# LATAH CREEK INSTREAM FLOW STUDY: FINAL REPORT

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APPENDICES

# ACKNOWLEDGEMENTS

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## LIST OF ACRONYMS

| | |
|---|---|
| cfs | cubic feet per second |
| HSC | Habitat suitability criteria |
| HSI | Habitat suitability index |
| IFG-4 | A hydraulic simulation model developed by the Instream Flow Group |
| IFIM | Instream Flow Incremental Methodology |
| PHABSIM | Physical Habitat Simulation |
| RHABSIM | Riverine Habitat Simulation (a version of PHABSIM developed by TR Payne) |
| RM | River mile; distance from the mouth to a given site |
| SCCD | Spokane County Conservation District |
| SNTEMP | Stream Network Temperature model |
| USGS | United States Geological Survey |
| WDF | Washington Department of Fisheries |
| WDFW | Washington Department of Fisheries and Wildlife |
| WDG | Washington Department of Game |
| WDOE | Washington Department of Ecology |
| WUA | Weighted Usable Area (index of fish habitat) |

## EXECUTIVE SUMMARY

Habitat conditions in Latah Creek and its tributaries were studied using PHABSIM, SNTEMP, and hydrological investigations. PHABSIM studies indicated that rainbow trout physical habitat conditions were low at flows below 15-20 cfs. At these low flow levels, the rate of change in WUA for adult rainbow trout was 5% or more per 1 cfs change in flow. In general, WUA values for suckers and minnows were higher than those for trout, particularly at low flows.

Based on WUA vs. flow, and the low-flow season hydrograph, flow recommendations were developed for three levels of resource protection. Optimal flows, providing 80% of maximum WUA, were 50 cfs below Marshall Creek and 26 cfs above Marshall Creek. Minimum flows, at which 1 cfs changed WUA by 5% or more, were 15 cfs below and above Marshall Creek. Critical flows, at which 1 cfs changed WUA by 10% or more, were 6 cfs and 7 cfs below and above Marshall Creek, respectively.

Recommended flows developed in this study apply to the low-flow period. The minimum and critical levels indicate flows below which physical habitat for salmonids is greatly reduced. Recommendations for overall ecosystem health would need to consider flows during other times of the year, and for other purposes.

Temperature, as measured directly and as modeled by SNTEMP, appears to be a limiting factor for salmonids in most of Latah Creek. Additional flow, if it could be provided, would provide only limited temperature reductions under present-day conditions, due to lack of shade over much of the reach. When existing shade conditions (approximately 20% shade) were increased in the simulation to 70% shade, a significant decrease (1-2 C) in water temperature over most of the reach resulted.

Limited storage capacity in the Washington portion of the watershed, and low rainfall indicate that the current condition of low summer flows is difficult to improve significantly. Low flows and high summer air temperatures also make it difficult to bring high stream temperatures within State guidelines for salmonid-bearing streams. Restoration within the study area is unlikely to make the entire Washington portion of the mainstem suitable for salmonids year-round. However, the PHABSIM study indicates that even small additions to flow during the summer period would result in large WUA increases. The SNTEMP study indicates that shade restoration could significantly increase the length of stream usable by salmonids compared to present conditions. Improving both conditions simultaneously would provide the greatest benefits. Further flow and temperature improvements might be possible with restoration in the tributaries and in the upper (Idaho) basin.

# I. INTRODUCTION

## A. Geographic setting

Latah Creek (Hangman Creek), a major tributary of the Spokane River, originates in Benewah and Kootenai Counties, Idaho and flows NW into Washington, crossing the border near the town of Tekoa. From the Washington border to the confluence with the Spokane River is approximately 58 river miles. Significant tributaries are Little Hangman Creek, Rattler's Run, Rock Creek, California Creek, and Marshall Creek (Figure 1).

Latah Creek drains a land area of approximately 689 square miles south of Spokane, Washington, and is a significant tributary to the Spokane River, eventually discharging to the Columbia River. The Latah Creek watershed area lies within the Columbia Plateau, which is characterized by narrow, east-west trending ridges, separated by broad basins. The land surface is roughly parallel to the dip of the numerous basalt flows of the Plateau. Regional drainage is strongly influenced by a series of erosional features, resulting in the topography characterized as 'scablands', formed during the Pleistocene Missoula Floods. Other than that portion of the Creek that enters urban Spokane, the drainage area land use is generally rural.

The historic Latah Creek uplands have been characterized as heavily forested while the lower canyons contained scattered stands of pine with bunchgrass understory. Riparian vegetation was composed of cottonwood, aspen, alder and willow communities. Riparian vegetation is sparse over much of the creek today, or is dominated by reed canary grass. Present day upland land cover is about 50% annual crops, 28% woodland, and a variety of other uses (Edelen & Allen 1998).

Within the area of the investigation, Latah Creek flows in a northwest direction and is believed to be following the lineament of structural faults in the Latah Valley (The Latah Fault, Hamilton et al. 2001). The stream channel flows over, and at some locations cuts into, the middle Miocene aged Columbia River Basalt. Topographic uplands are mantled with Holocene and Pleistocene aged loess which forms dune-shaped rolling hills known regionally as Palouse. Holocene alluvium of silt, sand, and gravel is found in stream channels, flood plains, and terraces, and consists of reworked glacial Missoula flood deposits and reworked loess (USDA SCS 1994). The volume of deposited alluvium within Latah Valley is observed to vary considerably along the reach, and will be discussed with more detail for each transect location.

## B. Hydrological conditions

The mean annual flow in Latah Creek (measured near the mouth) is 241 cfs; mean monthly flows range from 14 to 740 cfs (Figure 2). Latah Creek has a flashy hydrograph, with high flows (2000-5000 cfs) in the spring. During the summer, the median flow at the USGS gage is less than 15 cfs (Figure 3).

Flows measured at the USGS gage, near the mouth of Latah Creek, are not representative of conditions over most of its length. This is particularly true of low-flow conditions. Data collected in 2002 by the Spokane County Conservation District (SCCD) at three temporary gages indicate that when flows fall to 8-10 cfs at the gage, they are as low as 1-2 cfs above the confluence of Rock and California Creeks (Figure 4).

## C. Fishery

Historically, Latah Creek supported salmon and steelhead runs in the mainstem all the way to the headwaters. Anadromous fish were blocked by the construction of Little Falls Dam in 1910. Resident trout still occur in Latah Creek, but the numbers and distribution are sparse (Edelen & Allen 1998). Low summer flows and high temperatures are thought to be the main limiting factors to salmonid populations today. At present, the Latah Creek fishery is dominated by minnows (Cyprinidae) and suckers (Catostomidae). Based on recent collections, at least 12 species occur in Latah Creek (Edelen and Allen 1998; Laumeyer and Maughan 1973, 1974); 3 of these are introduced (Table 1).

## D. Study goals

In the 1990's the SCCD initiated studies on Latah Creek to quantify current conditions and identify opportunities for restoration (SCCD 1994; Edelen & Allen 1998). To further these goals, SCCD hired Hardin-Davis Inc. in 2002 to carry out an instream flow study for Latah Creek, from the Idaho border to its confluence with the Spokane River.

The objectives of this study were to:

1. Review the existing information on hydrology and assess the opportunities for increasing base flow

2. Use the Physical Habitat Simulation model (PHABSIM) to determine the relationship between discharge and fish habitat; recommend optimum flow levels for fisheries

3. Model water temperatures in the creek under current conditions, and estimate effects of potential improvements in shade and streamflow

4. Estimate the effects of improved flows and temperatures on other water quality parameters

5. Recommend optimum flow levels for recreation.

## E. Instream flow assessment

Many methods have been developed to quantify instream flows for fisheries and other needs. Among those in wide use in the state of Washington are the Tennant method, toe width, and IFIM; the latter two are commonly used by the state in making flow recommendations.

Tennant: The Tennant method is one of the simplest and most widely used. Briefly, flow recommendations follow directly from average flow data from a USGS gage. The recommendations can be summarized (Tennant 1976) as:

| Flow | Fishery condition |
|---|---|
| 10% of average flow | minimum, short-term survival |
| 30% of average flow | satisfactory fish habitat |
| 60% of average flow | excellent to outstanding habitat |

The Tennant method has value for making first-cut recommendations and for generating results when time and budget are lacking or non-existent. A major drawback to generalized application of the method is that two streams with very different natural hydrographs can have identical mean annual flows. For example, a spring-fed stream can have a near-constant flow all year, while a desert stream may be nearly dry much of the time, with occasional flood flows. The Tennant method would recommend a flow far below natural low flows in the first case, and far above natural low flows in the second case.

<u>Toe width</u>: The toe-width method was developed by the Washington Department of Fisheries (WDF), Washington Department of Game (WDG), and the U.S. Geological Service (USGS) in the 1970s. The toe-width is the distance across the channel measured from the toe (location where bank angle and substrate change from terrestrial to aquatic) of one streambank to the toe of the other streambank . This width of the stream is used in a power function equation to derive the flow needed for spawning and rearing salmon and steelhead (Swift 1976 and 1979). Washington Dept. of Fish and Wildlife (WDFW) and Washington Dept. of Ecology (WDOE) also use the criteria for rearing steelhead to estimate flow needs for resident trout.

<u>IFIM</u>: The Instream Flow Incremental Methodology (Stalnaker et al. 1994; Bovee 1982) refers to a group of methods for studying the incremental effects of flows on microhabitat, water quality, sediment transport, and other parameters. The most widely used part of IFIM is the Physical Habitat Simulation (PHABSIM).

The basic premises of PHABSIM are that numbers of fish are positively correlated with the amount of physical habitat; that physical habitat is related to discharge; and that physical habitat can be quantified in terms of depth, velocity, substrate, and cover. The four principal components of PHABSIM are field measurements, a hydraulic model, habitat suitability criteria, and a habitat model.

