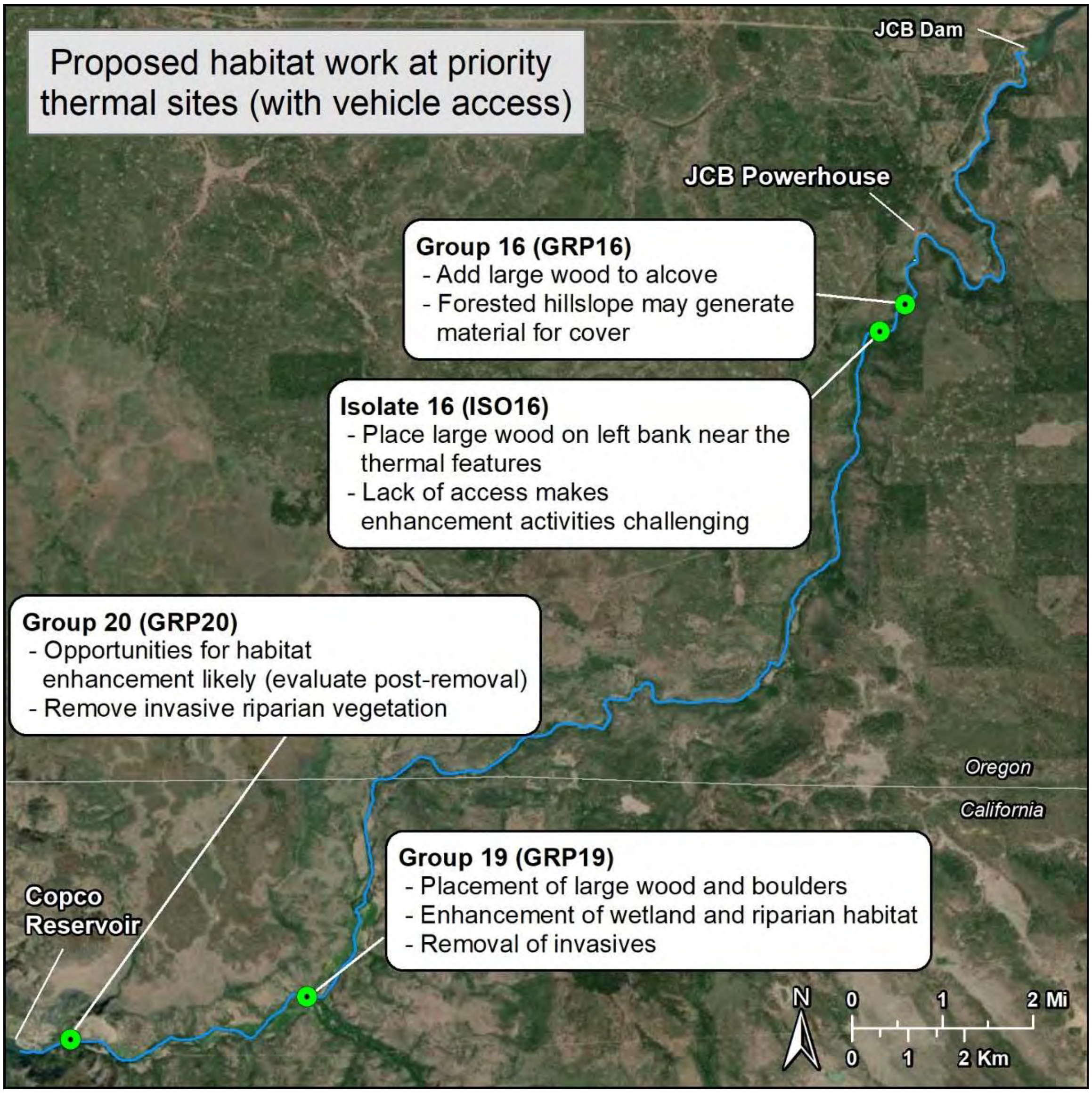


Figure 23. Proposed habitat enhancement activities at the top four priority thermal sites accessible by road along the study reach.

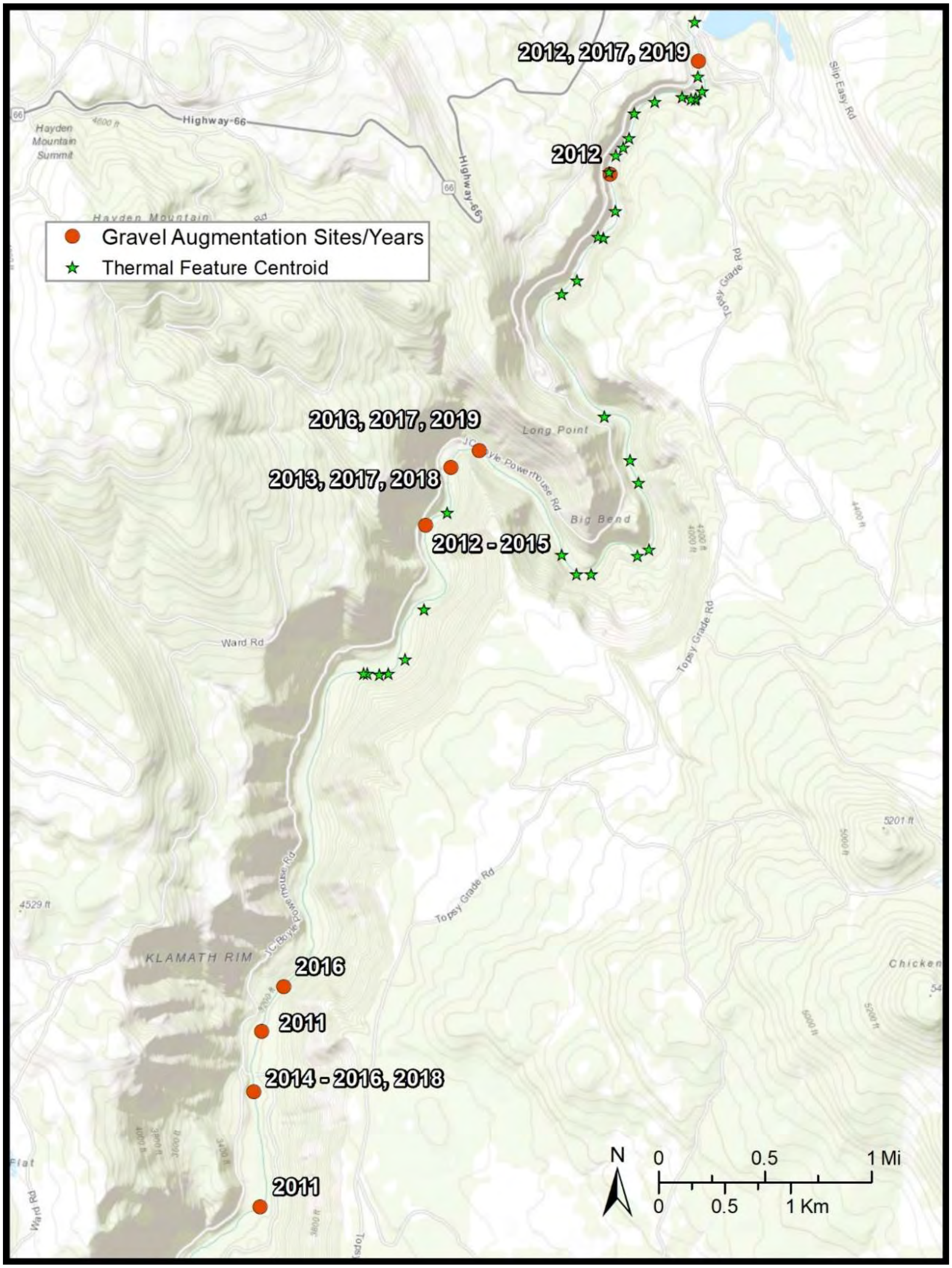


Figure 24. Locations of gravel augmentation sites in the bypass reach, labeled with years in which augmentations occurred. Thermal feature centroids are also shown.

3.6.1 Downstream ~1,000 ft. from USGS gage #11510700 (GRP16)

Juvenile rearing habitat for salmonids is expected to benefit from additions of stable large wood or other cover objects in the downstream connected portion of the alcove. Difficult river-left ground access for large equipment may be prohibitive for some designs and construction techniques. The forested hillslope on river-left could be used to generate large wood and slash cover objects that could be placed by hand crews.

3.6.2 Downstream ~1,750 ft. from USGS gage #11510700 (ISO16)

Holding and resting habitat for adult salmonids is expected to be improved in this location from placement of stable large wood or other cover objects on the left bank near the thermal features. If it is determined that these placed features can remain stable through a wide range of flows, juvenile rearing conditions may also be enhanced through large wood placement by providing cover and/or slowing water velocities. However, lack of access for heavy equipment, steep boulder scree slopes, and small footprints of individual thermal features make enhancement activities challenging and are likely to yield limited benefits.

3.6.3 Shovel Creek Confluence (GRP19)

The confluence of Shovel Creek with the Klamath River offers perhaps the most enhancement opportunity of any of the thermal features investigated in this work. Restoration opportunities in the vicinity of Shovel Creek have also been included as priority projects in the K3RP Plan (O'Keefe et al. 2022). The relatively lower gradient in the mainstem Klamath River, inputs of stable flows and cooler water, and ease of access all contribute to the value of this location. Although specific plans have not been developed at the time of this report, there are a multitude of actions that could occur in this area. Placement of cover such as the addition of large wood and boulders is expected to greatly increase juvenile rearing potential for salmonids in the Klamath River just downstream of Shovel Creek. Placement of stable large wood structures on the river-left channel margin and floodplain would provide cover and complexity during high flow events. Depending on the configuration, boulders and/or large wood could also be used to isolate and delay the relatively cool Shovel Creek water from mixing with the warmer mainstem flow. Existing limited spawning substrate could be enhanced with the addition of appropriately sized gravels. Gravel augmentation may need to be repeated following large-flow events, depending on placement location and hydraulic conditions. Re-grading of the stream channel and/or river-left floodplain could be utilized to improve floodplain connectivity or to create additional alcove or side channel habitats. Riparian and wetland enhancement would also improve habitat and water quality conditions. Cattle exclusion through fencing or changes in land use would help recover the riparian vegetation community and help reduce fine sediment inputs to Shovel Creek and the Klamath River. Removal of invasives, such as Himalayan blackberry, and planting native trees would increase the quality of riparian conditions, provide shade, increase macrodetrital inputs such as leaf litter or other plant-based materials, and provide overhead cover. Adequate access for heavy equipment is provided by Ager-Beswick Road and across a flat pasture to the site.

3.6.4 Long Prairie Creek Confluence (GRP20)

Long Prairie Creek appears to have substantial potential for habitat enhancement, but the specifics of what may be most beneficial at this location will depend on site conditions following dam removal and reservoir drawdown. The confluence of Long Prairie Creek and the Klamath River is expected to be substantially altered by the loss of the reservoir backwater. However, given the sufficient volume of cool water present during the initial field assessment, the confluence area will likely provide opportunities to enhance habitat conditions for juvenile rearing, and potentially adult holding and spawning following reservoir drawdown. Placement of large wood and/or boulders could be used to increase habitat complexity and create cover. Channel grading may be necessary following reservoir drawdown to enhance channel and floodplain connectivity and improve fish passage. Potential fish passage barriers such as the culvert upstream of the reservoir should also be assessed and replaced if necessary. Riparian conditions could also be improved through the removal of invasive species and re-vegetating exposed reservoir surfaces. A road grade is located just upstream of the site, and heavy equipment access is feasible through the riparian zone to the confluence area.

3.7 Tributary Thermal Conditions and Proposed Restoration Efforts

Basin-wide restoration planning efforts have been described in the K3RP report (O'Keefe et al. 2022). The K3RP report summarizes proposed restoration prioritization as it relates to aquatic habitat enhancement work within the Project reach, with particular emphasis on tributaries to the Klamath River. Given that this report is focused on restoration prioritization of the mainstem Klamath River, the tributary work described in the K3RP is summarized to provide a broader perspective on thermal conditions and existing considerations for habitat enhancement in the surrounding stream network.

Seven-day average (Aug 14 – 20) of the daily maximum temperatures of tributary stream locations near the confluence with the Klamath River were less than 15.5°C in Grouse Spring Creek[1], Long Prairie Creek, and Shovel Creek, based on measurements from 2018 – 2020 (**Figure 25**; **Table 12**).

As such, these tributaries are expected to support thermal conditions suitable for the various species and life stages of salmonids expected to occur in the area post-dam removal. Unlike expected future temperatures of the Klamath River mainstem described above, these tributary temperatures are not expected to be affected by changes in flow regimes following dam removal and may offer thermal refugia for salmonids during the warm summer timeframe.

A total of fourteen proposed K3RP projects within the Project reach involve nine distinct tributaries and are generally intended to reduce fine sediment input; divert vehicle traffic out of the stream and associated riparian areas; and improve fish passage, refugia, habitat, and channel connectivity. The implementation of these projects includes culvert maintenance or construction; removal of vehicle crossings or replacement with newly constructed bridges; and the realignment of tributary channels to receive spring water, prevent salmonid entrainment, and create refugia (O'Keefe et al. 2022).