Field measurements are used to quantify the matrix of depth, velocity, substrate, and cover combinations that occurs along representative transects at a particular flow. A hydraulic model is then used to simulate this matrix over a range of flows. Habitat suitability criteria (HSC) describe the value to a species of any combination of physical variables. A habitat model combines HSC with output from the hydraulic model to generate an index of habitat value, termed Weighted Usable Area (WUA), as a function of flow. Thus, for any given flow, PHABSIM sums all the usable habitat. When the model is used over a range of flows, it generates a WUA vs. flow curve. This curve is used as a basis for making flow recommendations.

Because of its adaptability and general acceptance by resource agencies, the PHABSIM model was selected as the primary tool for assessing flows in Latah Creek. The Tennant and toe-width models were also used in order to compare results.

The PHABSIM study of Latah Creek followed procedures outlined by the Instream Flow Group (Bovee 1982). It also complied with guidelines established by the State of Washington (WDFW and WDOE 2000). The PHABSIM study consisted of the following steps.

- Mapping and transect selection
- Model selection
- Field data collection
- Computer simulation of hydraulics
- Development of habitat suitability criteria (HSC)
- Determination of weighted usable area (WUA) as a function of flow
- Interpretation of WUA results, and recommended flows

The habitat quantified by PHABSIM does not include temperature or other water quality parameters. SNTEMP, a stream temperature model developed for relating downstream temperatures to changes in flow and shade, is often applied concurrently with PHABSIM to evaluate the combined habitat value of physical space and temperature (Bovee 1982; Bartholow 1989).

## II. METHODS

### A. Hydrological investigations

1. Field evaluations:

The objective of the hydrogeologic portion of the study was to evaluate subsurface soils and geology, topography, and correlation of the geomorphic setting for an initial assessment of the interrelationship between the surface and ground water along the stream reach. The field component of this study was accomplished by a hydrogeologic evaluation the week of September 3, 2002, during low-flow conditions. The investigation included the installation of temporary miniature piezometers, limited streambed hydraulic conductivity testing, and data evaluation. The piezometers facilitated the mapping of key segments of Latah Creek that exhibited influent and effluent conditions, and characterization of those portions of the effluent stream that are sensitive to subsurface perched or ground water conditions. Hydraulic conductivity of bed sediment was evaluated in order to determine the relationship between stream flow and groundwater.

The method of miniature piezometer construction and installation is described by Lee and Cherry (1978), and has been employed successfully to investigate the hydrologic interactions between ground water and surface water. Five sites in the watershed were evaluated: three in mainstem Latah Creek, and one each in Rock Creek and California Creek. The cross section locations were selected for accessibility, stream bed characteristics, and representativeness of the stream profile, and correspond with the five PHABSIM sites.

The piezometers were installed along each cross section. Static ground water potentiometric elevations in relation to the stream level were determined for each piezometer. Difference in hydraulic head was measured for 15 piezometers at five cross section locations. Small differences in hydraulic head relative to the surface water were measured using a manometer. Static water levels were measured before and after piezometer surging and development and in many piezometers the ground water hydraulic head was measurably different from the free-flowing stream surface.

To measure the hydraulic conductivity of the sediment adjacent to the piezometer screen, a falling head test was conducted for a number of installations. The equations and method used to calculate the hydraulic conductivity (K) of aquifer material were first developed by Hvorslev (1951) for the U.S. Army Corps of Engineers. The equation used in this application is based on field data generated from falling head tests and is a simple method of obtaining order-of-magnitude estimates of hydraulic conductivity. The method consists of measuring the rate at which the elevation within the piezometer falls after being drawn upward by suction. With K values greater than approximately 3 ft/day (such as in coarse sands and gravels), the rate at which the water level falls within the piezometer is too rapid to measure.

The method assumes a screened piezometer of length L in an unconfined aquifer material. The equation is:

$$K = r^2 / 2L(t_2 - t_1)\, ln\, (L/R)\, ln\, (S_1/S_2)$$

Where: $r$ = radius of screen intake (0.125 in.)
$R$ = internal radius of piezometer (0.125 in.)
$t_1$ = initial time (seconds)
$t_2$ = elapsed time (seconds)
$S_1$, $S_2$ = drawdown within piezometer, at time $t_1$ and $t_2$
*ln* = natural log

For this method to be valid, the piezometer must be constructed so that the screen does not inhibit ground water flow; a clogged screen or silting of the piezometer would generate erroneous data. Piezometers installed in coarse sands or within gravels would not be capable of measuring hydraulic conductivities greater than approximately 3 ft/day.

### 2. Basin geology and geomorphology review:

Reports on the geology, hydrology, and geomorphology of the Latah basin in Washington were reviewed in order to determine hydrologic conditions and the potential for greater basin storage.

### 3. Hydrograph interpretation:

Streamflow data from the USGS gauge near the mouth were evaluated in order to determine long-term trends. The annual 3,7, and 30-day minima and maxima were plotted, as well as annual mean flow for the period of record (1948-present).

## B. Physical habitat assessment (PHABSIM)

### 1. Habitat mapping

Measurements made at a study site must be put into the context of the entire reach being studied. Habitat was mapped in the vicinity of each of our study sites in order to quantify the percentages of habitat units (mesohabitats) near the site, and to have an estimate of the percentages in the entire study area.

The study area was subdivided into five reaches for the PHABSIM study. These five reaches - Denny (RM35.4), Keevy (RM29.2), Paintball (RM2.5), Rock Creek, and California Creek - are shown in Figure 1. Within each reach, a two-person crew walked a length of stream (0.5 to 2.5 miles) in July 2002, making measurements at each habitat unit; habitat units were classified following definitions in W.T. Helm (1985). (Table 2). Percentages of each habitat type within the reach were calculated, and these percentages were used to weight the PHABSIM transect measurements. Habitat mapping results are included in Appendix 1.

Toe width measurements were taken at appropriate sites (generally pool tail-outs) during the habitat mapping. The Hardin-Davis crew collected 22 toe width measurements near the five PHABSIM sites.

2. Site selection

Due to time and budget limitations, the entire study area could not be mapped. The study team relied on local expertise, topographic maps, and two days of field reconnaissance to select study sites. The sites were meant to be typical of the watershed in terms of riparian conditions, gradient, and fish habitat. Three study sites( RM35.4, RM29.2, RM2.5) were selected in mainstem Latah Creek, and two in the tributaries (Rock Creek and California Creek). At each site, 6-7 transects were placed across different habitat types. Site locations and characteristics are listed in Table 3.

3. Collection of flow data

Field measurements were made at each of the five study sites in May, June, and September 2002 (Table 4). During the week of May 20, 2002, water surface and velocity measurements were taken at every transect. At the middle and low flows, water surface elevations were re-surveyed, and discharge was measured at one or two transects per site. Substrate and cover data based on WDFW (2000) guidelines, were collected during the lowest flow (Table 5). The highest flows, 42 to 85cfs in the mainstem, 6-35 cfs in the tributaries) were measured in May. Lowest flows (1 to 7 cfs in the mainstem, 0.2-0.7 in the tributaries) were measured in September. (Note: "high flow" in this study refers to the upper end of the low-flow period, and not to higher flows that occur in Latah Creek in the spring).

4. Computer Simulation of Hydraulics

Immediately after the field measurements, data were entered into a format for the hydraulic simulation program known as IFG-4 (Bovee 1982). Various error-checks were carried out with programs in the RHABSIM (Riverine Habitat Simulation) model. Discharge was calculated for each set of measured velocities, and compared to the known discharge for the field date. Stage-discharge relationships at each transect were examined for abnormalities. Simulated and measured velocities were compared at the observed discharges; simulated velocities were also examined at the upper and lower bounds of extrapolation to make sure the predicted values were reasonable. Once the error checking was complete, the IFG-4 program was used to generate hydraulic data for the flow range of interest. Based on the performance of the IFG4 model at the measured flows, a range of flows was determined that could be modeled for each site (Table 6).

WDFW and WDOE(2000) maintains a list of data for evaluation of the accuracy of instream flow data modeling studies. This includes information on water surface elevations at all measured flows, accuracy of velocity prediction, and other information listed below. Based on these guidelines, the following information was supplied to WDFW and WDOE in April 2003:

- Input file including bed elevations, water surface elevations, velocities, substrate/ cover, and calibration discharges for IFG-4;

- Table for each transect of "calibration details" with simulated velocities paired with corresponding measured velocities for each calibration flow;

- Table of velocity adjustment factors (VAF) for each transect and each simulated flow over the proposed range of the model;

- Table of stage differences between flows and between transects.

### 5. Habitat suitability criteria (HSC) development

HSC data were developed from literature sources. Data were available for four of the species potentially found in Latah Creek. For a fifth, largescale sucker, data on the closely-related white sucker and Sacramento sucker were used. HSC curves were created for summer habitat conditions for adult and juvenile life stages of these five species, based on the literature. These candidate curves were approved by WDFW. Separate HSC were developed for rainbow trout in California Creek. Since it is a much smaller channel than Latah or Rock Creek, depth and velocity criteria were revised based on literature data from smaller streams. A list of the HSC, and the sources used, is in Table 7. Final HSC curves are in Appendix 2.

## C. Temperature modeling

### 1. SNTEMP

The Stream Network Temperature Model (SNTEMP) is a steady-state model that incorporates all of the significant sources of heat gain and loss in a moving stream (Theurer et al. 1984; Bartholow 1989). It was specifically designed to evaluate the downstream temperature impacts of changes in flow regime, but it can also be used to evaluate changes in shade.

SNTEMP is a DOS-based model that uses a group of interrelated input files, containing data on stream geometry, shade, discharge, and meteorology (Table 8). At each location in the stream network (Figure 5), SNTEMP predicts average water temperature for each time period of interest. For Latah Creek, a weekly time step, which was most appropriate based on the estimated travel time, was used.

The study length for SNTEMP modeling was from Hays Road to the mouth, a total of 35.4 river miles (RM). Flows in SNTEMP needed to be supplied at each location in the network. These flows were estimated based on the USGS gage (mouth of Latah Creek) and SCCD gages at Bradshaw Rd. (RM32.9), Duncan (RM18.7), and Rock Creek. Data from the 2001-2 seepage runs (SCCD 2002) were also incorporated. Table 9 lists the site-by-site flow estimates, and the underlying data and assumptions.