3.8 Fish Disease Considerations

Significant juvenile salmon mortality in the Klamath River downstream of Iron Gate Dam has resulted from exposure to the parasite *Ceratonova shasta*. A benthic worm (annelid; *Manayunkia occidentalis* spp.) hosts the *C. shasta* parasite (Atkinson et al. 2020). Habitat preferences of this annelid overlap with spawning salmonids, which are the source of the parasite stage that infects the annelids, which in turn increases the likelihood of infection and disease in outmigrant juvenile salmon that rear and/or pass through these reaches. Downstream from Iron Gate Dam optimum annelid host habitat is driven by substrate, depth (1 – 4 m), and velocity (<0.16 ft/s) (Alexander et al. 2014; Alexander et al. 2016). In water years characterized by benthic

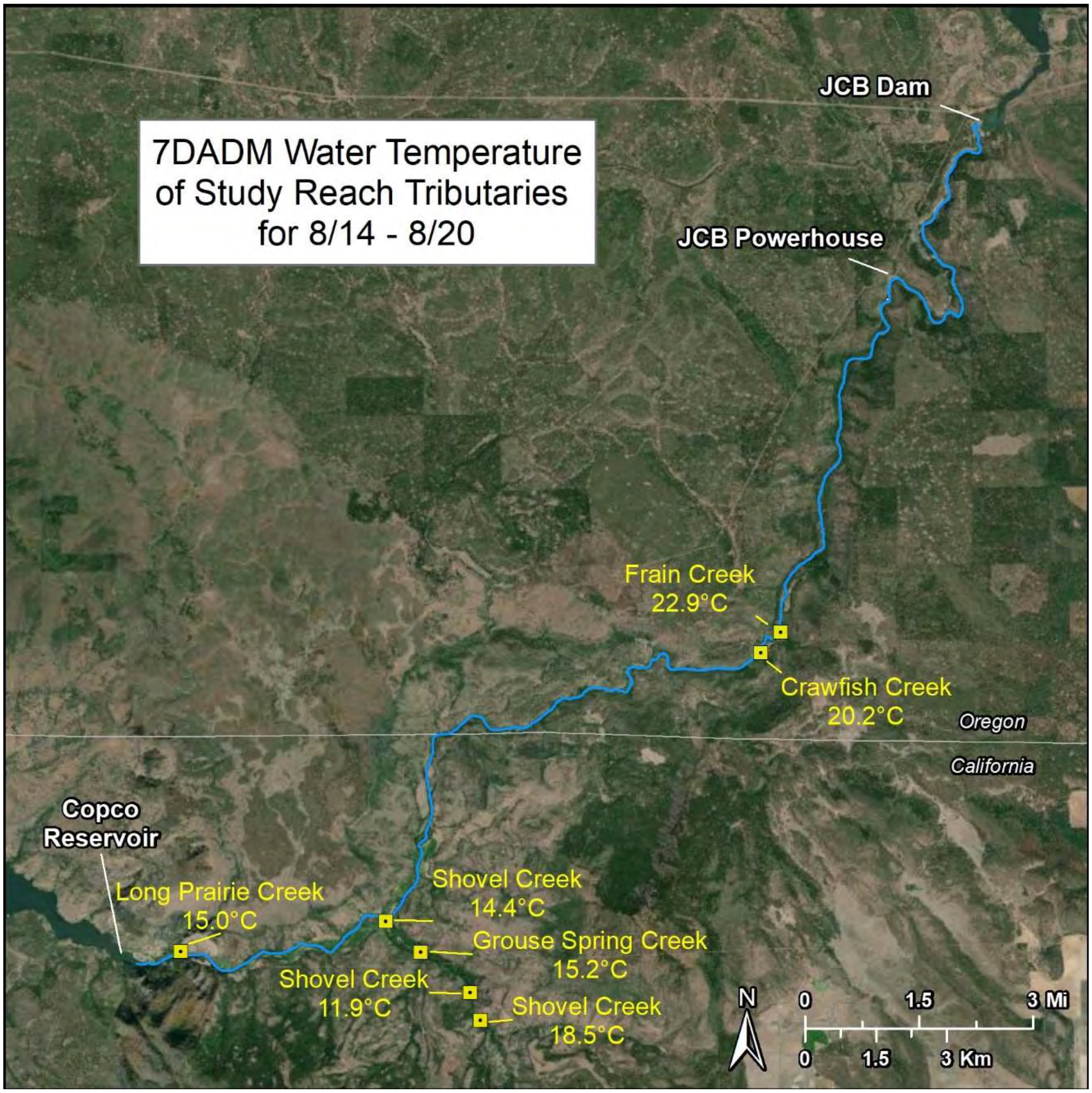


Figure 25. Tributaries along the study reach and 7-day average daily maximum (7DADM) water temperatures during 08/14 – 08/20. Temperatures shown are from data collected in 2020 and 2021 for every site except Grouse Spring Creek, which represents 2022 measurements only (O'Keefe et al. 2022).

Table 12. Descriptive statistics of tributary stream temperature during August 14 – August 20 (averaged across available years) based on half-hourly or hourly measurements at the specified locations.

					7-day value (°C) [1]			
Stream	**Site ID**	**Latitude**	**Longitude**	**Measurement Years**	**Mean**	**Range**	**Minimum**	**Maximum (7DADM)**
Crawfish Creek	CRA	42.022259	-122.10584	2021, 2022	19.1	1.1	17.8	20.2
Frain Creek	FRA	42.026181	-122.10079	2021, 2022	18.7	4.2	15.1	22.9
Grouse Spring Creek	GRS	41.96587	-122.19369	2022	13.7	1.5	12.1	15.2
Long Prairie Creek	LOP	41.966407	-122.25491	2021, 2022	14.1	0.9	13.2	15.0
Shovel Creek	SHV1	41.9717887	-122.20256	2018, 2019	12.9	1.5	11.7	14.4
	SHV2	41.958122	-122.18103	2018, 2019	11.2	0.6	10.6	11.9
	SHV3	41.952709	-122.17849	2021, 2022	17.3	1.2	16.1	18.5

[1] All site data were collected half-hourly over the indicated time period by the Pacific States Marine Fisheries Commission, except SHV1 and SHV2 data, which were collected hourly over the indicated time period by California State Polytechnic University, Humboldt (O'Keefe et al. 2022). Data shown are two-year averages of each statistic, except for Grouse Spring Creek, for which one year of data was collected.

disturbance in the Klamath River downstream of Iron Gate Dam (e.g., peak discharge greater than roughly 6,000 cfs at the USGS gage downstream of Iron Gate Dam; gage #11516530), annelid distribution is restricted to large (boulder/bedrock) substrates; however, annelids are associated with all substrates in water years characterized by low benthic disturbance. In other words, when peak flows are not adequate to disturb the riverbed, annelid densities are highest on fines, followed by boulder/bedrock substrates. Little is known about annelid distribution in the study area; however, efforts are currently underway to characterize annelid habitat suitability in portions of the Project reach (J. Alexander, personal communication), which will be used for comparison with annelid habitat suitability downstream of Iron Gate Dam and development of annelid predictive models under post-dam removal scenarios. Because creation of slower-water habitats that juvenile salmonids would favor as rearing habitat may also be favorable to host worms, understanding fish disease dynamics will be an important element to assess post-dam removal.

4 CONCLUSIONS

Maximum water temperatures throughout much of the J.C. Boyle bypass reach are expected to be approximately 5°C warmer than existing conditions following the removal of J.C. Boyle Dam. This warming is particularly evident in the high flow (1,800 cfs) model scenario results that suggests the entire bypass reach will reflect 7DADM water temperatures warmer than 22°C within the simulated August timeframe. Given that these warmer temperatures may result in adverse habitat conditions for salmonids, preservation of existing cold-water conditions and other habitat enhancement activities are important considerations for maintenance of existing refugia and spawning habitat for resident and anadromous fish. Thermal features represent relatively cold-water temperature conditions during summer. These features were prioritized for field investigation to consider potential habitat enhancement opportunities. Although some of the coldest and largest thermal features, as indicated by the thermal imagery and confirmed with *in situ* flow measurements, are located in the J.C. Boyle bypass reach; access to these sites is extremely difficult by foot and virtually impossible for equipment. Because of access challenges, prioritization of habitat enhancement activities was focused on sites with potential access by road. Among the top 10 potentially accessible priority sites, habitat enhancement activities were discussed at four sites. Of those, the confluence of Shovel Creek showed the greatest potential for restoration because of the location in the watershed, accessibility, volume of incoming cold water, and expected use by anadromous salmonids. Recommendations for the Shovel Creek area include enhancing river - floodplain connectivity, adding boulders and large wood to create cover and habitat complexity, augmenting spawning gravels, and improving wetland function and riparian vegetation conditions.

5 NEXT STEPS

The following are presented as potential future actions should interested parties continue to investigate the potential benefits of protecting and enhancing cold-water habitat areas in the reach between Copco Reservoir and J.C. Boyle Dam.

5.1 Potential Future Studies

This study describes an initial set of investigations based on the spatially continuous thermal data developed by McDonnell et al. (2022). Future work will contribute to understanding habitat enhancement potential and overall ecology of this study reach. An initial step would be to expand beyond the initial 10 priority sites with road access that are the focus of this report, and explore the remaining dozens of other thermal features identified in McDonnell et al. (2022). Additional candidate locations for habitat enhancement work could be identified with the understanding that much of this work would require materials and equipment to be transported on-site by boat or helicopter. While access constraints may limit the types of restoration and enhancement efforts that can be feasibly implemented in the study reach, placing large wood by helicopter or using hand crews to fall trees, reposition boulders, or improve riparian vegetation conditions may be appropriate at many of the remaining thermal features that were not visited during the field assessment portion of this study.

Shovel Creek has the potential to be a very important stream for anadromous fish returning to the Project reach following dam removal. Appropriately designed restoration projects in the Klamath River at Shovel Creek and within Shovel Creek itself could create the variety of habitats that salmonids require to be successful. This restoration design would align with the K3RP recommendations and provide an opportunity to develop creative, functional, and robust prescriptions. Such efforts could focus on multi-faceted restoration designs that would support the variety of species and life stages expected to benefit at various times of the year.

Future studies to further identify and characterize thermal features in the study reach include:

- Identification of beneficial habitat enhancement activities at sites accessible by helicopter through further evaluation of remotely sensed data and/or field efforts.
- Deployment of temperature logger arrays associated with the highest priority thermal features to better understand the volume/extent of cool water (and relatively warm water in winter) throughout the year.
- Augmentation of existing bathymetric data in the study reach with boat-based data collection at selected priority sites.
- Temperature transmitting radio tags could be used to monitor existing resident fish movement and their use of cool water areas in the study reach. These data could then be used in habitat restoration design, as well as future studies of population dynamics associated with resident and anadromous fish.
- Isotopic dating of spring inflows to determine residence time from source, as well as the source of a given spring complex and potential factors that influence its flow rate.
- Consider collecting additional post-dam removal thermal imaging data to better understand thermal features under the new flow regime to characterize the thermal regime at different times of year (e.g., multiple flights) to assess ecological benefits for various salmonid life stages.
- A variety of opportunities for modeling studies exist to further characterize site-level (2D models) and longitudinal (1D models) thermal conditions of the study reach. Development of site-level models would provide information related to hydraulics under varying flow rates throughout the year and could provide support for restoration designs. Additional longitudinal temperature modeling can be developed to consider temperature conditions at other times of the year, under different flow regimes, and be used to simulate conditions associated with climate change.
- Expected future temperature conditions throughout the Klamath River, among other foundational data, could be utilized within a bioenergetics modeling framework to simulate future fish condition for returning fish or across full life cycles.
- Further understanding of habitat suitability for annelids that host *C. shasta*, and associated potentials for fish disease transmission and effects on fish populations, will be useful for locating and designing future habitat enhancement projects.

Although some of the topics presented here may be best addressed post-dam removal, further establishment of baseline pre-removal conditions related to water temperatures and annelid habitat may be helpful to inform management decisions related to habitat enhancement design work, fish reintroduction, and operational flow schedules in the near term. Such baseline data would also be useful in comparative studies to quantify the extent to which dam removal affects ecosystem components.

5.2 Review Site Conditions and Designs After the Removal of J.C. Boyle Dam and Adjust Designs to Accommodate Sediment Accumulation or Changes in the Flow Regime

The removal of J.C. Boyle Dam will immediately release a large volume of sediment into the river downstream of the dam. Given the high-gradient nature of much of the study area reach, most of this will likely move downstream into lower gradient areas of the Klamath River, but some if it will settle in downstream reaches (e.g., near the Frain Ranch) and in pockets of calmer water. The change in flow regime within the bypass and peaking reaches, coupled with the introduction of this sediment, may change site-specific conditions. It is anticipated that a new biological opinion will have been issued to the Bureau of Reclamation by NMFS and USFWS by the time dam removal occurs that sets flow targets in the Klamath River downstream of Keno Dam, as Keno Dam will be the downstream-most control point for flow. Review of the post-dam removal conditions at each proposed restoration location will be necessary to ensure the initial designs remain feasible, appropriate, and provide the desired benefits. Final designs and permits should be developed in this step.

5.3 Source Funding and Implement Restoration/Enhancement Projects

Use final designs and permits to obtain funding for selected projects and implement projects. Recently (2022) there have been several grant programs announced for the Klamath Basin (and other areas) that include tens of millions of dollars in funding.

5.4 Monitor and Report on Project Effects

Ideally, effectiveness monitoring is included in every funded project. In reality, funding sources typically support implementation but not monitoring or evaluation. Other sources of funds will need to be identified so that accurate data can be collected to provide feedback to interested parties, stakeholders, and management and permitting agencies relating to ongoing and proposed restoration projects. Resource managers can use effectiveness monitoring to determine efficacy of projects as well as to modify projects as needed.

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APPENDICES

Appendix A. Site Visit Itinerary

Itinerary used for the May 26, 2022, site visit to discuss significant thermal feature (STF) prioritization and related project goals, along with maps of Klamath River surface temperatures observed on September 22, 2021 and associated STF designations in the general vicinity of river locations visited during the visit. Individual STF points are labeled with the original STF number designations (i.e., 1 – 116; prior to the development of RCWA polygon identifiers).

J.C. Boyle Thermal Studies

May 26 Site Visit Draft Itinerary

08:00 – Meet at J.C. Boyle Dam, Red Barn area

- Access waivers
- Safety briefing
- Logistics overview
- Carpool

08:45 – 11:00

- Drive Power Canal Road stopping to observe STFs from the road where it's safe to stop (Map below)
- Wooden Bridge (STFs 10, 11)
- First corner (STFs 15-32)
- Alcove (STF 57-60)

11:30 – 14:30 – Bypass Reach Instream Access

- Riverside Lunch
- Walk down to river at Mark's access point

15:00 – 16:30 – Spring Island Boat Launch

- STFs 76-78
- Discussion about observations and planning for field efforts

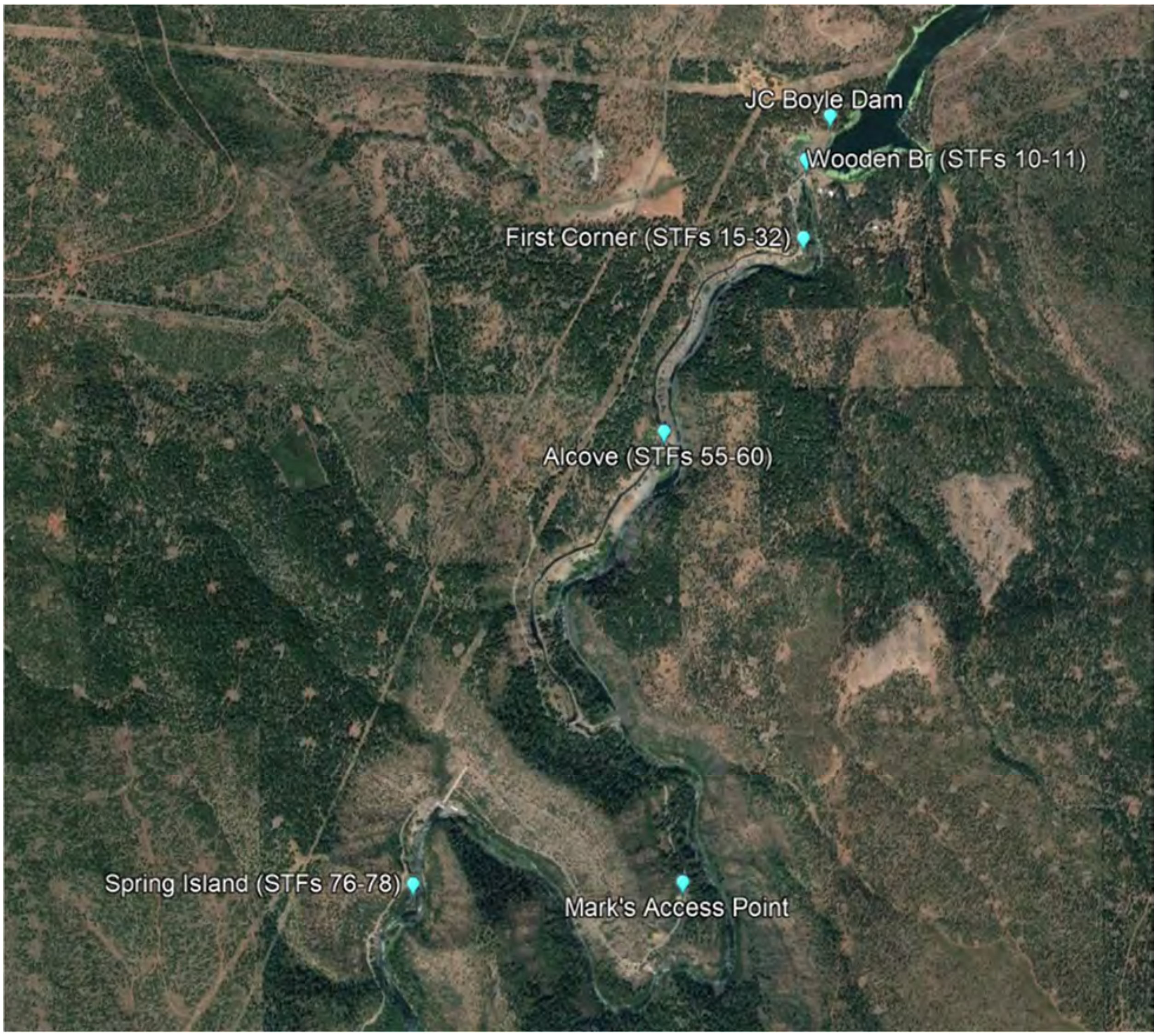
17:00 – Adjourn (return to Red Barn for vehicles)

Personal Equipment

- Lunch and Water
- Daypack
- Appropriate clothing for the weather (hat, sunglasses, sunscreen, etc.)
- Waders or dry suit, wading staff, and wading boots with studded felts
- Binoculars, Spotting Scope
- Field notebook, thermometer, data sonde, and any other water quality equipment you want
- GPS Unit, Tablet

Required Personal Protective Equipment

- Long pants
- Safety-toed shoes or other sturdy hiking boots
- Safety glasses/sunglasses
- Hard hat (for the Red Barn area)


JC Boyle Dam
Wooden Br (STFs 10-11)
First Corner (STFs 15-32)
Alcove (STFs 55-60)
Spring Island (STFs 76-78)
Mark's Access Point

May 26, 2022 Field Site Visit Notes

Location: Klamath River bypass reach below J.C. Boyle Dam

Purpose: Initial site visit to consider data and methods for STF prioritization and associated study objectives

Attendees:

Kurt Bainbridge – CDFW

Mike Deas – Watercourse Engineering, Inc.

Demian Ebert – PacifiCorp

Pete Gruendike – River Design Group, Inc.

Mark Hereford - ODFW

Brian Knees – E&S Environmental

Todd McDonnell – E&S Environmental

Bob Pagliuco – NOAA-NMFS

Benji Ramirez – ODFW

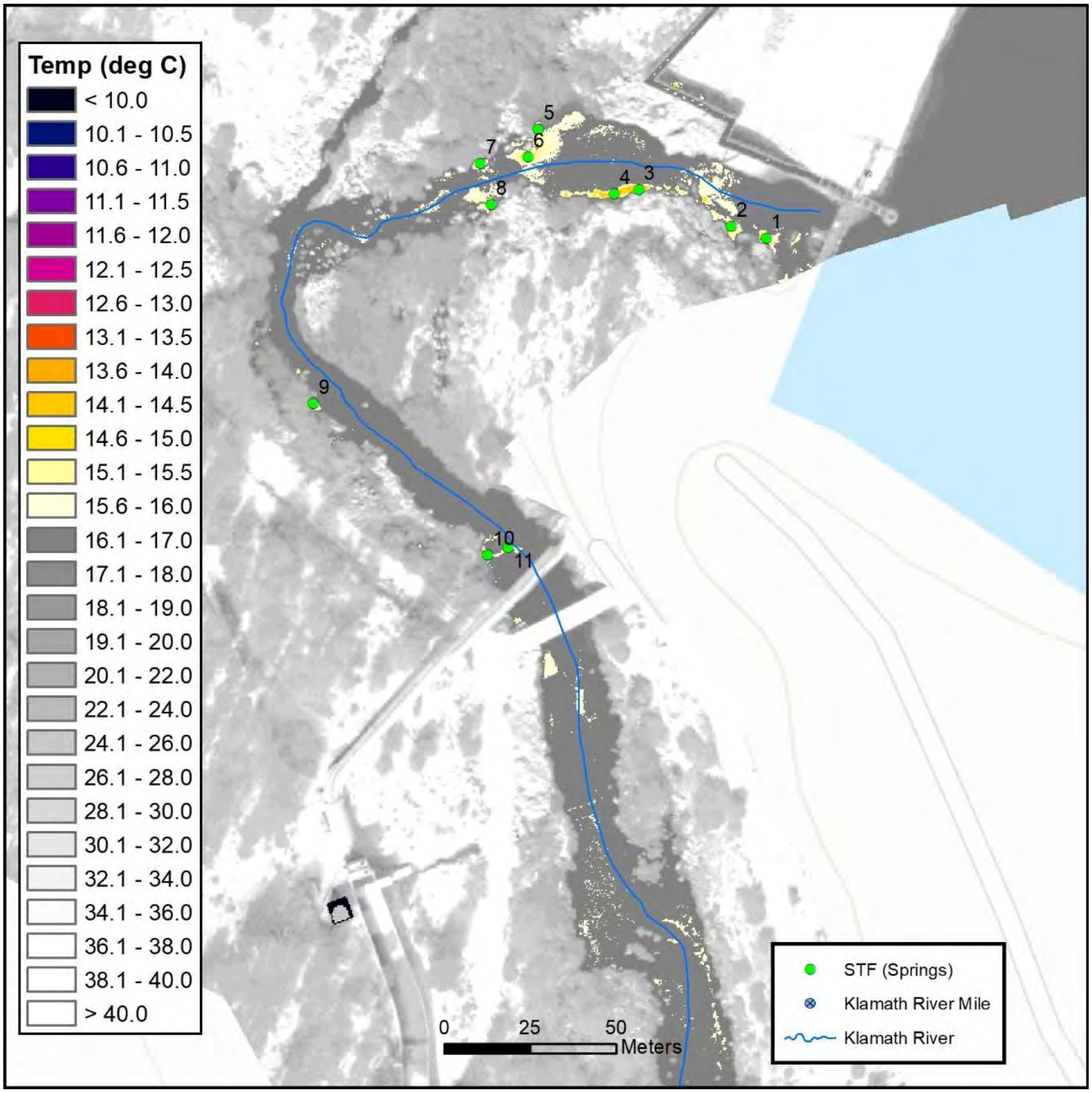
Ted Wise – ODFW

- Gathered at Pioneer East parking area
- Safety briefing and logistics overview
- Departed for Wooden Bridge
- Arrived Wooden Bridge for a short discussion about thermal features and related topics
- Drove Power Canal Road stopping to observe STFs from road turn-offs
- First Corner (STFs 15 – 32)
    - Identified small spring entering main river channel with naked eye and spotting scope
    - Discussed restoration possibilities in general
    - Confirmed that light restoration by hand is possible in the bypass reach
    - Discussed grouping springs
    - Confirmed the general purpose/objectives of the work
        - Identify location of springs with relatively high flow rates
        - Explore possibilities for stream restoration efforts focused on habitat enhancement/protection
        - Inform fish monitoring

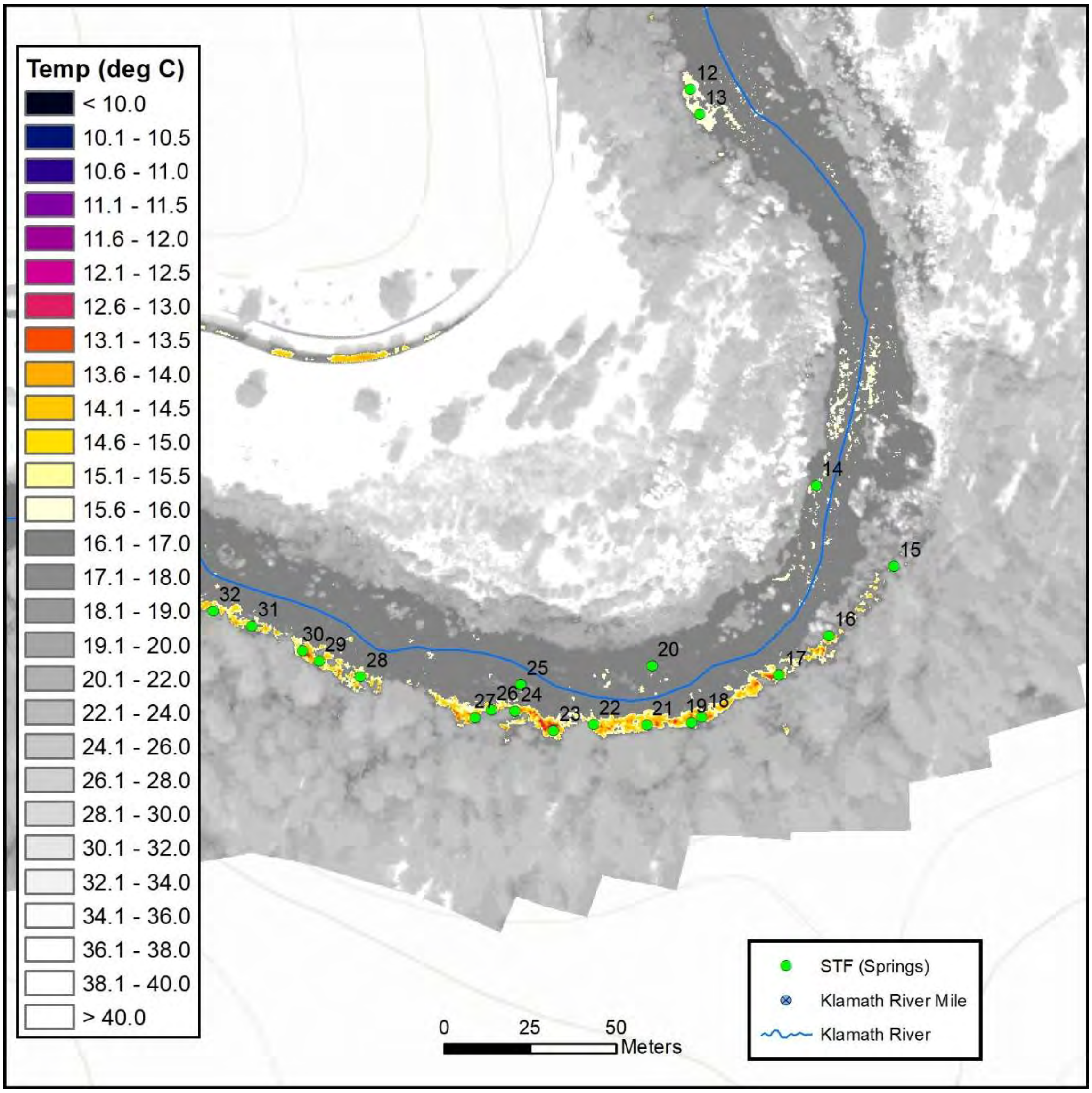
  - Redband trout are generally not monitored in the bypass reach
    - Tough to access
    - Fish look healthy, albeit small, when observed
    - Good evidence that these populations are productive and sending fish downstream
    - Observations of redband using augmented spawning gravel
  - Bypass reach could be good spawning/holding habitat in a post-dam environment
  - Sediment behind dam will help with conditions in the bypass reach which is currently "starved" of sediment; also expected to help with creating side channels etc.
  - Probably good idea to wait until sediment settles to decide on specific restoration treatments – keep restoration conceptual at this point
  - Keep locations in which springs are sparse in mind
  - These bypass springs are the last cold-water areas until the Williamson
  - Flow transects can be established as permanent
  - No indication that these springs were making substantial contributions to the flow
- STF 43
  - Likely the start of the significant spring contribution to flow
  - Locate the uppermost flow transect here
- STF 55 and 56
  - Visualized several other springs
  - Indication that flow had increased significantly here
  - Locate the next flow transect here
- Locate a third flow transect just above the Powerhouse
  - Any opportunity for an additional flow transect; perhaps at "Mark's" access point?
- Post-lunch discussion: next steps
  - Implement inflow assessments at flow transects
  - Prioritize STFs
    - Group sites and report mean and standard deviation of temperature attributes
    - Conduct terrain analysis using topo-bathy LiDAR data
      - Identify STFs located in areas where the channel width expands under higher flow conditions
      - Select flow conditions to analyze – perhaps 600, 1200, and 1800 cfs? 3600 cfs??