Approximately 20 inputs are required in the SNTEMP model. Sources of data include field measurements, published data, and default values (Table 10). Default values were applied only for variables that generally have a negligible effect on model predictions (Bartholow 1989). The variables that generally exert the greatest influence on predicted water temperatures are beginning water temperature, discharge, air temperature, shade, and relative humidity. Stream width can also be important in some cases.

In order to calibrate the model, simulated vs. measured weekly average stream temperatures were compared at 11 locations (Table 11). Minor adjustments were made to the wind speed to improve the agreement between modeled and measured water temperatures.

Once calibrated, the SNTEMP results represented existing conditions. Three other scenarios were then compared to existing conditions, in order to estimate the potential benefits from different management options. It is important to note that the scenarios incorporate simplifying assumptions, and do not represent actual proposed alternatives. Instead, they were created to evaluate the relative potential of changes in shade and streamflow. The three scenarios were

Increased shade: The shade values at each site were increased to simulate 70% of the streambanks being lined with trees, compared to current conditions of about 20%. Natural shading conditions were not known; this simulation was intended to approximate restored conditions.

Increased flow: It was assumed for the purpose of the study that increased flow could take two general forms: surface water and ground water. Simulated additions were 1, 2, and 3 cfs. The additional inflow was simulated by increasing the flow at the top of the SNTEMP site (Hays Rd, RM35.5).

For surface water addition, the temperature of this added water was set to be the same as that of the flow already existing at the site (ambient water temperature). Additional groundwater, if it could be provided, would enter Latah Creek at more than one location. However, for the purposes of the simulation, the additional water was also treated as though it all entered at Hays Rd. Simulated additions were 1,2, and 3 cfs. The temperature of the inflow water was assumed to be 5C below ambient. Therefore, depending on the relative quantities, the resulting instream temperature at the Hays Road site was reduced by 0.25 to 3.5 C.

Increased shade plus flow: In this scenario, increased shade and increased flow were combined into the same simulations.

## D. Other water quality

Other water quality parameters were reviewed, based on WDOE measurements. Parameters on the 303d list included temperature, as well as coliform bacteria, dissolved oxygen, and pH. The number of water quality exceedances for the latter three parameters were tabulated.

## E. Recreation

In order to ascertain the recreational use of Latah Creek, local boaters and the Latah Creek Streamkeeper were consulted, and additional observations were made during habitat mapping and IFIM investigations. Hardin-Davis staff did not float the creek due to insufficient flows throughout the field season.

# III. RESULTS

## A. Hydrology

### 1. Streamflow/groundwater interaction

Figure 6 illustrates the hydrologic setting of Latah Creek. As the creek cut down into the basalt bedrock, sediments were deposited within the flood plain, with the grain size of the sediments a function of source material and stream velocity. The Holocene-aged alluvium consists of silt, sand, and gravel of reworked glacial Missoula flood deposits and reworked loess (USDA SCS 1994). The volume of deposited alluvium within Latah Valley varies considerably along the reach, and is contained within the bedrock and bounded on each side by bedrock. The Holocene alluvial aquifer material stores ground water, and is recharged during periods of high flow. Within the Holocene aquifer, groundwater flow direction is generally in the same direction as stream flow; however, the stream meanders across the aquifer with the direction of stream flow at times nearly perpendicular to groundwater flow. Ground water sustains the base flow within the stream, and as ground water elevations drop, the base flow is reduced and may diminish to no observable flow within the stream channel. In this setting, at conditions of low flow, ground water may enter and exit the stream, exhibiting both influent and effluent conditions within the same reach. The installation of miniature piezometers allowed for the measurement of influent/effluent conditions at several locations along the main channel and tributaries.

Of the twenty-nine miniature piezometers installed in the main channel and two tributaries, fifteen produced reliable data. Rocky streambed conditions prohibited data collection from the other installation locations. Flow at the USGS gauging station averaged 9 cfs for the 3-day period of investigations. Site names and transect numbers are taken from the PHABSIM study.

As Latah Creek meandered across the incised channel, the cross section topography typically consisted of a steep bank on one side and an alluvial plane on the opposite side. The ground water – surface water relationship in this setting typically consists of ground water discharge to the stream along the steep bank, and influent stream conditions on the opposite, lower elevation bank. This result is consistent with the longitudinal variability in base flow found by SCCD. This type of surface water – ground water interrelationship is typical for streams in low-flow conditions, where the aquifer is in balance with the stream discharge. Overall, the stream would not exhibit consistent influent conditions unless the surface water elevation remained above the water table, and this is likely only under high flow or flooding conditions. Due to the limited areal extent and thickness of the aquifer, the stream would not exhibit consistent effluent conditions because the major source of recharge to the Holocene aquifer is the stream.

RM 35.4 SITE, TRANSECT 7: After alternative piezometer installation procedures and materials were tested and the field procedure was refined, measurements were recorded, as shown on Table 12. The creek at this transect location was approximately 40 feet wide and 0.5 to 1.3 feet in depth. The streambed material varied from silts and gravels to large cobbles, and land surface topography varied from a steep bank that rose to hills and ridges to the west and low, relatively level alluvial plain to the east. Flow at this site on September 3 was 1.1 cfs.

The static water level in the piezometers varied across the section, with effluent conditions observed adjacent to the steep bank (ground water recharging the stream) and influent conditions (stream water draining to ground water) observed over most of the stream (Figure 7). Falling head hydraulic conductivity testing was attempted and is discussed below.

RM 29.2 SITE, TRANSECT 2: This cross section lies within a canyon eroded into the basaltic bedrock. Streambed materials consisted of bedrock, boulders, sand, gravel, and cobbles; the bed was approximately 32 feet wide. Water depth varied between 0.7 – 1.0 ft. Piezometer installation was difficult and after several attempts, only two measurements were made. Ground water discharges to the stream along this reach, maintaining baseflow. Flow at this site on September 3 was 0.9 cfs.

Falling head hydraulic conductivity testing failed (rate of fall too fast to measure) suggesting the hydraulic conductivity is greater than 3 feet/day.

ROCK CREEK SITE, TRANSECT 4: The topographic setting of this cross section is similar to that at the RM35.4 site: the stream channel is adjacent to a steep bank (north) and a low-lying alluvial plain exists along the opposite bank (south). Rock Creek is a tributary to Latah Creek, and is approximately 30 feet wide at this location. Stream depth ranged from 0.4 to 1.2 ft. at the piezometer testing locations. Flow at this site on September 4 was 0.7 cfs.

The stream exhibited effluent conditions adjacent to the north bank, and influent conditions to the south. Although the stream bed consisted of more sands and finer grain materials than the rocky channels encountered at the two upper cross sections, falling head rates were too rapid to obtain measured results.

CALIFORNIA CREEK SITE, TRANSECT 4: At the California Creek site, streambed sediments were coarse-grained sands and the stream channel was approximately ten feet wide, with water depth 0.2 to 0.4 ft. Piezometer installation was difficult; piezometers equilibrated quickly, suggesting a highly transmissive hydraulic conductivity. Flow at this site on September 4 2002 was 0.2 cfs.

Both piezometer measurements indicated influent conditions, meaning surface water was discharging to ground water along this reach.

~~3.1~~RM 2.5 SITE, TRANSECT 2:

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The coarse sands within the stream channel of this cross section resulted in difficulties in measuring falling heads, again suggesting relatively high hydraulic conductivity. The three successful piezometer installations all exhibited effluent stream conditions, with ground water discharging to and maintaining base flow. The channel was approximately 42 feet wide and the depth of water ranged from 1.0 to 1.9 ft. Flow at this site on September 5, 2002 was 7.4 cfs.

## ~~3.6~~2. Hydraulic Conductivity Testing

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Falling head tests were attempted at four of the five stream sections – in all tests the rate of piezometer drawdown was equivalent to or more rapid than aquifer materials exhibiting a K value of 3 feet/day—highly transmissive streambed sediments. Observations of stream bed conditions along the transects were consistent with these findings; coarse sands and gravels were noted at each transect. This suggests close communication between the stream and ground water -- there are no significant deposits of fine-grained sediment to retard flow or to perch stream flow above the water table.

## 3. Basin geology and geomorphology review

Reviews of the geology of the watershed (Hamilton et al. 2001, USDA 1994) indicate a lack of available aquifer storage. Alluvial sediments have been deposited within the main channel of the creek and tributaries, but the areal extent and storage volume of these sediments is limited. The majority of the watershed's drainage network is incised into basalt bedrock, with ground water storage capacity limited to fractures and cracks within the massive rock. Loess soils are deposited along the bedrock highlands, but within the lower Latah watershed these areas of potential aquifer storage are typically perched above the incised stream channel. The storage capacity of perched seepage and bank storage along the basalt canyons contributes little to the stream baseflow of the watershed.

### 4. Hydrograph interpretation

The record over this period indicates two trends: increasing seasonal flow variability, and a gradually decreasing mean flow. Mean annual discharge at the USGS gage show a slight (statistically-insignificant) downward trend over the 1948-to-present period of record (Figure 8). The average from 1949-1974 was 257 cfs, vs. 213 cfs from 1975 to present. The high flows (3,7, and 30 day maxima) were also lower in the 1975-2001 period. Low flows (3, 7, and 30 day annual minima) showed a slight downward trend, and higher variability, in the 1975-2001 period.

### 5. Precipitation/streamflow relationship

Figure 9 presents the stream flow data recorded for the Latah Watershed at the USGS gauging station located near the mouth of the creek. The Latah Creek watershed responds rapidly to rainfall, draining and discharging the precipitation as it is collected by the tributaries and main channel of the creek.

Both Figures 8 and 9 are important to understanding the nature of flow in Latah Creek. The flow is 'flashy', responding quickly to rainfall with little opportunity to be stored in the Holocene aquifer. This lack of storage opportunity is due to the physical dimensions of the alluvial channel and shallow depth to bedrock. This setting is typical of a young stream incised into bedrock. As the stream ages (over geologic time) the physical volume of the aquifer will increase with more deepening of the incised channel and deposition of alluvial material.