    - Incorporate results from the inflow assessments at flow transects
  - Conduct site surveys and habitat assessments at priority STFs/STF groups
    - Site photos, substrate size distribution/extent, characterize large woody debris, etc.
    - Additional bathymetry data not needed until sediment settles out and restoration designs can move beyond conceptual phase

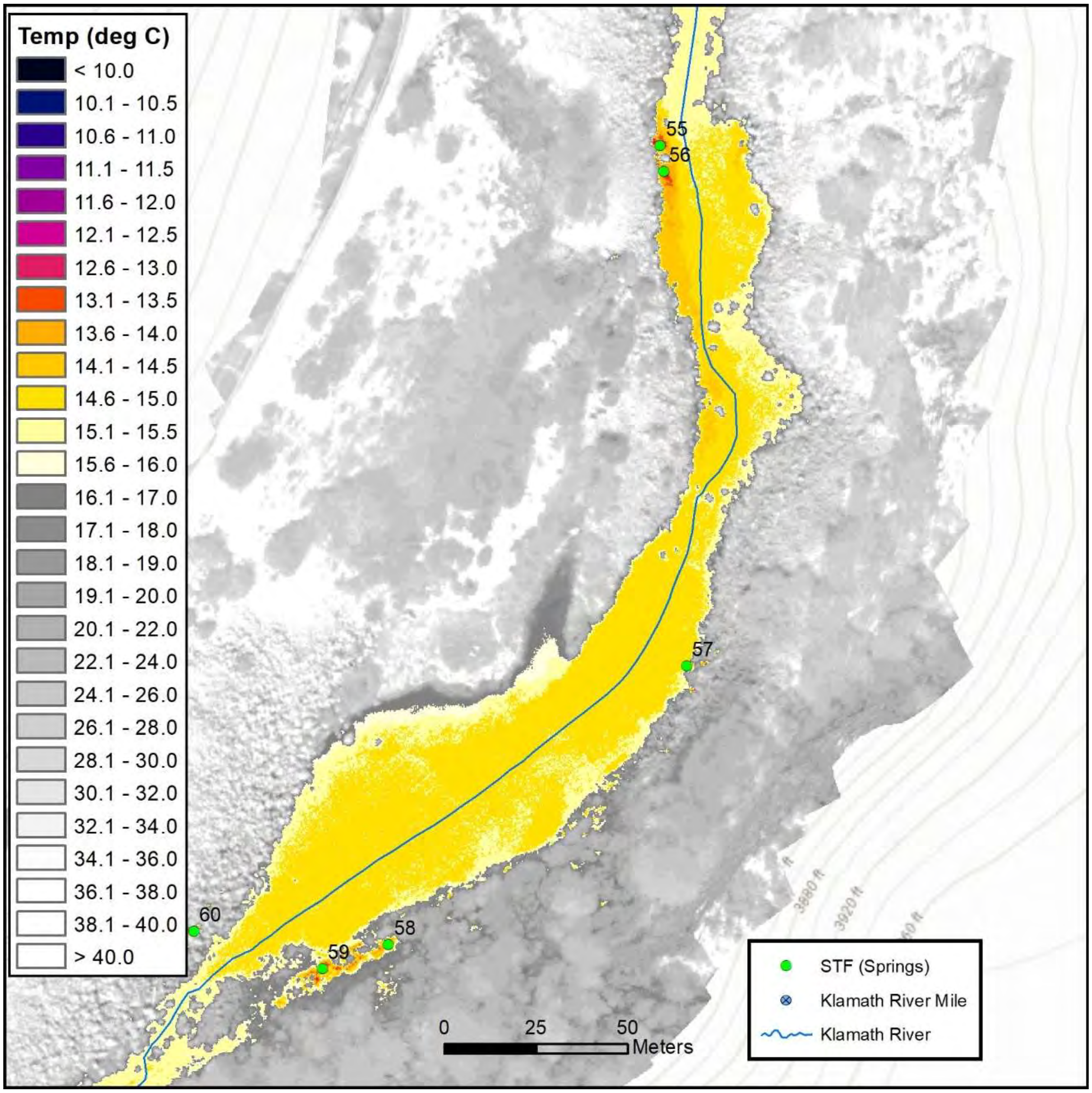
Wooden Bridge (STFs 10, 11)



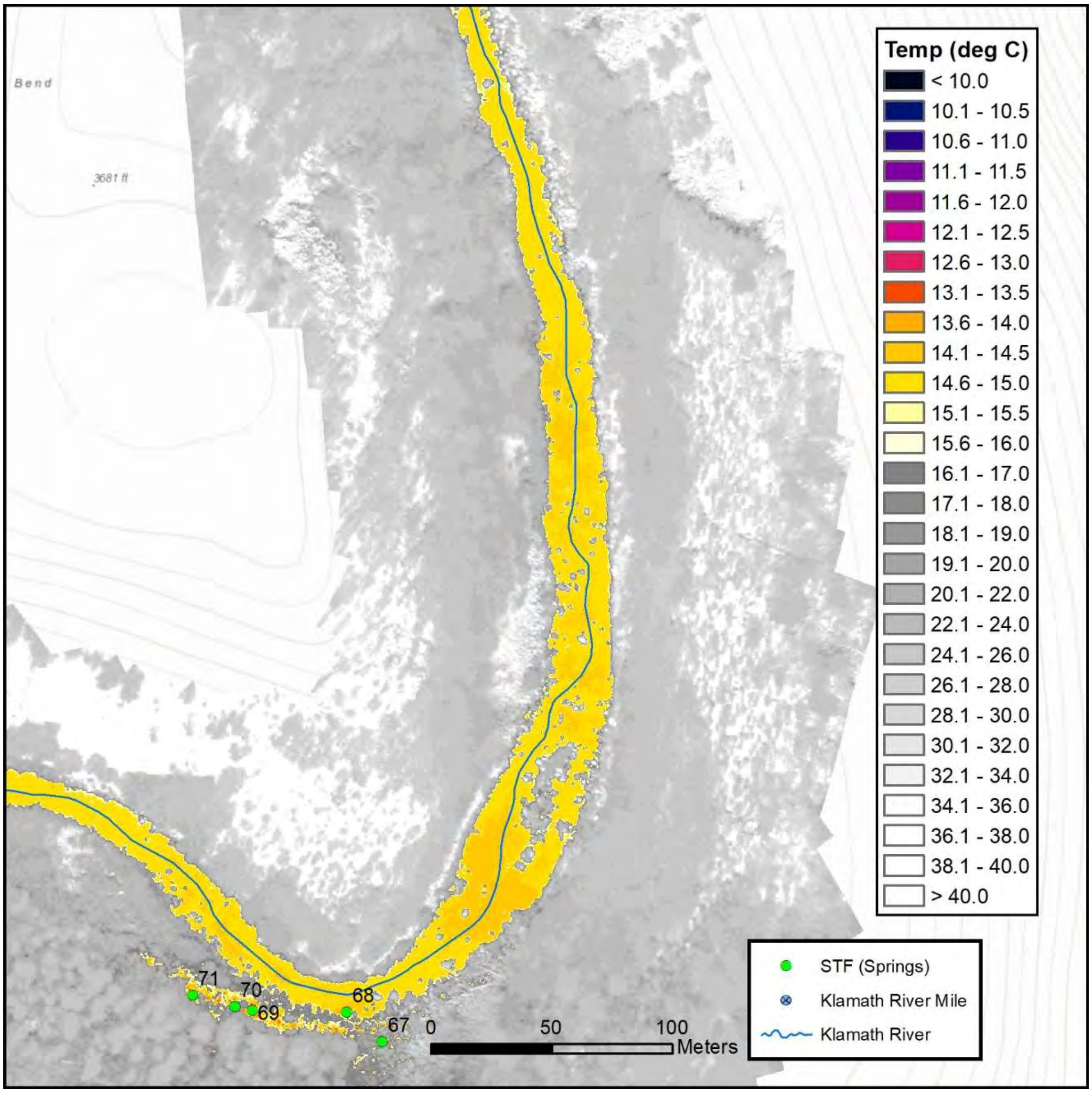
First Corner (STFs 15-32)



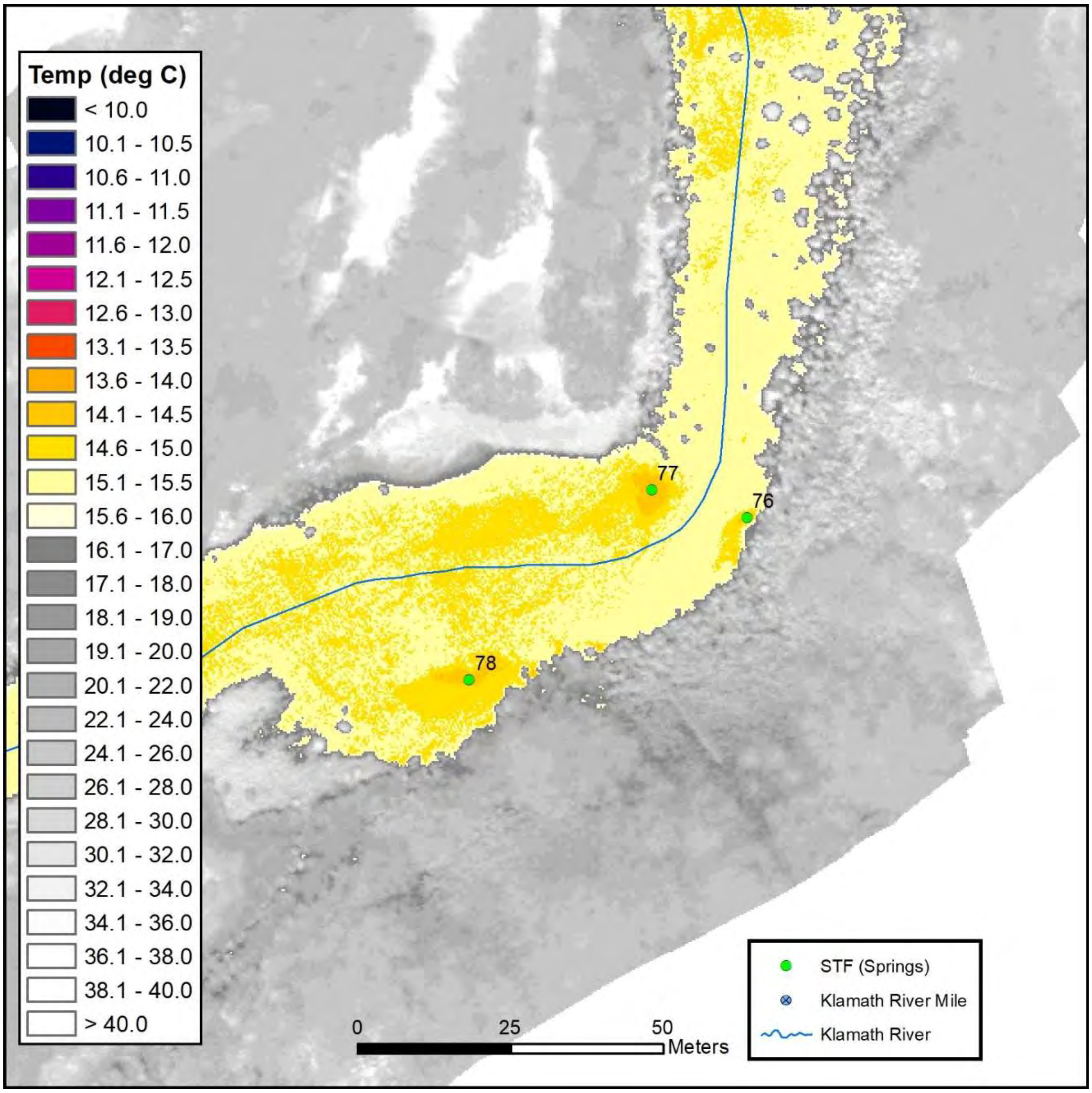
Alcove (STFs 55-60)



Vicinity of Mark's Access Point



Spring Island (STFs 76-78)



Appendix B. Sontek RS-5 Acoustic Doppler Current Profiling (ADCP) Settings

Profiling Range	0.1-6 m (*1)
Velocity Range	±5 m/s
Accuracy	1% ±0.002 m/s
Resolution	0.001 m/s
Number of Cells	Up to 128
Cell Size	2.5-30 cm
Data Output Rate	1.0 Hz
Bottom Tracking	
Depth Range	0.1-6 m (*1)
Accuracy (*2)	1% ± 0.002 m/s
Resolution	0.001 m/s
Depth Measurement	
Range	0.1-6.5 m (*1)
Accuracy	1% ±0.005 m
Sensors	
Temperature Sensors	Resolution: ±0.01°C, Accuracy: ±0.5°C
Compass/Tilt Sensor	Range: ±180° Pitch/Roll, 0-360° Heading, Heading Accuracy: ±2°, Pitch/Roll Accuracy: ±1°
Transducers	
Total Number	Five, 3.0 Mhz
Beam Angle	25°
Beam Width	3°
Bandwidth	25%
Battery Characteristics	
Input Voltage	3.3-4.2 VDC
Power Source - Li-Ion	1x size 18650, Tenergy, Type 30016-04, 3.7Vdc, 2600mAh
Battery Life - 1 x size 18650	Seven hours continuous use, typical settings (*3)
Power Consumption	1.0 W (Average)
Dimensions	19.2 mm x 69.7 mm
Communications	
Radio Protocol	Bluetooth Low Energy (BLE5)
Range	100 m (*4)
Bluetooth Compliance	FCC Part 15, FCC ID: XPYNINAB30, ISED Certification: 8595A-NINAB30
Environmental	
Operation Temperature	-5° to 45°C (23°F to 113°F)
Storage Temperature	20° to 70°C (-4°F to 158°F)
Storage with Battery Temperature (*5)	-20° to 45°C (-4°F to 113°F)
RS5 Physical Properties	
Dimensions - HBII Micro	76 cm (30") x 50 cm (20") x 11cm (4.25")
Dimensions - RS5 Unit	24 cm (9.5") x 5 cm (2.2")
Weight in Air - RS5 Unit	0.45 kg (1.0 lbs)
Weight in Water - RS5 Unit	0.15 kg (0.33 lbs)
Weight in Air - RS5/HBII Micro/Geode	3.63 kg (8.0 lbs)
Waterproof Rating	IP67
DGNSS	
Horizontal RMS	SBAS (WAAS): <0.3 m (0.98 ft)
2DRMS	SBAS (WAAS): <0.6 m (1.96 ft)
Frequency	L1, Multi-GNSS

*Additional notes
1 Maximum range will vary with environmental conditions.
2 Bottom velocity accuracy.
3 Seven hours continuous use, typical settings.
4 When using provided SonTek USB radio with antenna.
5 Remove batteries from the RS5 if storage temperatures exceed the storage temperature of the Li-Ion battery

Figure B-1. SonTek RS5 ADCP specifications and settings employed during recording of flow transects.

Appendix C. Thermal Feature Prioritization Matrix and Descriptive Statistics of The Three Quantitative Prioritization Metrics

Table C-1. Descriptive statistics of the three quantitative prioritization metrics among the 54 relatively cool water areas identified along the study reach.

Statistic	Thermal Strength	Proximity	Connectivity (m)
Maximum	56483	8080	16
75th percentile	7304.8	1502.5	3
Mean	6279.7	1306.7	3.1
Median	474	605	2
25th percentile	111	327.5	1
Minimum	18	40	0

Table C-2. Thermal feature prioritization matrix: metric values

Name	River Bank	River km (from TIR acquisition)	Klamath River Mile	Thermal Strength	Proxmity: Upstream	Proxmity: Downstream	Proximity: Upstream+Downstream	Habitat Description (long)	Habitat Description (short)	Connectivity (m)
GRP01	R	36.26	225	12995	-	550	550	Channel margins at base of JCB	Pool	16
GRP02	L	35.71	224	1197	550	130	680	Pool margin	Pool	1
ISO01	L	35.58	224	110	130	90	220	Channel margin in riffle / pool transition	Riffle	7
GRP03	R	35.49	224	54828	90	0	90	Riffle margin	Riffle	1
ISO02	L	35.49	224	66	0	40	40	Mid riffle boulders	Riffle	9
ISO03	R	35.45	224	75	40	70	110	Riffle margin	Riffle	3
GRP04	R	35.38	224	18210	70	240	310	Riffle margin	Riffle	3
GRP05	R	35.14	224	50183	240	180	420	Channel margin in lb sc	Off-channel	1
ISO04	L	34.96	224	146	180	200	380	Off channel seepage in talus / pool margin	Pool	0
GRP06	R	34.76	224	2635	200	80	280	Riffle margin	Riffle	2
GRP07	R	34.68	224	12322	80	90	170	Channel margin in riffle / pool transition	Pool	4
GRP08	R	34.59	224	25290	90	140	230	Full channel at pool head	Pool	4
ISO05	L	34.45	224	7808	140	300	440	Channel margin in pool	Pool	5
GRP09	L	34.15	223	8593	300	240	540	Pool margin	Pool	1
GRP10	R	33.91	223	3453	240	30	270	Off channel seepage in talus / pool margin	Pool	2
ISO06	L	33.88	223	153	30	390	420	Off channel seepage in talus / rapid margin	Rapid	0
ISO07	R	33.49	223	61	390	140	530	Riffle margin	Riffle	2
GRP11	R	33.35	223	162	140	1200	1340	Rapid margin	Rapid	3
ISO08	L	32.15	222	971	1200	520	1720	Rapid margin	Rapid	3
ISO09	R	31.63	222	422	520	180	700	Riffle margin	Riffle	2
ISO10	R	31.45	222	152	180	550	730	Riffle margin	Riffle	9
GRP12	R	30.90	222	5795	550	100	650	Mid channel pool upwelling	Pool	2
GRP13	R	30.80	222	8106	100	510	610	Off channel seepage in talus / rapid margin	Rapid	6
ISO11	R	30.29	221	311	510	90	600	Off channel seepage in talus / rapid margin	Rapid	4
GRP14	R	30.20	221	9777	90	190	280	Off channel seepage in talus / rapid margin	Rapid	10
ISO12	R	30.01	221	17619	190	1740	1930	Mid channel and pool margin	Pool	3
GRP15	R	28.27	220	672	1740	980	2720	Mid channel pool	Pool	2
GRP16	R	27.29	220	14320	980	470	1450	Connected lb side channel / alcove	Off-channel	1
ISO13	R	26.82	219	253	470	140	610	Connected lb side channel / alcove	Off-channel	1
ISO14	R	26.68	219	187	140	70	210	Channel margin adjacent to rapid	Rapid	3
GRP17	R	26.61	219	526	70	90	160	Channel margin riffle adjacent to rb sc	Riffle	2
ISO15	R	26.52	219	41	90	30	120	Channel margin riffle downstream of rb sc	Riffle	2
ISO16	R	26.49	219	48	30	8040	8070	Channel margin pool downstream of rb sc	Pool	1
ISO17	R	18.45	214	36	8040	40	8080	Channel margin adjacent to rapid	Rapid	1
ISO18	R	18.41	214	41	40	100	140	Channel margin in riffle	Riffle	1
ISO19	R	18.31	214	21	100	480	580	Channel margin adjacent to rapid	Rapid	2
ISO20	L	17.83	214	114	480	10	490	Channel margin at pool transition	Pool	3
ISO21	R	17.82	214	3813	10	960	970	Channel margin at pool transition	Pool	2
ISO22	R	16.86	213	27	960	40	1000	Channel margin in rapid	Rapid	3
ISO23	R	16.82	213	18	40	450	490	Channel margin at pool transition	Pool	1
ISO24	L	16.37	213	2196	450	180	630	Low vel area at base of rb sc adjacent to rapid	Off-channel	2
ISO25	L	16.19	213	283	180	1460	1640	Channel margin below rapid	Pool	2
ISO26	R	14.73	212	4017	1460	960	2420	Channel margin / eddy in riffle pool transition	Riffle	2
ISO27	R	13.77	211	120	960	320	1280	Channel margin in pool below rapid	Pool	1
GRP18	L	13.45	211	4079	320	110	430	Mid channel in pool above rapid	Pool	3
ISO28	R	13.34	211	100	110	1030	1140	Small eddy adjacent to rapid	Rapid	1
ISO29	R	12.31	210	806	1030	1980	3010	Split channel below rapids	Rapid	2
ISO30	L	10.33	209	152	1980	330	2310	Pool margin	Pool	1
ISO31	L	10.00	209	20	330	2060	2390	Pool margin with some connected floodplain	Pool	8
ISO32	L	7.94	208	19	2060	510	2570	Riffle margin downstream of sc complex	Riffle	2
ISO33	L	7.43	207	223	510	60	570	Riffle margin / eddy	Riffle	3
ISO34	L	7.37	207	568	60	1460	1520	Pool margin / eddy	Pool	2
GRP19	L	5.91	206	56483	1460	4930	6390	Confluence, channel margin, sc complex (rb)	Off-channel	3
GRP20	L	0.98	203	8480	4930	-	4930	Confluence, alcove, gravel bar	Off-channel	6

Table C-3. Thermal feature prioritization matrix: metric scores

Name	River Bank	River km (from TIR acquisition)	Klamath River Mile	Thermal Strength Score	Proximity Score	Habitat Score	Connectivity Score	Total Score	Thermal Strength Score (weighted)	Proximity Score (weighted)	Habitat Score (weighted)	Connectivity Score (weighted)	Total Score (weighted)
GRP01	R	36.26	225	2	1	2	3	8	8	3	4	3	18
GRP02	L	35.71	224	1	1	2	1	5	4	3	4	1	12
ISO01	L	35.58	224	1	1	2	2	6	4	3	4	2	13
GRP03	R	35.49	224	3	1	2	1	7	12	3	4	1	20
ISO02	L	35.49	224	1	1	2	3	7	4	3	4	3	14
ISO03	R	35.45	224	1	1	2	1	5	4	3	4	1	12
GRP04	R	35.38	224	2	1	2	1	6	8	3	4	1	16
GRP05	R	35.14	224	3	1	3	1	8	12	3	6	1	22
ISO04	L	34.96	224	1	1	2	1	5	4	3	4	1	12
GRP06	R	34.76	224	1	1	2	1	5	4	3	4	1	12
GRP07	R	34.68	224	2	1	2	2	7	8	3	4	2	17
GRP08	R	34.59	224	2	1	2	2	7	8	3	4	2	17
ISO05	L	34.45	224	2	1	2	2	7	8	3	4	2	17
GRP09	L	34.15	223	2	1	2	1	6	8	3	4	1	16
GRP10	R	33.91	223	1	1	2	1	5	4	3	4	1	12
ISO06	L	33.88	223	1	1	1	1	4	4	3	2	1	10
ISO07	R	33.49	223	1	1	2	1	5	4	3	4	1	12
GRP11	R	33.35	223	1	2	1	1	5	4	6	2	1	13
ISO08	L	32.15	222	1	2	1	1	5	4	6	2	1	13
ISO09	R	31.63	222	1	1	2	1	5	4	3	4	1	12
ISO10	R	31.45	222	1	1	2	3	7	4	3	4	3	14
GRP12	R	30.90	222	1	1	2	1	5	4	3	4	1	12
GRP13	R	30.80	222	2	1	1	2	6	8	3	2	2	15
ISO11	R	30.29	221	1	1	1	2	5	4	3	2	2	11
GRP14	R	30.20	221	2	1	1	3	7	8	3	2	3	16
ISO12	R	30.01	221	2	2	2	1	7	8	6	4	1	19
GRP15	R	28.27	220	1	2	2	1	6	4	6	4	1	15
GRP16	R	27.29	220	2	2	3	1	8	8	6	6	1	21
ISO13	R	26.82	219	1	1	3	1	6	4	3	6	1	14
ISO14	R	26.68	219	1	1	1	1	4	4	3	2	1	10
GRP17	R	26.61	219	1	1	2	1	5	4	3	4	1	12
ISO15	R	26.52	219	1	1	2	1	5	4	3	4	1	12
ISO16	R	26.49	219	1	3	2	1	7	4	9	4	1	18
ISO17	R	18.45	214	1	3	1	1	6	4	9	2	1	16
ISO18	R	18.41	214	1	1	2	1	5	4	3	4	1	12
ISO19	R	18.31	214	1	1	1	1	4	4	3	2	1	10
ISO20	L	17.83	214	1	1	2	1	5	4	3	4	1	12
ISO21	R	17.82	214	1	1	2	1	5	4	3	4	1	12
ISO22	R	16.86	213	1	1	1	1	4	4	3	2	1	10
ISO23	R	16.82	213	1	1	2	1	5	4	3	4	1	12
ISO24	L	16.37	213	1	1	3	1	6	4	3	6	1	14
ISO25	L	16.19	213	1	2	2	1	6	4	6	4	1	15
ISO26	R	14.73	212	1	2	2	1	6	4	6	4	1	15
ISO27	R	13.77	211	1	2	2	1	6	4	6	4	1	15
GRP18	L	13.45	211	1	1	2	1	5	4	3	4	1	12
ISO28	R	13.34	211	1	1	1	1	4	4	3	2	1	10
ISO29	R	12.31	210	1	2	1	1	5	4	6	2	1	13
ISO30	L	10.33	209	1	2	2	1	6	4	6	4	1	15
ISO31	L	10.00	209	1	2	2	2	7	4	6	4	2	16
ISO32	L	7.94	208	1	2	2	1	6	4	6	4	1	15
ISO33	L	7.43	207	1	1	2	1	5	4	3	4	1	12
ISO34	L	7.37	207	1	2	2	1	6	4	6	4	1	15
GRP19	L	5.91	206	3	3	3	1	10	12	9	6	1	28
GRP20	L	0.98	203	2	3	3	2	10	8	9	6	2	25

Table C-4. Thermal feature prioritization matrix: site access

Name	River Bank	River km (from TIR acquisition)	Klamath River Mile	Access Description (long)	Access Description (short)	Access Score	Comments	Flow Rate (cfs)
GRP01	R	36.26	225	Dam removal access roads	Road both	3	Could be sign diff after removal	NR
GRP02	L	35.71	224	Bypass reach	Boat or Walk	1		< 1
ISO01	L	35.58	224	Bypass reach	Boat or Walk	1		< 1
GRP03	R	35.49	224	Bypass reach	Boat or Walk	1	May be a rapid under elevated flows	< 1
ISO02	L	35.49	224	Bypass reach	Boat or Walk	1	May be a rapid under elevated flows	< 1
ISO03	R	35.45	224	Bypass reach	Boat or Walk	1	May be a rapid under elevated flows	< 1
GRP04	R	35.38	224	Bypass reach	Boat or Walk	1	May be a rapid under elevated flows	< 1
GRP05	R	35.14	224	Bypass reach	Boat or Walk	1	May not be connected for fish ingress / egress	< 1
ISO04	L	34.96	224	Bypass reach	Boat or Walk	1	May not be connected for fish ingress / egress	< 181
GRP06	R	34.76	224	Bypass reach	Boat or Walk	1	May be a rapid under elevated flows	< 181
GRP07	R	34.68	224	Bypass reach	Boat or Walk	1	May be a rapid under elevated flows	< 181
GRP08	R	34.59	224	Bypass reach	Boat or Walk	1		< 181
ISO05	L	34.45	224	Bypass reach	Boat or Walk	1		< 181
GRP09	L	34.15	223	Bypass reach	Boat or Walk	1		< 181
GRP10	R	33.91	223	Bypass reach	Boat or Walk	1		< 53
ISO06	L	33.88	223	Bypass reach	Boat or Walk	1		< 53
ISO07	R	33.49	223	Bypass reach	Boat or Walk	1		< 53
GRP11	R	33.35	223	Bypass reach	Boat or Walk	1		< 53
ISO08	L	32.15	222	Bypass reach	Boat or Walk	1		< 53
ISO09	R	31.63	222	Bypass reach	Boat or Walk	1	May be a rapid under elevated flows	< 53
ISO10	R	31.45	222	Bypass reach	Boat or Walk	1	May be a rapid under elevated flows	< 53
GRP12	R	30.90	222	Bypass reach	Boat or Walk	1		< 53
GRP13	R	30.80	222	Bypass reach	Boat or Walk	1	May not be connected for fish ingress / egress	< 53
ISO11	R	30.29	221	Bypass reach	Boat or Walk	1	May not be connected for fish ingress / egress	< 53
GRP14	R	30.20	221	Bypass reach	Boat or Walk	1	May not be connected for fish ingress / egress	< 53
ISO12	R	30.01	221	Bypass reach	Boat or Walk	1		< 53
GRP15	R	28.27	220	At boat ramp	Road same	3	potential resting adult resting area	< 21
GRP16	R	27.29	220	Potential equip access on rb and cross riv?	Road opposite	2	Looks connected at low flows without stranding	NR
ISO13	R	26.82	219	Potential equip access on rb and cross riv?	Road opposite	2	Looks connected at low flows without stranding	NR
ISO14	R	26.68	219	Potential equip access on rb and cross riv?	Road opposite	2		NR
GRP17	R	26.61	219	Potential equip access on rb and cross riv?	Road opposite	2		NR
ISO15	R	26.52	219	Potential equip access on rb and cross riv?	Road opposite	2		NR
ISO16	R	26.49	219	Potential equip access on rb and cross riv?	Road opposite	2		NR
ISO17	R	18.45	214	Boat only?	Boat or Walk	1	Potential resting area below rapid	NR
ISO18	R	18.41	214	Boat only?	Boat or Walk	1	Potential resting area below rapid	NR
ISO19	R	18.31	214	Boat only?	Boat or Walk	1	Potential resting area below rapid	NR
ISO20	L	17.83	214	Boat only?	Boat or Walk	1	Potential resting area below rapid	NR
ISO21	R	17.82	214	Boat only?	Boat or Walk	1	Potential resting area below rapid	NR
ISO22	R	16.86	213	Boat only?	Boat or Walk	1	Potential high flow sc on rb	NR
ISO23	R	16.82	213	Boat only?	Boat or Walk	1	Potential high flow sc on rb	NR
ISO24	L	16.37	213	Boat only?	Boat or Walk	1	May have adult resting and rearing potential	NR
ISO25	L	16.19	213	Boat only?	Boat or Walk	1		NR
ISO26	R	14.73	212	Right bank road, may be inaccessible to equipment	Road opposite	1		NR
ISO27	R	13.77	211	Potential ATV access upstream on LB	Boat or Walk	1	Potential resting area below rapid	NR
GRP18	L	13.45	211	Potential ATV access upstream on LB	Boat or Walk	1	Upwelling? Some channel margin habitat available	NR
ISO28	R	13.34	211	Boat only?	Boat or Walk	1	Potential adult resting area	NR
ISO29	R	12.31	210	Left bank road	Road same	2	Potential adult resting area	NR
ISO30	L	10.33	209	Left and right bank roads, LB may be steep	LB and RB Road	3	Potential resting area below rapid	NR
ISO31	L	10.00	209	Left and right bank roads	Road both	3		NR
ISO32	L	7.94	208	Left bank road, RB may be confined by hillslope	Road opposite	2		NR
ISO33	L	7.43	207	Left bank road, RB confined by hillslope	Road opposite	2	Likely associated with steep hillslope	NR
ISO34	L	7.37	207	Left bank road, RB confined by hillslope	Road opposite	2	Likely associated with steep hillslope	NR
GRP19	L	5.91	206	Left and right bank roads	Road both	3	Shovel Cr confluence, RB side channel	NR
GRP20	L	0.98	203	Left and right bank roads	Road both	3	Cold alcove / Long Prairie Cr confluence	NR