Since the geomorphologic setting of Latah Creek is that of a young, flashy stream, the relationship between rainfall and stream flow is likely to have been historically consistent. Periods of higher flows would be associated with above-average precipitation. However, historical records do not show any clear trend in annual precipitation.

## B. Physical Habitat

### 1. Hydraulic simulations:

Average discharge for each site, at each flow level, is listed in Table 6. Water surface elevations and velocities simulated by IFG4 showed good agreement with measured values. There were no significant problems with the hydraulic model at any of the sites. Very few calibration adjustments were needed, since the models were not extrapolated much beyond measured flows (Table 6).

2. Habitat

WUA was calculated for 5 species, and for 1-2 life stages per species for each site, for the range of flows determined above. All WUA values are reported in Appendix 3. For the purpose of illustrating habitat responses to flow, three species (one life stage each) were selected from the array available. These three WUA curves together represent most of the physical habitat types available in Latah Creek.

-Rainbow trout adults were selected because they are a species of primary interest; their WUA curve represents primarily moderate-to-deep water, with moderate-to-high velocity.

- Largescale sucker adult WUA represents deep, slow water.

-Speckled dace adult WUA represents shallow water with low-to-moderate velocity.

RM35.4 site: Rainbow trout adult WUA increased with discharge over the 1-40 cfs range modeled; the rate of increase appeared to taper off at the upper end of the range. Largescale sucker and WUA increased, but leveled off after about 20 cfs. Speckled dace WUA decreased at flows above 5 cfs (Figure 10).

Increasing flow generates more WUA for trout at this site, because depth is not limiting, and moderate to high velocities are more prevalent at higher flow. Largescale sucker WUA increases, then levels off; this is because greater depths initially increase WUA , but velocities increase at higher discharge, reducing WUA. Speckled dace habitat decreases above 5 cfs, indicating shallow water of low-moderate velocity is less available at higher flows. Overall, WUA values are higher for sucker vs. trout (Figure 10); this is because about half the site is dominated by fine substrates.

RM29.2 site: Rainbow trout adult WUA increased with discharge over the 1-40 cfs range modeled, and appeared to be increasing sharply at flows beyond 40 cfs . Largescale sucker WUA increased up to 40 cfs, where the WUA increase appeared to be leveling off. Speckled dace WUA increased at low flows, and leveled off at 10-15 cfs. (Figure 11).

In this site, the trout WUA curve is very steep, increasing over the modeled flow range and likely beyond. This site is dominated by boulder cover; as flow comes up, velocities remain in the optimum range for salmonids, rather than surpassing the range as in a channel with no cover. Speckled dace WUA remains high compared to other species (Figure 11) probably because edge habitats with shallow depths are available over a wide range of flows.

RM2.5 site: Rainbow trout adult WUA showed the same general relationship as at the RM29.2 site, increasing with discharge over the 1-40 cfs range modeled. Largescale sucker WUA increased up to about 25 cfs, then began to level off. Speckled dace WUA leveled off at about 10 cfs (Figure 12).

This site is low-gradient, with instream cover. For this reason, the WUA curves for trout is steep. Increasing flow brings more habitat into the optimum depth range, and velocities do not increase too rapidly at higher flows. Largescale sucker WUA is higher overall than other species; this is probably due to the presence of a large pool and fine substrates, both of which favor suckers over trout.

Rock Creek: The WUA results here were very similar to those at the RM2.5 site. The general similarities of the sites are in width, low gradient, and the presence of a large pool. Rainbow trout WUA increased with flow up to and beyond 40 cfs. Largescale sucker adult WUA peaked at around 20 cfs. Speckled dace WUA increased up to 15 cfs then leveled off (Figure 13). Speckled dace WUA is relatively high at all flows; this is due to the fact that in this wide site, edge habitat with shallow depths is available over a range of flows.

California Creek: WUA increased over the range 1-10 cfs for small-stream rainbow trout, with the rate of increase leveling off at 8 to 9 cfs. For largescale sucker, the peak occurred at 4 cfs. For speckled dace adults, the WUA curve was flat, with the maximum occurring at 3-4 cfs (Figure 14).

All sites: Overall, the WUA results indicate that habitat at low flows is better for catostomids and cyprinids than for salmonids. Low velocities are the primary reason, though fine substrates also contribute. At higher flows, WUA for catostomids and cyprinids decreases, while trout WUA continues to increase.

### 3. Toe width flow calculations

Toe width measurements were averaged near each of the five PHABSIM sites. The average toe width measurement was then used with the power function developed for rearing steelhead, with the assumption that this would produce a reasonable estimate for resident trout (B. Caldwell, WDOE, personal communication). The resulting flow recommendations varied from 9 to 25 cfs on the mainstem; recommendations were 4.8 cfs in California Creek and 14.1 cfs in Rock Creek (Table 13) .

## C. Temperature (SNTEMP)

### 1. Calibration

Only minor adjustments were needed in the SNTEMP model to match measured temperatures. The wind speed parameter in SNTEMP is the primary calibration tool. When the weekly average wind speed input values were varied from 4 to 16 miles per hour (Table 14), the modeled temperatures showed good agreement with measured temperatures during most weeks, and at most sites. Figures 15-18 show the prediction errors longitudinally for weeks 24, 28, 32, and 36. Table 15 summarizes the errors at all sites and weeks; the median absolute error was 0.56 C, and 79% of the errors were less than 1C. Root mean squared errors were under 1C for most weeks and sites. Given this level of agreement, no further calibration adjustments were made.

Weeks 27 and 33 had the poorest agreement; simulated temperatures were too high by an average of 1.5C in week 27, and too low by 0.75 C in week 33. These results could have been due to discrepancies between conditions at the meteorological station (Spokane Airport) and local conditions. Among the sites, RM29.2 and Avista Substation Bridge (RM3.6) had the largest errors. SNTEMP overpredicted temperature at RM29.2 by an average of 1.05C; this may have been because the actual topographic shading effect in the canyon was greater than estimated. The model underpredicted by 0.81 at Avista Substation Bridge, probably because groundwater cooling was less than estimated (Table 15).

Weekly average temperatures at all sites (Appendix 4) showed a peak at week 28 (mid-July), and a secondary peak at week 34 (late August). The simulated behavior was consistent with measured values. Longitudinally, the pattern was more complex. Depending on the week, the temperature either increased gradually from RM35.5 to RM8.8, or varied erratically. In either case, water temperature was at or near its longitudinal maximum at RM8.8. Temperature dropped sharply from there to RM3.6; SNTEMP followed the measured data closely over this distance (Figures 15-18).

Maximum temperatures (weekly average maxima) measured by SCCD were 1.0 to 5.2 C greater than weekly averages (Figures 19-22). The greatest differences were in the upstream portion of the reach, where shade and groundwater are minimal (Figure 22). SNTEMP is designed for best results with average, as opposed to maximum temperatures; thus, no comparisons were made between measured and simulated maxima. The effects of scenarios on temperature maxima were not simulated with SNTEMP.

2. Scenarios:
In order to illustrate the results and compare scenarios, figures are included for Weeks 24, 28, 32, and 36. These weeks represent mid June, July, August and September, thus spanning most of the summer low-flow, high-temperature period.

Increased flow: Increased flow at ambient temperature made almost no difference in predicted water temperatures throughout the 35.5 mile SNTEMP study area. With a 3 cfs addition at Hays Road (RM35.5), weekly temperatures were unchanged at individual sites, and also longitudinally . Increased flow with cold water did reduce downstream temperatures, but only between RM35.5 and 29.2. Downstream of RM29.2, the temperatures with 3 cfs of cold inflow were virtually the same as with existing conditions (Figures 23-30).

Restored shade. With restored shade, simulated water temperatures were 1.0 to 1.5 C lower than existing conditions at most sites; this difference decreased in the vicinity of Marshall Creek (RM4.4), where groundwater input is high (Figure 31-34).

Flow plus shade: Increased flows of 1 to 3 cfs at ambient temperature did not add to the effect of shade alone. Addition of cold inflow added to the shade effect only at the upstream end of the SNTEMP study reach (Figures 35-38).

## D. Water quality

Data on coliform bacteria, pH, and dissolved oxygen are displayed in Figures 39 - 41. The numbers of exceedances are shown for two sites- one near the mouth, and the other at RM33.

## E. Recreation

Compared to other creeks in the region, Latah Creek receives limited use by recreational boaters. The predominantly agricultural character of the stream and its surrounding landscape limits its attractiveness to casual boaters. The canyon section between river miles ca25-35 offers attractive scenery, but is generally too steep for casual boaters. Furthermore, flows necessary to float the creek generally exist only in the winter to spring, when the weather and stream temperature and turbidity are typically not conducive to leisurely paddling. Consequently, the greatest boating use of Latah Creek is by whitewater enthusiasts--principally kayakers.

The two sections that are floated most commonly by whitewater paddlers are the canyon section and the lower section . Kayakers usually put in at the monument off North Kentuck Trails Road, and take out at the Valley Chapel Road bridge just downstream from the Rock Creek confluence. The flow range for best kayaking of this reach is approximately 2000 to 5000 cfs at the USGS gauge, although it is considered runnable down to around 500 cfs. The put-in for the lower section is most often the Hatch Road bridge, and the take-out at the Riverside Avenue bridge. The optimal flow range for this reach is approximately 1000 to 2000 cfs, but as in the upper reach is runnable down to around 500 cfs. The highest flow advised for experienced boaters is in the neighborhood of 8000 to 12000 cfs for either run.

The two sections favored by kayakers, as well as other parts of the creek, could conceivably be run at flows lower than 500 cfs in shallow-draft craft such as inflatable rafts and kayaks. However, a trip of any reasonable length at flows below 500 cfs would involve extensive boat-dragging over rocks and other debris.