Appendix D. Acoustic Doppler Current Profiling (ADCP) Data

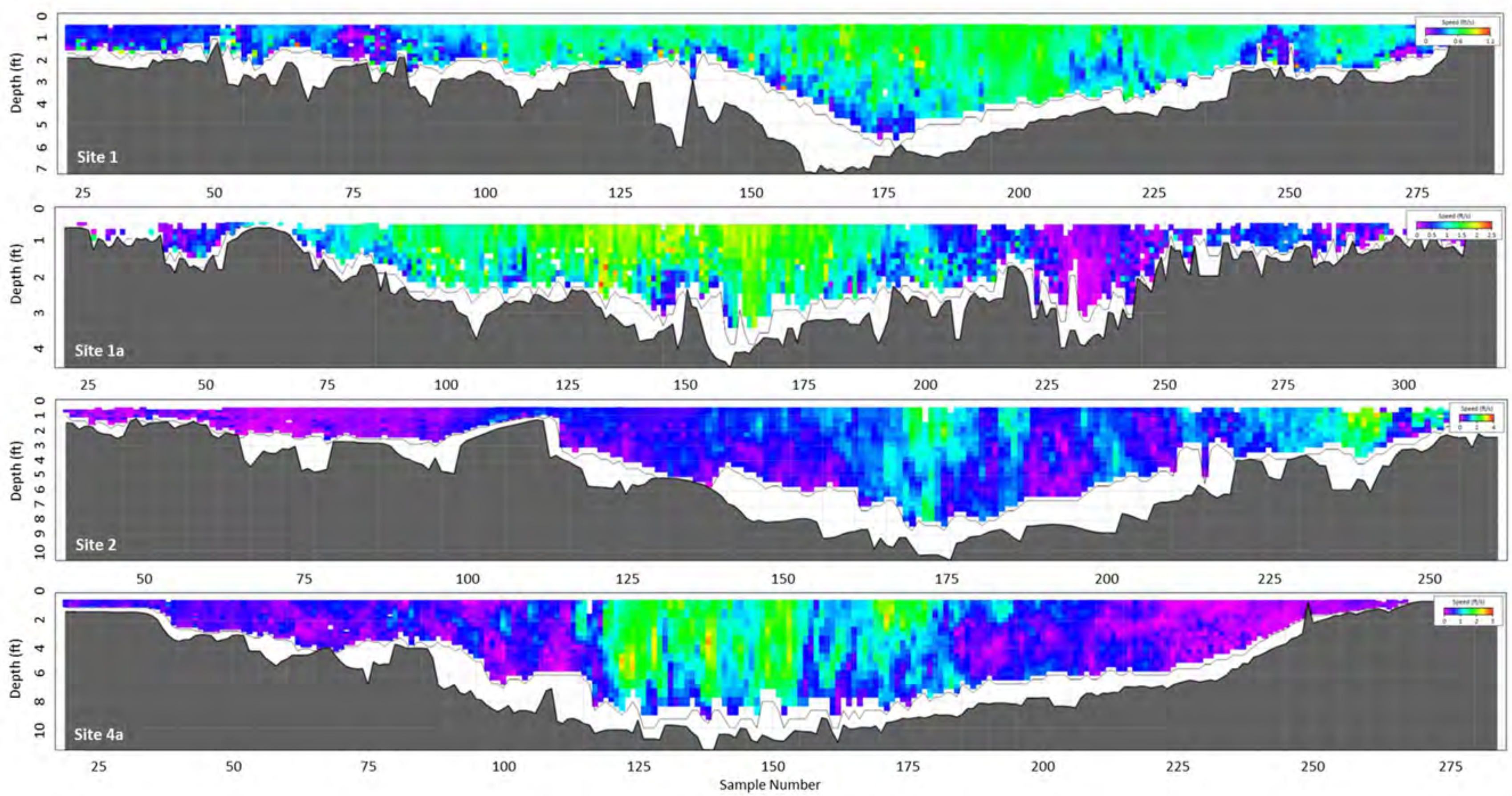
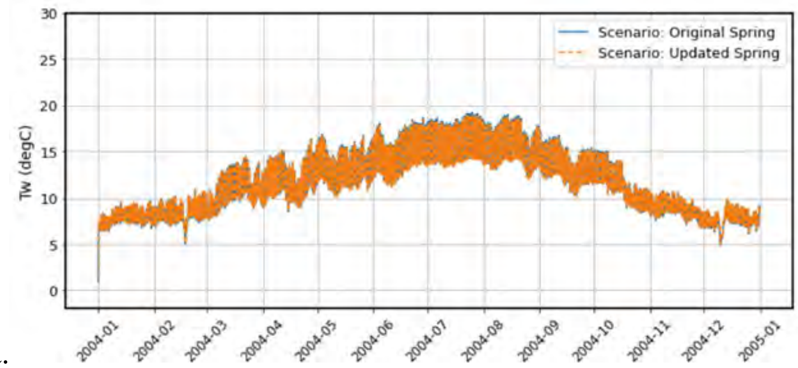


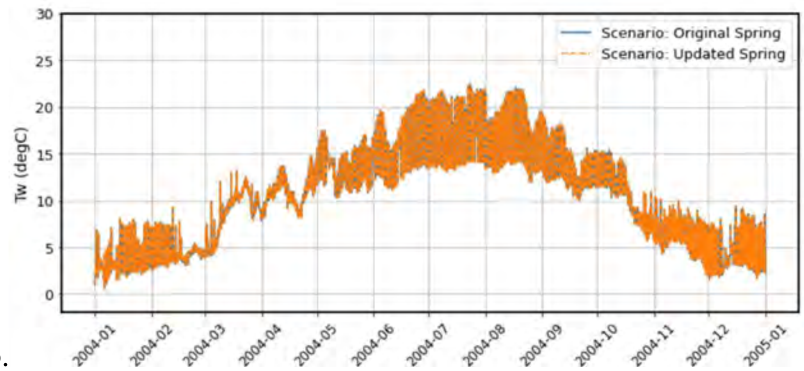
Figure D-1. Acoustic doppler current profile data for the four flow transect measurement sites: 1, 1a, 2 and 4a. Data collected August 3-4, 2022.

Appendix E. RMA-11 Water Temperature and Flow Modeling Results For Selected Model Nodes Along The Study Reach

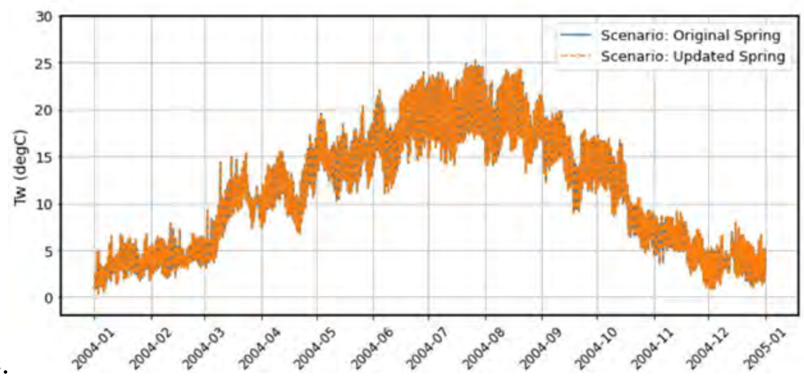
The results suggest that the location and flow rate of springs along the study reach show little influence on modeled water temperatures at the modeled locations represented by the nodes.



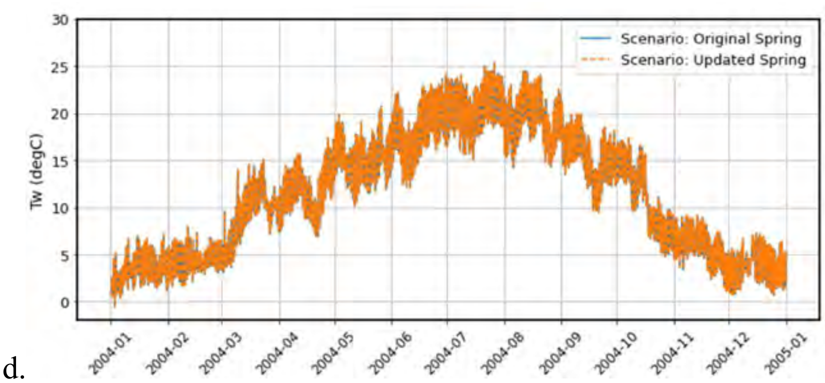
a.



b.



c.



d.

Figure E-1. Simulated Klamath River water temperature: original and updated spring locations for (a) above JCB powerhouse (node92); (b) below JCB powerhouse (node102); (c) Oregon and California Stateline (node 331); (d) at Shovel creek (node 388). 2004. The updated spring scenario appears as 'Existing Conditions' elsewhere in the report.

Appendix F. Field Assessment Summaries For Six Sites With No Proposed Thermal Habitat Protection Opportunities

Group 1 (GRP 01)

Feature: Seep / Spring

Location: Between J.C. Boyle Dam and Wooden Bridge

Centroid: 42.122397, -122.049119

Ownership: PacifiCorp

Priority: Unknown

Recon Type: Remote sensing

Habitat Characteristics / Quality: Requires assessment following dam removal.

Restoration / Enhancement Potential: Requires assessment following dam removal.

Existing Condition: Group 1 consists of numerous seeps around bedrock and scree slopes near the base of J.C. Boyle Dam. Site conditions were observed from the wooden bridge that crosses the Klamath River, but a more intensive field assessment of the site was not completed. Some of the seep inputs may be attributed to the hydrostatic pressure caused by the dam and reservoir upstream, however, given the shallow nature and short residence time of water within J.C. Boyle Reservoir, it's unlikely that water temperatures would be significantly different than in the Klamath River downstream of the dam. Because the site is located within the anticipated construction footprint for the planned removal of J.C. Boyle Dam, there is potential for the channel to be in a different location and/or elevation following dam removal and restoration activities. Therefore, we suggest that Group 1 is fully assessed following dam removal and restoration activities anticipated to begin in 2023.

Preliminary Proposed Action: Complete assessment of sites following dam removal and restoration activities slated to begin in 2023.

Proposed Treatment: To be determined following field assessment.

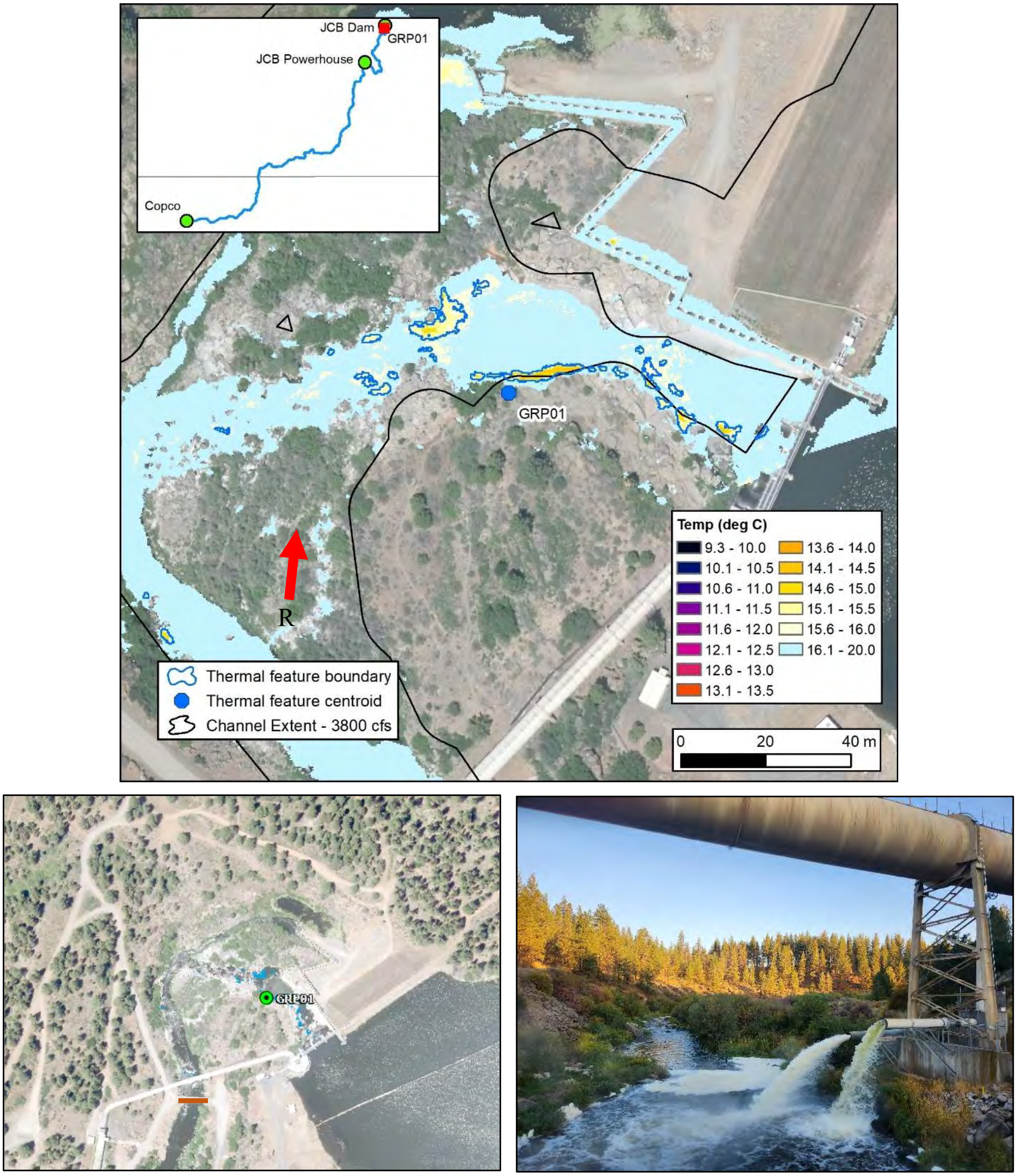


Figure F-1. Above: Thermal infrared imagery in the vicinity of Group 01. "R" arrow indicates approximate vantage point direction for the below right site photo. Left photo: Aerial image depicting the location of thermal features between J.C. Boyle Dam and the Wooden Bridge. Blue polygons represent individual raster cells where temperatures are colder than surrounding river temperatures; the green dot represents the centroid of all polygons associated with the thermal feature. The orange line highlights the location of the Wooden Bridge. Photo taken November 12, 2021. Right photo: View looking upstream from the Wooden Bridge at the location of one of the small features identified from the thermal imagery. Photo taken October 12, 2022.

Group 15 (GRP 15)

Feature: Hydraulic upwelling

Location: Pool at Spring Island Boat Access

Centroid: 42.08909, -122.072277

Ownership: United States Bureau of Land Management

Priority: Low

Recon Type: Remote sensing, field assessment

Habitat Characteristics / Quality: Good resting and holding conditions for migrating adult salmonids under existing conditions.

Restoration / Enhancement Potential: Low potential due to existing depths, velocities, and access constraints.

Existing Condition: There are two main thermal features associated with Group 15. Both features share similar habitat characteristics and are located along opposite eddy lines adjacent to the thalweg in a large pool located at the BLM-operated Spring Island Day Use site. Water depths within the thermal features and the pool in general are likely to be greater than 6 feet during normal daily peak flows. Substrate ranges from coarse gravel at the river-right bar to large boulders mid-channel. Substrate within the features is primarily a mix of boulders and large cobbles. Macrophytes are present on the pool margin where velocities are slow and substrate is finer, but macrophytes occupy less than 20 percent of the upstream thermal feature. Velocities in the thalweg wave train entering the pool are approximately 4-6 ft/s, and slowing to approximately 2-3 ft/s at approximately 200 ft downstream of the pool head. Velocities within the eddies are between 0-1 ft/s and both features provide good resting and holding habitat adjacent to the thalweg for migrating adult salmonids.

Cover is limited to boulder substrate, and no large wood or other cover objects were noted near the features or within the pool. Both mapped features are greater than 20 feet from the low flow bank line so it’s unlikely that bank edge or riparian vegetation is providing any additional overhead cover. Because of the proximity of the features to the thalweg and the existing depths, it’s unlikely that the addition of any cover objects would be stable during high flows other than the placement of boulders which are already present in large quantities at the site and within the reach in general.

Access to the site is via a public boat ramp located on the river-right wetted edge of the pool. However, based on the location of remotely sensed thermal signatures, both features are located a sufficient distance away from the boat ramp that land-based equipment would be unable to place objects within the cold-water extents. Boat or hand placement of cover objects would be possible but given the lack of stable features to tie structures into, placement of boulders would be the most appropriate cover type and the existing substrate is already currently dominated by large boulders.

Preliminary Proposed Enhancement Activities: None.

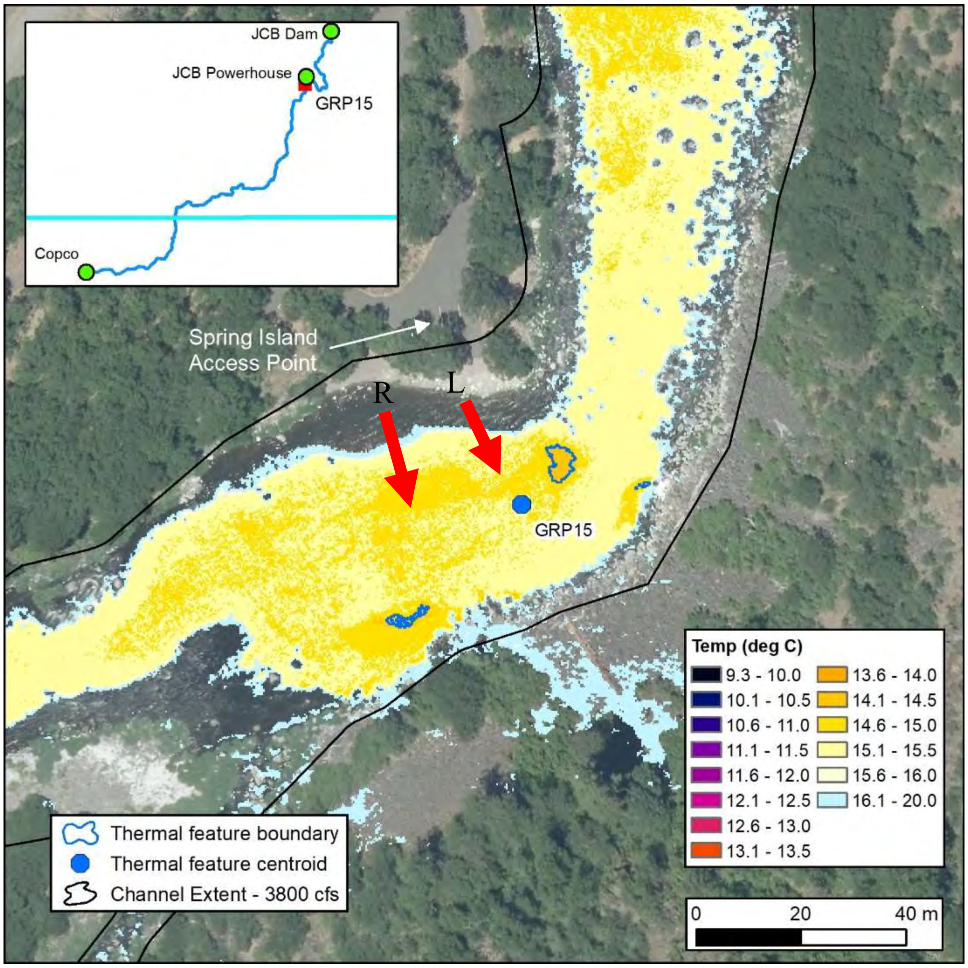


Figure F-2. Above: Thermal infrared imagery in the vicinity of Site Group 15. "L" and "R" arrows represent approximate vantage points for below left and right site photos, respectively. Left photo: View from right bank to upstream eddy feature. Thermal infrared imagery depicts the cold-water extents just to the river-right side of the thalweg (red circle). Right photo: View from right bank to downstream eddy feature. Thermal infrared imagery depicts the cold-water extents just to the river-left side of the thalweg (red circle). Photos taken October 12, 2022 at discharge of approximately 600 cfs at USGS gage #11510700.

Isolate 30 (ISO30)

Feature: Spring / Upwelling

Location: River-right ~500 ft below Hayden Creek confluence

Centroid: 42.006153, -122.190186

Ownership: PacifiCorp

Priority: Low

Recon Type: Remote sensing, field assessment

Habitat Characteristics / Quality: Good resting and holding conditions for migrating adult salmonids under existing conditions.

Restoration / Enhancement Potential: Low potential for cover enhancement due to distance from bank, existing depths and velocities, and access constraints.

Existing Condition: Isolate 30 is located in a narrow seam 20 ft from the bank at the upstream end of a river-right eddy line at the tailout of a rapid on the left-turning bend downstream of the Hayden Creek confluence. The tailout leads into a several hundred-foot-long pool. Water depths in the eddy are likely to be greater than 6 ft during normal daily peak flows. Substrate in the feature is dominated by boulders and cobbles. Velocities in the thalweg at the rapid entering the pool are approximately 4-6 ft/s and slowing to approximately 2-3 ft/s at approximately 200 ft downstream of the upstream end of the eddy. Velocities within the eddy are between 0-1 ft/s, and the features provide good resting and holding habitat adjacent to the thalweg for migrating adult salmonids. Cover is limited to boulder substrate, and no large wood or other cover objects were noted near the feature. There were no macrophytes observed in the feature. Remotely sensed cool temperatures in features may be associated with eddy hydraulics rather than springs. Because the cool water is isolated from the bankline, we suspect that upwelling of cool water from greater depths in the eddy is the source of cooler temperature water.

The steep river-right bank adjacent to the eddy is composed of basaltic bedrock and 2 to 4 ft diameter boulders. A single layer of riparian trees is present at the top of the bank between the mainstem and the river-right irrigation canal. The mapped feature is 20 ft from the low flow bank line, so it's unlikely that bank edge or riparian vegetation is providing any additional overhead cover. The canal is located approximately 15 ft above the water level at the time of assessment. The river-left bank along the rapid is composed of 1 to 10 ft diameter boulders. A shallower 60-ft-wide eddy located between the river-left bank line and the tailout thalweg did not have cool water detected.

Access to a nearby the site is via an unimproved access road on private property on river right. Vehicle access from the access road is restricted to the narrow irrigation canal, which is separated from the channel by a steep bedrock-boulder bank approximately 15 ft above the water surface. Based on the location of remotely sensed thermal signature 20 ft from the bankline, land-based equipment would be unable to place objects within the cold-water extent. Hand placement of cover objects would be possible but given the lack of stable features to tie objects into, combined with the presence of high velocities during high flows, it's not anticipated that any placed objects would remain stable other than the placement of boulders, which are already present in large quantities at the site and within the reach in general. Furthermore, placement of cover objects in the eddy could disrupt the hydraulics currently responsible for the presence of the mapped thermal feature.

Preliminary Proposed Enhancement Activities: None.

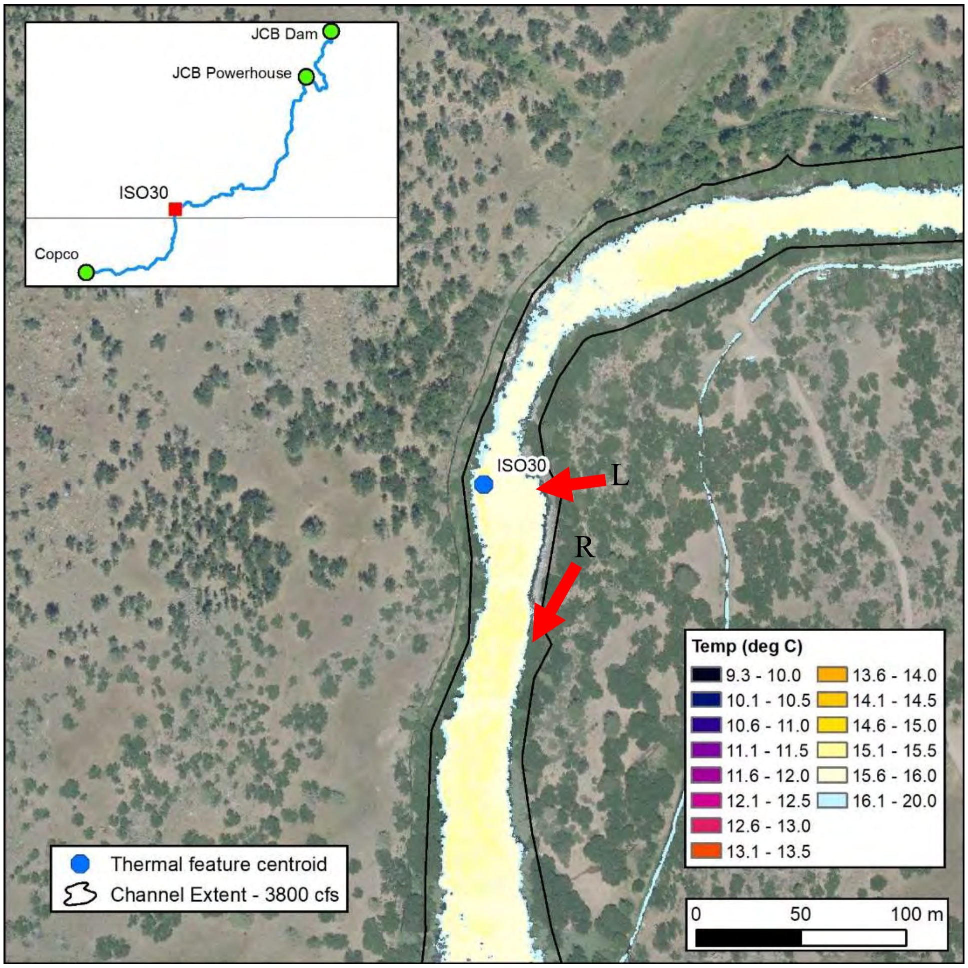


Figure F-3. Above: Thermal infrared imagery in the vicinity of Isolate 30. "L" and "R" arrows represent approximate vantage points for below left and right site photos, respectively. Left photo: Looking across the Klamath River at Isolate 30, which is located at the eddy line along the river-right bank (red circle). Right photo: View looking downstream at large pool downriver of Isolate 30. The large pool offers quality resting and holding opportunities for migrating adult salmonids. Photos taken October 13, 2022.

Isolate 31 (ISO31)

Feature: Spring / Upwelling

Location: River-right ~1,500 ft below Hayden Creek confluence

Centroid: 42.003345, -122.190506

Ownership: PacifiCorp

Priority: Low

Recon Type: Remote sensing, field assessment

Habitat Characteristics / Quality: Good resting and holding conditions for migrating adult salmonids under existing conditions.

Restoration / Enhancement Potential: Low potential for cover enhancement due to distance from bank, existing depths and velocities.

Existing Condition: Access near the site during the assessment was from the river-left irrigation canal, which is located on a hillslope 30 ft above river level, and therefore the site description is generated by combination of on-site observation from a distance, insights from Isolate 30 as an analog, and remote analysis.

Isolate 31 is located in a narrow seam 30 ft from the bank at the upstream end of a river-right eddy line at the tailout of a rapid. The tailout leads into a several hundred-foot-long pool. Water depths in the eddy are likely greater than 6 ft during normal daily peak flows. Substrate in the feature is likely boulders and cobbles based on the boulder composition of the river-right bank. Velocities in the thalweg at the tailout entering the pool are approximately 4-6 ft/s and slowing to approximately 2-3 ft/s at approximately 200 ft downstream of the upstream end of the eddy. Velocities within the eddy are between 0-1 ft/s, and the features provide good resting and holding habitat adjacent to the thalweg for migrating adult salmonids. Cover is limited to boulder substrate, and no large wood or other cover objects were noted near the feature. A single layer of riparian trees is present at the top of the bank between the mainstem and the river-right irrigation canal. The mapped feature is 30 ft from the low flow bank line, so it's unlikely that bank edge or riparian vegetation is providing any additional overhead cover. Remotely sensed cool temperatures in features may be associated with eddy hydraulics rather than springs. Because the cool water is isolated from the bankline, we suspect that upwelling of cool water from greater depths in the eddy is the source of cooler temperature water.