The average number of days per year that provide flows sufficient for enjoyable whitewater boating is limited, particularly at the higher flows (Table 16). Optimal flows (1000-2000 cfs in the lower section, and 2000-5000 cfs in the canyon section, based on the USGS gauge) occur most frequently from January to April, and are generally of short duration. A flow at the gauging station of 500 cfs is considered to be the lowest runnable flow, and would involve considerable rock-scraping in many of the riffle and cascade sections of the creek. Finally, the warmer months of the year (June-September) have an average of less than 1 day per year where flow is greater than 250 cfs.

In addition to boating, other recreational uses occur on Latah Creek (SCCD personal communication). Fishing occurs on a limited basis in the spring months, and is hindered by high flows and turbidity. Summer fishing for trout is limited by high temperatures. Swimming occurs in the study area in some locations. Large swimming holes are heavily used by local teenagers in summer months. Wading is a frequent use by local residents.

## IV. INTERPRETATION

### A. Hydrology:

While many factors influence the response of a stream to rainfall, the subsurface storage capacity of a basin often exerts the strongest influence. Watersheds with limited subsurface retention cannot absorb large enough volumes of water to provide long-term base flow in the dry season. Surface conditions, such as vegetative cover and land use, have some impact on the rate of overland flow and infiltration, but cannot change the storage capacity of the aquifer.

Latah Creek is incised into bedrock within the study area, and aquifer storage is limited to sediments deposited by the stream within the incised channel. Deeper upland sediments are generally perched and effectively isolated from the stream network. The limited bank storage capacity and volume of connected aquifer storage does not allow for retention of recharge, resulting in a 'flashy' hydrograph response to precipitation. Due to the physical limitations for retention of stream flow within the lower (Washington) portion of the Latah Creek Watershed, little opportunity exists to improve baseflow with alternative land management activities. The hydrologic system is controlled by the physical characteristics of geology and storage capacity.

Artificial retention of high flows and engineered storage facilities would allow for dampening of the peak flood events, however the storage capacity of the underlying aquifer and stream banks would soon reach their physical capacity to store the surplus water. Consequently, a storage project would not add substantially to base flow. However, artificial storage could potentially allow for augmented flows throughout the low-flow season.

Dry-land farming is the predominant land use in the Palouse soils above Latah Creek. If irrigated faming had been predominant, opportunities for water management could have been implemented to enhance stream base flow. The watershed is capable of sustaining dry-land farming, which suggests a hydrologic system in balance. Short of increased precipitation, little opportunity exists within the study area to improve base flow significantly.

The upper reaches of the Latah Watershed (beyond the current study area) exhibit~~s~~ geologic conditions that may indicate the presence of a larger aquifer and greater storage capacity. Additional study of the upstream watershed is recommended. Changes in land management activities within an aquifer with higher storage capacity could result in increased baseflow.

Conclusions generated by this investigation reflect a 'snapshot' of the local ground water flow conditions measured during stream low-flow conditions. Variation in potentiometric head and hydraulic conductivity may be expected depending on seasonal flow, flow velocity, and stream bed sediment characteristics.

## B. PHABSIM

Flow recommendations are not directly generated by PHABSIM, as with the Tennant or toe width methods. Factors that are generally considered in developing flow recommendations from PHABSIM data are: key species and life stages, the raw WUA results, the natural hydrograph, and the percentage change in WUA per unit change in flow.

Rainbow trout adults are the primary life stage of interest, thus the PHABSIM flow recommendations that follow are based on this life stage alone. If the WUA curves are considered by themselves, without reference to the hydrograph, it would appear that the recommended flow for salmonids would be at or above the maximum flow modeled by PHABSIM. In other words, in the absence of other information, this would yield a flow "recommendation" of 40 cfs or more in the study area above Marshall Creek, and over 80 cfs below Marshall Creek.

For management purposes, it is important to know not only the raw WUA values, but the rate of change in WUA per unit of flow. When the PHABSIM results are plotted as the percentage increase in WUA per unit (cfs) of water added, the results show that the effect on habitat of adding of 1 cfs depends greatly on the existing flow level. When flows are low, a high percentage of WUA is gained per 1 cfs addition. Figures 42-44 illustrate this relationship for the 3 mainstem sites; figures 45-46 show the relationship in the two tributary sites.

Recommended flows are given for two different parts of mainstem Latah Creek. The portion below Marshall Creek, where tributary and groundwater inflow significantly increase the late-summer flows, is represented by the RM2.5 (Paintball) site. The portion between the Idaho border and Marshall Creek is represented by the combined results from RM29.2 and RM35.4 (Keevy and Denny) sites. Based on the longitudinal profile, the relative weighting of these two sites was estimated at 0.28/0.72. Figure 47 shows the percentage change in WUA per 1 cfs for these two sites combined.

Flow recommendations are presented for the June to October period. For each time period, three different recommended flow levels are possible:

-Optimum: the flow providing 80% of the maximum WUA
-Minimum: The flow at which the change in WUA per 1 cfs is 5%
-Critical: The flow at which the change in WUA per 1 cfs is 10%

For each recommended flow level (Table 17) , and each time period, the flow exceedance is given. Since flows are significantly higher in June compared to the other four months, exceedance values were calculated separately for June. Flow exceedances at the RM2.5 site were taken directly from the USGS records for 1948 to present. Exceedance values for flows upstream of Marshall Creek were estimated based on SCCD flows measured in 2002 at RM33 (temporary Bradshaw gage). The relationship between average weekly flows at the Bradshaw and USGS gages from June to September, 2002, was approximately:

| Flow at USGS gage | percent of USGS flow at RM33 |
|---|---|
| <12 cfs | 20% |
| 12-40 cfs | 30% |
| >40 cfs | 35% |

The flows presented in Table 17 can be interpreted as follows. In the mainstem upstream of Marshall Creek, when the existing flow is 26 cfs or less, flow withdrawal will adversely affect optimum habitat conditions. Withdrawals will adversely affect minimum and critical habitat conditions, respectively, when existing flows are 15 and 7 cfs. The same interpretation can be placed on flows of 50, 15, and 6 cfs in the section downstream of Marshall Creek.

Flow recommendations are compared for various methods in Table 18. Agreement among the methods is relatively good. This is probably because all the methods are fundamentally based on the width and shape of the channel. PHABSIM gives more usable results than the other two methods, because any increment of flow change, for any species, can be evaluated.

It is important to note that the numbers given in Table 17 for PHABSIM are narrowly defined. They are low-flow period recommendations, below which physical habitat for salmonids is greatly reduced. Recommendations for overall ecosystem health would need to consider flows during other times of the year, and for other purposes.

## C. SNTEMP

The SNTEMP model accurately reproduced existing conditions from RM35.5 to the mouth of Latah Creek. The scenarios examined indicated that improved shade could reduce summer water temperatures by 1-1.5 C in most locations. Increased flow, on the other hand, had little or no effect on simulated stream temperatures. This indicates that direct solar heating has the biggest effect on water temperature in the reach, and this solar heating is capable of quickly canceling any temperature reductions that might come from flow increases. Reduction of solar heating (via improved shade) could lead to lower stream temperatures over long reaches of Latah Creek.

Superimposed on the SNTEMP results are two temperatures relevant for salmonid potential (B. Caldwell, WDOE, personal communication). Above 19C, metabolism of trout becomes inefficient, with little or no growth possible. Above 23C, lethal effects begin, meaning trout have difficulty surviving in a reach where temperatures exceed 23C for extended periods.

In Week 28, simulated temperatures are above 23 C for most of the reach, even with added inflow or restored shade (Figures 26, 32). In other weeks, simulated temperatures above 19C occur over much of the reach. Restored shade (and to a lesser extent, cool inflow) reduce the length of reach, and the number of weeks, that these temperature thresholds are surpassed. However, these results are from a model, and are not precise enough to predict the future thermal conditions for trout. The results indicate that shade could improve the situation, but the exact amount of improvement is harder to pin down.

Published temperature standards are an indication of habitat conditions, but not absolute thresholds that exclude trout populations. It is well documented that rainbow trout can adapt to temperatures much higher than published standards. Behnke (1992) noted active feeding at temperatures above 28C in a desert population of redband rainbow trout. E. Andersen (WDFW, unpublished) found a population of rainbow trout in Skookumchuck Creek surviving at 28.9C. In addition to genetic adaptation, cool nighttime temperatures and the presence of groundwater seeps are factors that can contribute to survival of rainbow trout populations in waters where temperatures are above published standards.

<u>Interaction of temperature and physical habitat</u>: From the Idaho border to the mouth, Latah Creek is 58 river miles. During the summer, much of the creek has very low physical habitat (WUA) due to low flows; it also has temperatures above published guidelines for salmonids over much of the length. Physical habitat would increase substantially for each 1 cfs of added flow during the low-flow period (Figures 42-44). The length of stream with suitable temperatures could also be increased by shade restoration. Taken together, the increase in total habitat area (added length plus increased WUA) could be significant (Bovee 1982).

Figure 48 illustrates the combined benefits of increased flow and reduced temperature. The baseline condition is given for the RM29.2 site (Keevy) at a summer flow of 3cfs, and it is assumed for the example that temperatures are adequate for trout over a length of 10,000 feet. If flow is increased by 2 cfs, or if shade restoration is accomplished in the reach, total WUA in the reach increases as shown in the first two bars of the graph. But if both improvements are combined, the increase in total WUA exceeds the sum of the two separate improvements.

## D. Water quality

Small increases in flow and decreases in temperature may have other water quality benefits. Pollutants such as coliforms could be slightly diluted by higher discharges. Dissolved oxygen would be slightly higher (other things being equal) with lower temperatures. The benefits would be minor compared to the benefits of cutting off the sources of pollution.

## E. Recreation

The lack of flows adequate for boating during summer months makes Latah Creek an unpopular choice for most boating enthusiasts. Winter flows attract some whitewater enthusiasts during the few days of higher (near flood stage) flows. Incremental gains in summer base flow would not alter these circumstances.

## V. SUMMARY AND CONCLUSIONS

The geology and climate of the watershed indicate that large increases in baseflow are unlikely. However, significant physical habitat gains could be produced with very small increments of flow addition. Each 1 cfs of additional water in the mainstem would add 5% or more to physical habitat values during the low-flow season.

Physical habitat increase alone may not improve salmonid potential, because stream temperatures are very warm over most of the distance. Even with a simulated additional inflow of cool water, stream temperatures were improved over only a short distance. Therefore, it appears that flow augmentation would need to be combined with temperature reduction to improve trout habitat significantly.

Simulations with SNTEMP indicate that shade restoration could significantly lower stream temperatures. Shade could thus increase the total length of the mainstem available for salmonids, even without flow augmentation.

Shade restoration and flow augmentation, if combined, could yield the biggest improvement in the amount of habitat suitable for salmonids in Latah Creek. There would be increases in usable area (WUA), and there would be an increase in the length of the creek with suitable temperatures. Flow and temperature improvement have a positive synergistic effect on habitat (Figure 48).

Improvements made in the major tributaries (Rock and California Creek) could contribute to better flow and temperature conditions in Latah Creek. Improvements made in the upper watershed could also make such a contribution.

No single action (e.g. change of flow) will restore salmonid habitat conditions to its maximum potential. However, the combined effects of several projects (riparian restoration, upper watershed improvement, increased flows from tributaries) could significantly improve fish habitat in Latah Creek.

## VI. LITERATURE CITED

Bartholow, J.M. 1989. Stream temperature investigations: field and analytic methods. Instream Flow Information Paper 13. U.S. Fish and Wildl. Service Biological Report 89(17). 139 pp.

Behnke, R. J. 1992. Native trout of western North America. American Fisheries Society Monograph 6. Bethesda, MD.

Bovee, K.D. 1982. A guide to stream habitat analysis using the Instream Flow Incremental Methodology. Instream Flow Information Paper 12. U.S. Fish and Wildlife Service, FWS/OBS-82/26. 248 pp.

Edelen, W. and D. Allen. 1998(?). A chronicle of Latah (Hangman) Creek: Fisheries and land use. Spokane County Conservation Dist.

Hamilton, M. M, and D. F. Stradling, R.E.Derkey. 2001. *Geology of the Hangman (Latah) Creek Flood Hazard Management Area,* Spokane Co. Conservation District and Washington State Department of Natural Resource, Division of Geology and Earth Resources.

Helm, W.T., editor. 1985. Glossary of stream habitat terms. Habitat inventory committee of the Western division, American Fisheries Society.

Laumeyer, P.H. and O.E Maughan. 1974. Further information on the inventory of fishes in Hangman Creek. Northwest Science 48:172:174.

Laumeyer, P.H. and O.E Maughan. 1973. Preliminary inventory of fishes in Hangman Creek. Northwest Science 47:66-69

Lee, D.R., and J. A. Cherry, *A Field Exercise on Ground Water Flow using Seepage Meters and Mimi-Piezometers,* Journal of Geological Education, Volume 27,1978. 4

Spokane County Conservation District 2002a. WRIA 56 Watershed Planning Instream Flow Recommendations for Hangman (Latah) Creek.

Spokane County Conservation District. 2001b, 2002b. Seepage run reports.

Spokane County Conservation District 2001a. Phase 1 Level 1 Task Report

Spokane County Conservation District. 1994. Hangman Creek Watershed Management Plan.

Stalnaker, C., et al. 1994. The instream flow incremental methodology: A primer for IFIM. National Ecology Research Center, Internal Publication. National Biological Survey. Fort Collins, Colorado. 99 pp.

Swift III, C. H. 1976. Estimation of stream discharges preferred by steelhead trout for spawning and rearing in western Washington. USGS Open-File Report 75-155. Tacoma, Washington.

Swift III, C. H. 1979. Preferred stream discharges for salmon spawning and rearing in Washington. USGS Open-File Report 77-422. Tacoma, Washington.

Tennant, D.L. 1976. Instream flow regimens for fish, wildlife, recreation and related environmental resources. Fisheries. 1:6-10.

USDA Soil Conservation Service. 1994. Hangman Creek watershed preliminary investigation – Benewah County, Idaho. Boise, ID. *Map (Fig. 2.2), Hangman Creek General Soils Map (Fig. 2.3), Hangman Creek General Landuse Map (Fig. 2.6).*

Washington Department of Fish and Wildlife, and Washington Department of Ecology 2000. Guidelines for instream flow studies.

WDFW unpublished. Toe width calculations for developing flow recommendations.

**References used for Habitat suitability curves**

Baltz, D.M., P.B. Moyle, and N.J. Knight 1982. Competitive interactions between benthic stream fishes, riffle sculpin, *Cottus gulosis,* and speckled dace, *Rhinichthys osculus.* Canadian Journal of Fisheries and Aquatic Science 39:1502-1511.

Baltz, D.M. and P.B. Moyle. 1981. Segregation by species and size class of the rainbow trout (*Salmo gairdneri*), and Sacramento sucker (*Catostomidae occidentalis*), in three California streams. Environmental Biology of Fishes, Vol. 10 No. 1/2 pp 101-110, 1984.

Bovee, K.D. 1978. Probability-of-use criteria for family salmonidae. Instream Flow Information Paper No. 4. FWS/OBS-78/07. Cooperative Instream Flow Group; Western Energy and Land Use Team, Fort Collins, Colorado.

Dodge, K.L. 1993. Patterns of temporal and spatial habitat use by sympatric speckled dace (Rhinichthys osculus) and longnose dace (R. cataractae) in an Oregon Cascades stream. Master's thesis, Oregon State University, Corvallis.

Golder Associates Ltd. (EMA) 1994. Instream flow needs investigation of the Bow River, Part I. - Use and preference curves.

Hardin-Davis, Inc., Hosey & Associates Engineering Co., Clearwater BioStudies, Inc. 1990. Habitat suitability criteria for salmonids of the McKenzie River. Prepared for the Eugene Water and Electric Board.

Highwood. 1985 - IEC Beak. Highwood River instream flow needs study (1984). Use curves calculated from reported frequency distributions. Preference curves from Locke 1989 using coordinates.

Highwood (Delphi) 1998. Unpublished. Consensus curves developed for Highwood River (Alberta) IFIM study.

MESC file R0178. library use curves provided by USGS, Fort Collins, CO, coordinates provided, no author or study location provided

Moyle, P.B. and D.M. Baltz. 1985. Microhabitat use by an assemblage of California stream fishes: Developing criteria for instream flow determinations. Trans. Amer. Fish. Soc. 114:695-704.

Raleigh, R.F., T. Hickman, R.C. Solomon, and P.C. Nelson 1984. Habitat suitability information: rainbow trout. US Fish & Wildlife Service. FWS/OBS-82/10.60. 64 pp.

Rodnick, K.J. 1983. Seasonal distribution and habitat selection by the redside shiner, Richardsonius balteatus, in a small Oregon stream. Master's thesis, Oregon State University, Corvallis.

Smith, G.E. and M.E. Aceituno 1987. Habitat preference criteria for brown, brook, and rainbow trout in eastern Sierra Nevada streams, final report. Stream Evaluation Report 87-2. California Department of Fish & Game, Sacramento, California.

Twomey, K.A., K.L. Williamson, and P.C. Nelson. 1984. Habitat suitability curves: white sucker. Western Energy and Land Use Team, Division of Biological Services, U.S. Fish and Wildlife Service, U.S.D.I.

## Additional references

Annear, T. and 15 co-authors. Instream Flow Council 2002. Instream flows for riverine resource stewardship.

Celto, E., L.S. Fore, and M. Cather. 1998. Biological assessment of Hangman (Latah) Creek Watershed. Spokane County Conservation Dist.

Spokane County Conservation Dist. 1999. Hangman (Latah) Creek water quality monitoring report. Public Data File 99-01.

## FIGURES

## TABLES

| **Common name** | **Latin name** | **Native/ Introduced** | **Comments** |
|---|---|---|---|
| Rainbow trout | *Oncorhynchus mykiss* | Native | |
| Mountain whitefish | *Prosopium williamsoni* | Native | Not in historic collection data |
| Speckled dace | *Rhinychthys osculus* | Native | |
| Largescale sucker | *Catostomus macrocheilus* | Native | |
| Bridgelip sucker | *Catostomus columbianus* | Native | |
| Longnose sucker | *Catostomus catostomus* | Native | |
| Northern pikeminnow | *Ptychocheilus oregonensis* | Native | |
| Chiselmouth | *Achrocheilus alutaceus* | Native | |
| Redside shiner | *Richardsonius balteatus* | Native | |
| Torrent sculpin | *Cottus rhotheus* | Native | |
| Brown bullhead | *Ictalurus nebulosus* | Introduced | |
| Tench | *Tinca tinca* | Introduced | |
| Brook trout | *Salvelinus fontinalis* | Introduced | |

Table 1. Fish Species in Latah Creek.

| **Habitat type** | **Description** |
|---|---|
| Pool | Stream segment with reduced velocity and deeper water than surrounding areas |
| Riffle | Shallow rapids where water flowing over rough substrate produces surface agitation, but not standing waves |
| Run | Area of swiftly flowing water, without surface turbulence |
| SP | Step pool (pool downstream of a steep drop) |
| DP | Pool formed by a beaver dam |

Table 2. Habitat types and characteristics classified according to W.T. Helm.

| **Stream** | **Site** | **Distance from mouth (mi)** | **Habitat represented** |
|---|---|---|---|
| Latah Creek | Denny | 35.4 | Low gradient, open banks, little cover |
| | Keevy | 29.2 | Canyon, topographic shading, boulder cover |
| | Paintball | 2.5 | Downstream from groundwater inputs, altered banks, sandy substrate |
| Rock Creek | Dashiell | 4.0 | Wide channel, grazed, cobble substrate |
| California Cr | Elder Rd | 3.8 | Narrow, shaded channel, moderate gradient, cobble substrate |

Table 3. PHABSIM site locations and characteristics.