Access to a nearby the site is via an unimproved access road on private property on river right. The river-right bank adjacent to the eddy is approximately 6 ft above typical water level, and vehicle access to the top of bank is available. Based on the location of remotely sensed thermal signature 30 ft from the bankline, land-based equipment would be unable to place objects within the cold-water extent. Hand placement of cover objects would be possible but given the lack of stable features to tie objects into, combined with the presence of high velocities during high flows, it's not anticipated that any placed objects would remain stable other than the placement of boulders, which are already present in large quantities at the site and within the reach in general. Furthermore, placement of cover objects in the eddy could disrupt the hydraulics currently responsible for the presence of the mapped thermal feature.

Preliminary Proposed Enhancement Activities: None.

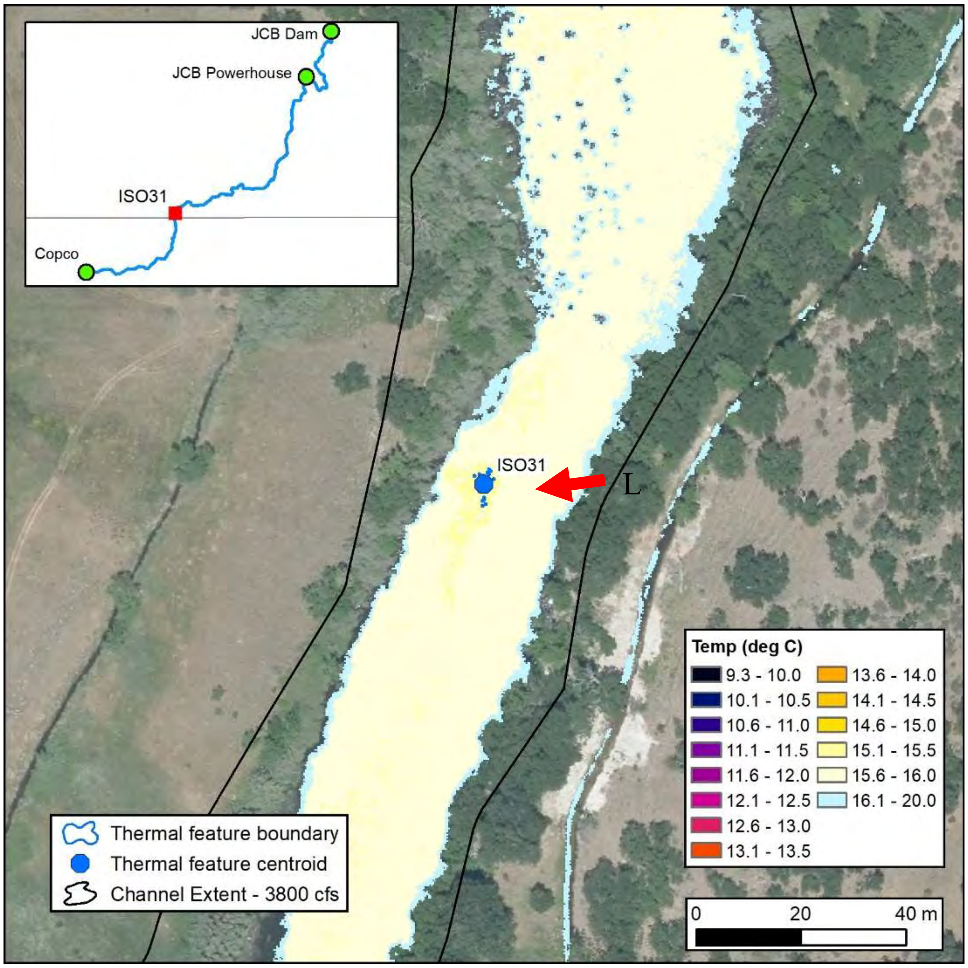


Figure F-4. Above: Thermal infrared imagery in the vicinity of Isolate 31. "L" arrow represents approximate vantage point for below left site photo. Left photo: View from river-left irrigation canal looking across the Klamath River at Isolate 31 near the river-right eddy line (red circle). Photo taken October 13, 2022. Right photo: Aerial view of the location of Isolate 31 near the river-right eddy line in the upper end of a large pool. Aerial imagery date June 11, 2018.

Isolate 32 (ISO32)

Feature: Hydraulic upwelling

Location: River-right ~1.1 miles upstream of Shovel Creek confluence

Centroid: 41.986104, -122.194090

Ownership: PacifiCorp

Priority: Low

Recon Type: Remote sensing only

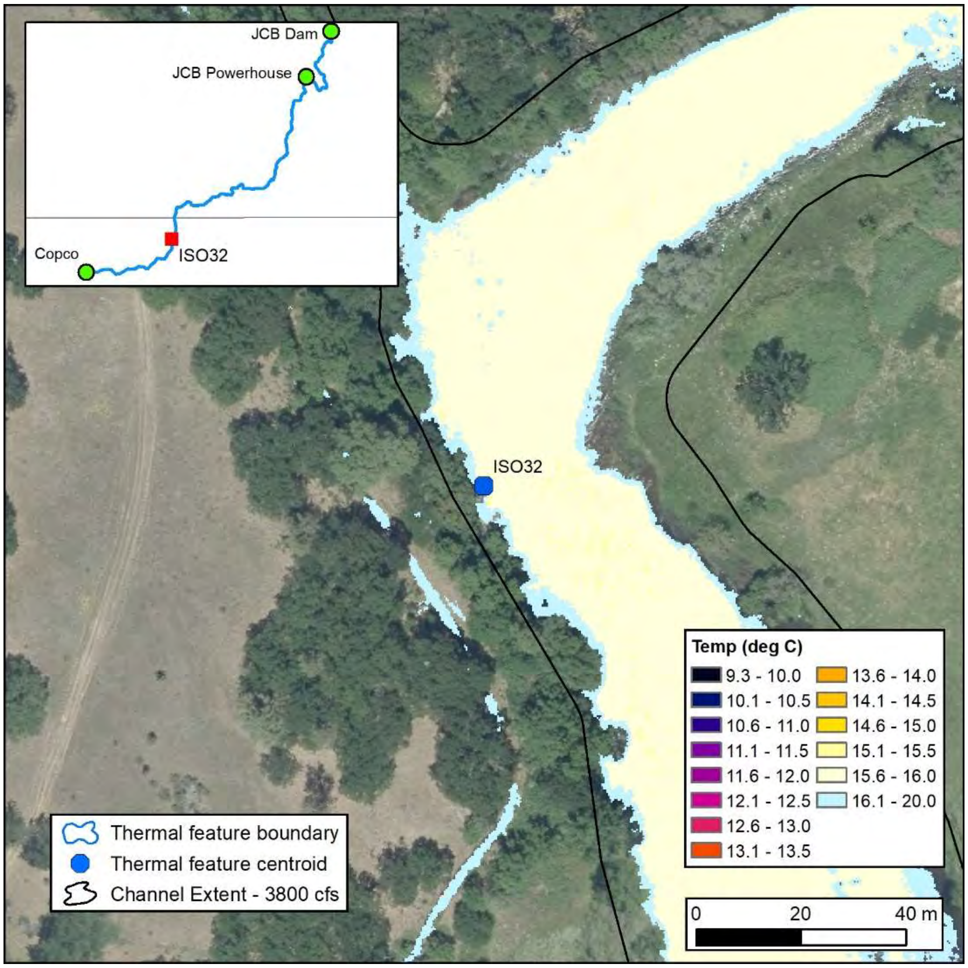
Habitat Characteristics / Quality: Likely good resting and holding conditions for migrating adult salmonids under existing conditions.

Restoration / Enhancement Potential: Low potential for cover enhancement due existing depths and velocities, and access constraints.

Existing Condition: Isolate 32 is located along the river-right bank where the tailout of a rapid on a left-turning bend meets a steep impinging hillslope. Velocities are likely 4-6 ft/s and depths are potentially greater than 6 ft in the feature during normal daily peak flows. Substrate is likely composed of boulders given that the steep bank is composed of hillslope material. An irrigation canal is located on the hillslope approximately 25 ft above river level. Relatively thick riparian vegetation on the steep bank between the irrigation canal and channel margin may provide overhead cover of the feature.

Access to the bank above the feature is via an unimproved access road on private property on river right and then along the narrow irrigation canal, which is in seasonal use. Land-based equipment would be able to place objects within the cold-water extent, and there are trees to serve stable features into which additional woody cover could be tied. However, given the steep bank and presence of high velocities during high flows, it’s not anticipated that any placed objects would remain stable other than the placement of boulders.

Preliminary Proposed Enhancement Activities: None.



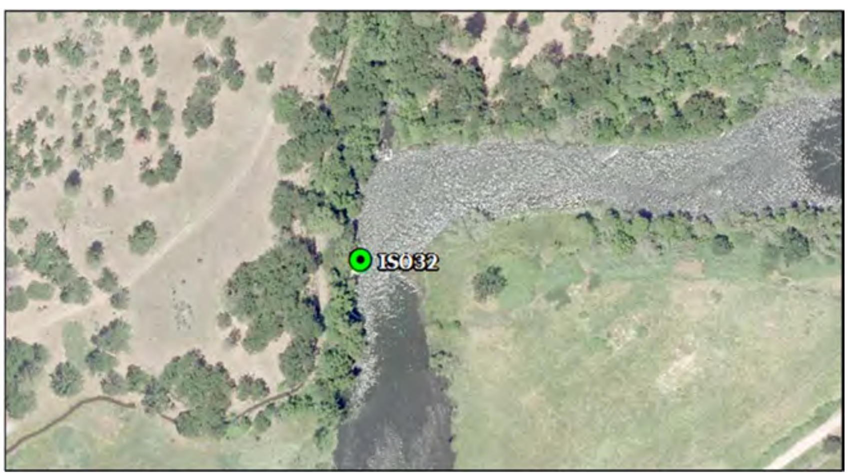


Figure F-5. Above: Thermal infrared imagery in the vicinity of Isolate 32. Below photo: Aerial view of the vicinity of Isolate 32 near the river-right eddy line in the upper end of a large pool. Aerial imagery date June 11, 2018.

Isolate 34 (ISO34)

Feature: Hydraulic upwelling

Location: River-right ~0.8 miles upstream of Shovel Creek confluence

Centroid: 41.981411, -122.194443

Ownership: PacifiCorp

Priority: Low

Recon Type: Remote sensing only

Habitat Characteristics / Quality: Likely good resting and holding conditions for migrating adult salmonids under existing conditions.

Restoration / Enhancement Potential: Low potential for cover enhancement due to existing depths and velocities, and access constraints.

Existing Condition: Isolate 34 is located along the river-right bank where the tailout of a rapid on a left-turning bend meets a steep impinging hillslope. Velocities are likely 4-6 ft/s and depths are potentially greater than 6 ft in the feature during normal daily peak flows. Substrate is likely composed of boulders given that the steep bank is composed of hillslope material. An irrigation canal is located on the hillslope approximately 25 ft above river level. Relatively thick riparian vegetation on the steep bank between the irrigation canal and channel margin may provide overhead cover of the feature.

Access to the bank above the feature is via an unimproved access road on private property on river right and then along the narrow irrigation canal, which is in seasonal use. Land-based equipment would be able to place objects within the cold-water extent, and there are trees to serve stable features into which additional woody cover could be tied. However, given the presence of high velocities during high flows, it's not anticipated that any placed objects would remain stable other than the placement of boulders.

Preliminary Proposed Enhancement Activities: None.

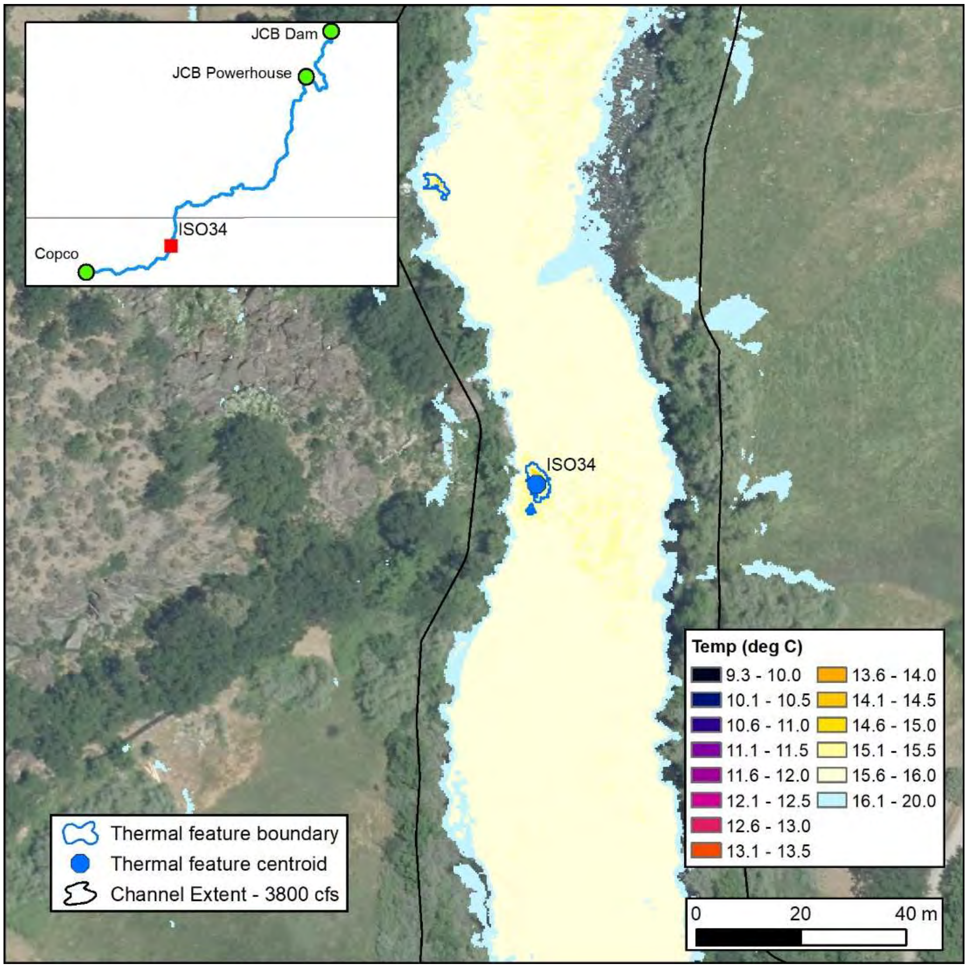


Figure F-6. Above: Thermal infrared imagery in the vicinity of Isolate 34. Below: Aerial view of Isolate 34 and its vicinity near the river-right eddy line, at the upper end of a large pool. Aerial imagery date June 11, 2018.