| | High flow (May) | Mid flow (June) | Low flow (Sept) |
|---|---|---|---|
| Headpin placement | ▨ | | |
| Benchmark survey | ▨ | | |
| Water surface elevations | ▨ | ▨ | ▨ |
| Velocities, all transects | ▨ | | |
| Site discharge | ▨ | ▨ | ▨ |
| Substrate | | | ▨ |
| Cover | | | ▨ |

Table 4. PHABSIM field tasks completed at all sites, by month.

| Code | Description |
|---|---|
| 1 | Clay-silt; organic |
| 2 | Sand |
| 3 | Fine gravel (0.1-0.3 inch diameter) |
| 4 | Medium gravel (0.3-1.25 inch) |
| 5 | Coarse gravel (1.25-2.5 inch) |
| 6 | Small cobble (2.5-5 inch) |
| 7 | Medium cobble (5-10 inch) |
| 8 | Cobble/Boulder (>10 inch) |
| 9 | Bedrock |

Table 5. Substrate codes used in data collection and habitat modeling.

| Stream | Site | Measured flows (cfs) | | | Modeled flow range (cfs) | |
|---|---|---|---|---|---|---|
| | | low | mid | high | low | high |
| Latah Creek | Denny (RM 35.4) | 1 | 11 | 42 | 1 | 40 |
| | Keevy (RM 29.2) | 1 | 11 | 43 | 1 | 40 |
| | Paintball (RM 2.5) | 7 | 39 | 85 | 1 | 80 |
| Rock Creek | Dashiell | 0.7 | 6 | 35 | 1 | 40 |
| California Creek | Elder Rd | 0.2 | 1.2 | 6 | 0.5 | 12 |

Table 6. Flow range modeled for habitat at each site.

| **Species** | **Sources** |
|---|---|
| Rainbow trout | WDFW 2000; Smith and Aceituno 1987; Hardin-Davis et al. 1989 |
| Mountain whitefish | Highwood River 1985 |
| Speckled dace | Moyle & Baltz 1985; Dodge 1993 |
| Largescale sucker | Twomey et al. 1984; Baltz and Moyle 1981 |
| Redside shiner | Rodnick 1983 |

Table 7. Sources of information for habitat suitability curves.

| **File type** | **Inputs** | **Sources** |
|---|---|---|
| Network files | river distances to all studied points | topo maps |
| Stream geometry | width, latitude, elevation | habitat mapping, topo maps |
| Meteorology | air temperature, wind speed, humidity, cloud cover | NOAA data, Spokane airport |
| Hydrology | Tributaries, other points (nodes) of flow change | USGS and SCCD gage data |
| | Discharge at every node | |
| | Water temperature at origin and validation points | SCCD temperature probes |
| Shade | topographic and vegetative shade estimates | habitat mapping, topo maps |
| Job control file | Options and calibration factors used | user discretion |

Table 8. Input files used in the SNTEMP program.

| River mi | Creek | Location | Stream flow estimate | Early-August flow (cfs) |
|---|---|---|---|---|
| 35.4 | Latah | Hays Rd | assumed same as Bradshaw gauge | 1.41 |
| 32.9 | Latah | Bradshaw Rd | SCCD gauge at Bradshaw | 1.41 |
| 29.2 | Latah | Keevy Rd | assumed same as Bradshaw gauge | 1.41 |
| 22.2 | Latah | Latah Rd | Bradshaw plus accretion* | 2.29 |
| 20.2 | Rock | near confluence | SCCD gauge in Rock Cr | 0.74 |
| 18.7 | Latah | Duncan | SCCD gauge at Duncan | 3.03 |
| 18.3 | California | near confluence | estimate from seepage run and IFIM studies | 0.46 |
| 18.2 | Latah | Valley Chapel Rd | sum of Duncan gauge and California Creek estimate | 3.49 |
| 13.8 | Latah | HV Golf Course | estimate for km 29.3, plus 1/3 of above-Marshall accretion estimate | 4.55 |
| 8.8 | Latah | Yellowstone Pipeline | estimate for km 22.2, plus 1/3 of above-Marshall accretion estimate | 5.61 |
| 4.5 | Latah | Qualchan Golf Course | estimate for km 14.2, plus 1/3 of above-Marshall accretion estimate | 6.67 |
| 4.4 | Marshall | near confluence | Marshall ungauged; assumed to be 100% of remaining inflow | 3.39 |
| 3.6 | Latah | Kampas Bridge | assumed same as USGS gage | 10.06 |
| 0.4 | Latah | Marne Bridge | assumed same as USGS gage | 10.06 |
| 0 | Latah | Mouth | USGS gage | 10.06 |

Table 9. Flow estimates in the SNTEMP network; data and assumptions used
* accretion = Duncan flow - (Rock flow + Bradshaw flow).

| Parameter | Data source |
|---|---|
| Latitude | Topographic maps |
| Elevation | Topographic maps |
| Average annual air temperature | Spokane airport meteorological station |
| Mean weekly air temperature | Spokane airport meteorological station |
| Mean weekly relative humidity | Spokane airport meteorological station |
| Mean weekly wind speed | Spokane airport meteorological station |
| Mean weekly solar radiation | Based on weather station data |
| Stream width | On-site measurements |
| Discharge, weekly, per site | SCCD and USGS gages |
| Mean water temp, per validation site | SCCD data loggers |
| Topographic shade | On-site measurements |
| Vegetative shade | On-site measurements |
| Dust coefficient | Default value |
| Ground reflectivity | Default value |

Table 10. Data sources for SNTEMP inputs.

| **Station** | **River mile** | **River km** | **Elevation (ft)** | **Elevation (m)** | **Lat (deg)** | **Lat (Rad)** |
|---|---|---|---|---|---|---|
| HC @ Marne Bridge, Riverside Ave. | 0.4 | 0.6 | 1730 | 527 | 47.65 | 0.83165 |
| HC @ Kampas Bridge near Cheney Spokane Rd. | 3.6 | 5.8 | 1780 | 543 | 47.63 | 0.83121 |
| HC @ US 195, D/S of Qualchan Golf Course | 4.5 | 7.2 | 1795 | 547 | 47.62 | 0.83107 |
| HC @ Yellowstone Pipe Line | 8.8 | 14.2 | 1830 | 558 | 47.58 | 0.83049 |
| HC @ Hangman Valley Golf Course | 13.8 | 22.2 | 1855 | 566 | 47.54 | 0.82976 |
| HC @ Valley Chapel Rd. | 18.2 | 29.3 | 1887 | 575 | 47.52 | 0.82932 |
| HC @ Duncan | 18.7 | 30.1 | 1896 | 578 | 47.51 | 0.82918 |
| HC @ Latah Rd. | 22.2 | 35.7 | 1945 | 593 | 47.47 | 0.82845 |
| HC @ Keevy Rd. near Mt. Hope, WA | 29.2 | 47.0 | 2195 | 669 | 47.42 | 0.82758 |
| HC @ W. Bradshaw Rd. near Fairfield, WA | 32.9 | 53.0 | 2295 | 700 | 47.38 | 0.82700 |
| HC @ Hays Rd. near Waverly, WA | 35.5 | 57.2 | 2325 | 709 | 47.36 | 0.82656 |
| **Tributaries** | | | | | | |
| Marshall Creek @ US 195 | 0.4 | 0.6 | 1820 | 555 | 47.62 | 0.83107 |
| California Creek @ Elder Rd. | 0.1 | 0.2 | 1975 | 602 | 47.52 | 0.82932 |
| Rock Creek @ Valley Chapel Rd. | 0.3 | 0.5 | 1915 | 584 | 47.49 | 0.82889 |

Table 11. Calibration locations for SNTEMP.

| Site | Piezo-meter # | Transect location (ft) | Notes on locations | Notes on piezometer readings |
|---|---|---|---|---|
| Denny T-7 (09/03/02, pm) | 1 | 45.25 | 1/4" gravel & silt | Not a good P. installation (vinyl tubing). |
| | 2 | 43.2 | | Not a good P. installation (vinyl tubing). |
| | 3 | 43.5 | | OK - P. made with stiff (HDPE) tubing. Falling head test. |
| | 4 | 37.2 | | |
| | 5 | 30 | rock - abandon location. | |
| | 6 | 27.7 | | |
| | 7 | 19.3 | with cobbles | |
| | 8 | 6.2 | edge of grass | |
| Keevy T-2 (9/03/02, pm) | 1 | 54.1 | rock | |
| | 2 | 50.5 | rock | |
| | 3 | 46.8 | rock | |
| | 4 | 43.6 | | |
| | 5 | 37.7 | gravel & big rocks | P. installation failed due to bolt stuck in end of pipe. |
| | 6 | 39.3 | gravel and sand | Falling head too fast to measure. |
| | 7 | | close to edge - too much rock | |
| | 8 | 22.6 | | P. installation failed due to bent pipe. |
| Rock Creek T-4 (9/04/02, pm) | 1 | 44.9 | 6" from south edge (flat bench) | |
| | 2 | 37.3 | | |
| | 3 | 15.6 | beside north edge (steep bank) | |
| California Cr T-4 | 1 | 21.9 | 9" from south edge (cut bank) | Not a good seal - equilibrates quickly. |
| (9/04/02, pm) | 2 | 11.8 | 5" from north edge (flat bank) | |
| | 3 | 20.3 | 32" from south bank (try again) | |
| Paintball T-2 (9/05/02, am) | 1 | closest to west edge | hit obstruction & abandon location | |
| | 2 | 49.8 | 26" from west edge | Not a good seal - equilibrates quickly |
| | 3 | 47.2 | | |
| | 4 | 40.8 | | Too loose - P. pulled right out (coarse sands). |
| | 5 | 8 | beside east edge (slower flow) | Some silt (fines) at this location. Falling head test. |
| | 6 | 14.5 | | Failure - P. stuck in pipe end & didn't remain in streambed. |
| | 7 | 15 | | |

Table 12a. Piezometer data for Latah Creek.

| Site | Piezo-meter # | Depth of bury beneath stream bed (in) | Depth of surface water (in) | Piezometer measurement below SW (in) |
|---|---|---|---|---|
| Denny T-7 (09/03/02, pm) | 1 | 12 | 8 | |
| | 2 | 16.75 | 11 | |
| | 3 | 14.75 | 11 | |
| | 4 | 12.75 | 10.5 | 0.75 |
| | 5 | | | |
| | 6 | 19.75 | 9 | 2.25 – 3 |
| | 7 | 15.875 | 7.5 – 8 | 3 |
| | 8 | 18.75 | 15.25 | 2.5 |
| Keevy T-2 (9/03/02, pm) | 1 | | | |
| | 2 | | | |
| | 3 | | | |
| | 4 | 7.75 | 8 | |
| | 5 | 13.75 | 10.75 | |
| | 6 | 16.75 | 11.5 | |
| | 7 | | | |
| | 8 | 18.75 | | |
| Rock Creek T-4 (9/04/02, pm) | 1 | 13.25 | 4.5 | 0.5 |
| | 2 | 13.75 | 8 | 0.5 |
| | 3 | 17.75 | 15 | |
| California Cr T-4 | 1 | 16.75 | | |
| (9/04/02, pm) | 2 | 17.75 | 3 | 1.5 |
| | 3 | 18.25 | 5 | 1 |
| Paintball T-2 (9/05/02, am) | 1 | | | |
| | 2 | 18.75 | 12 | |
| | 3 | 19.25 | 16 | |
| | 4 | 17.75 | 19.5 | |
| | 5 | 17.75 | 20 | |
| | 6 | 17.75 | 22.5 | |
| | 7 | 14.75 | 23 | |

Table 12b. Piezometer data for Latah Creek.

| Creek | Site | Number of measurements | Average toe width (ft) | Recommended Flow (cfs) |
|---|---|---|---|---|
| Hangman | Denny (RM 35.4) | 6 | 16.8 | 9.0 |
| | Keevy (RM 29.2) | 7 | 28.1 | 18.7 |
| | Paintball (RM 2.5) | 1 | 34.5 | 25.0 |
| California | | 4 | 10.8 | 4.8 |
| Rock | Dashiell | 1 | 23.0 | 14.1 |

Table 13. Toe width results in Latah Creek.

| Week | Airport (m/s) | SNTEMP (m/s) | Airport (mph) | SNTEMP (mph) |
|---|---|---|---|---|
| 23 | 3.5 | 2.0 | 7.7 | 4.4 |
| 24 | 4.1 | 3.5 | 8.9 | 7.7 |
| 25 | 2.6 | 5.0 | 5.7 | 11.0 |
| 26 | 5.2 | 3.5 | 11.5 | 7.7 |
| 27 | 4.0 | 7.5 | 8.8 | 16.5 |
| 28 | 3.0 | 3.5 | 6.6 | 7.7 |
| 29 | 3.5 | 5.0 | 7.7 | 11.0 |
| 30 | 5.7 | 2.0 | 12.5 | 4.4 |
| 31 | 3.7 | 2.0 | 8.2 | 4.4 |
| 32 | 4.2 | 7.0 | 9.3 | 15.4 |
| 33 | 3.7 | 5.0 | 8.2 | 11.0 |
| 34 | 2.9 | 3.5 | 6.4 | 7.7 |
| 35 | 4.5 | 2.0 | 9.9 | 4.4 |
| 36 | 3.0 | 2.0 | 6.5 | 4.4 |
| 37 | 3.8 | 2.0 | 8.3 | 4.4 |
| 38 | 3.0 | 2.0 | 6.6 | 4.4 |

Table 14. Wind speed values measured at Spokane International Airport and used in stream temperature modeling.

|  | **number** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **River mile** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** | **31** | **32** | **33** | **34** | **35** | **36** | **37** | **38** |
| 32.9 | -0.05 | 1.05 | 1.53 | -0.72 | 1.42 | -0.57 | -1.17 | 0.56 | 0.46 | 0.96 | -0.43 | 0.08 | -0.18 | 0.91 | -0.41 | 0.19 |
| 29.2 | 0.53 | 0.77 | 0.97 | 0.84 | 2.47 | 0.90 | 0.80 | 1.89 | 1.42 | 0.67 | 0.28 | 0.86 | 0.91 | 1.10 | 1.30 | 1.10 |
| 22.2 | -0.41 | -0.49 | 0.03 | 0.27 | 1.96 | -0.16 | -0.43 | 0.73 | -0.35 | -0.86 | -1.51 | -1.11 | * | * | * | * |
| 18.7 | -0.31 | -0.67 | 0.03 | -0.36 | 1.41 | -0.53 | -0.96 | 0.50 | -0.60 | -0.59 | -1.50 | -0.61 | -0.45 | 0.25 | 0.69 | -0.22 |
| 18.2 | 0.43 | -0.20 | 0.70 | 0.04 | 1.99 | 0.07 | -0.38 | 0.47 | -0.36 | -0.43 | -1.25 | -0.12 | -0.90 | -0.61 | -0.12 | -0.95 |
| 13.8 | -0.50 | -0.02 | 0.00 | 0.62 | 1.33 | 0.23 | -0.21 | 1.08 | 0.24 | -0.59 | -1.08 | -0.04 | -0.05 | 0.23 | 0.68 | 0.24 |
| 8.8 | 0.15 | 0.23 | 0.47 | 0.00 | 1.68 | 0.14 | -0.33 | 0.77 | 0.12 | -0.40 | -1.29 | -0.38 | -1.11 | -0.22 | -0.23 | -0.75 |
| 4.5 | 0.32 | 1.43 | 0.26 | -0.73 | 0.05 | -0.76 | -0.22 | 0.48 | 0.73 | 1.02 | 1.11 | 0.68 | 0.58 | 0.51 | 0.86 | -0.07 |
| 3.6 | -0.97 | -1.94 | -1.86 | -2.18 | 0.42 | -1.02 | -0.75 | -0.74 | -0.58 | -0.08 | -0.55 | -0.47 | -0.91 | -0.30 | -0.21 | -0.81 |
| 0.4 | -0.54 | -0.89 | -0.47 | -0.41 | 1.93 | 0.35 | 0.08 | 0.11 | -0.46 | -0.56 | -1.25 | -0.56 | -1.26 | -0.49 | -0.31 | -0.83 |
| **Error by** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Average | -0.14 | -0.07 | 0.17 | -0.26 | 1.47 | -0.13 | -0.36 | 0.59 | 0.06 | -0.09 | -0.75 | -0.17 | -0.37 | 0.15 | 0.25 | -0.23 |
| Minimum | -0.97 | -1.94 | -1.86 | -2.18 | 0.05 | -1.02 | -1.17 | -0.74 | -0.60 | -0.86 | -1.51 | -1.11 | -1.26 | -0.61 | -0.41 | -0.95 |
| Maximum | 0.53 | 1.43 | 1.53 | 0.84 | 2.47 | 0.90 | 0.80 | 1.89 | 1.42 | 1.02 | 1.11 | 0.86 | 0.91 | 1.10 | 1.30 | 1.10 |
| RMS** | 0.482 | 0.952 | 0.880 | 0.852 | 1.624 | 0.572 | 0.634 | 0.864 | 0.630 | 0.671 | 1.109 | 0.593 | 0.766 | 0.563 | 0.612 | 0.645 |

Table 15a. SNTEMP prediction errors by site and week (* data not recovered for these sites; **Root Mean Square).

| **River mile** | **Average** | **Minimum** | **Maximum** | **RMS*** |
|---|---|---|---|---|
| 32.9 | 0.23 | -1.17 | 1.53 | 0.805 |
| 29.2 | 1.05 | 0.28 | 2.47 | 1.169 |
| 22.2 | -0.19 | -1.51 | 1.96 | 0.769 |
| 18.7 | -0.25 | -1.50 | 1.41 | 0.718 |
| 18.2 | -0.10 | -1.25 | 1.99 | 0.750 |
| 13.8 | 0.13 | -1.08 | 1.33 | 0.603 |
| 8.8 | -0.07 | -1.29 | 1.68 | 0.694 |
| 4.5 | 0.39 | -0.76 | 1.43 | 0.716 |
| 3.6 | -0.81 | -2.18 | 0.42 | 1.052 |
| 0.4 | -0.35 | -1.26 | 1.93 | 0.805 |

Table 15b. SNTEMP prediction errors by site (*Root Mean Square).

| **Daily average flow (cfs)** | **Average number of days/year** |
|---|---|
| 500 - 1000 | 23.6 |
| 1000 - 2000 | 12.5 |
| 2000 - 5000 | 5.9 |

Table 16. Average number of days per year at flow ranges favorable for boating on Latah Creek (flow at USGS gauge; taken from 1949-2001 data).

| Site | Level | Flow (cfs) | Exceedance % (June) | Exceedance % (July-Oct) |
|---|---|---|---|---|
| Below Marshall Cr, based on RM 2.5 data | Optimum | 50 | 40% | <5% |
| | Minimum | 15 | 90% | 50% |
| | Critical | 6 | >95% | 80% |
| Idaho border to Marshall Creek, based on RM 29.2 and 35.4 | Optimum | 26 | 25% | 0% |
| | Minimum | 15 | 55% | 5% |
| | Critical | 7 | 80% | 20% |

Table 17. Flow recommendations and percent exceedance in Hangman Creek, June-October.

| **Location** | **PHABSIM (optimal)** | **PHABSIM (min)** | **PHABSIM (critical)** | **Toe width** | **Tennant (min)** | **Tennant (good)** |
|---|---|---|---|---|---|---|
| Latah Cr. below Marshall Cr. | 50 | 15 | 6 | 25 | 24 | 72 |
| Latah Cr. above Marshall Cr. | 26 | 15 | 7 | 9-19 | 10 | 30 |
| California Cr. | * | 8 | 6 | 5 | - | - |
| Rock Cr. | 27 | 14 | 6 | 14 | - | - |

Table 18. Summer flow recommendations using different methods
(units are flow at site in cfs; *flows above 10 cfs not simulated at this site).

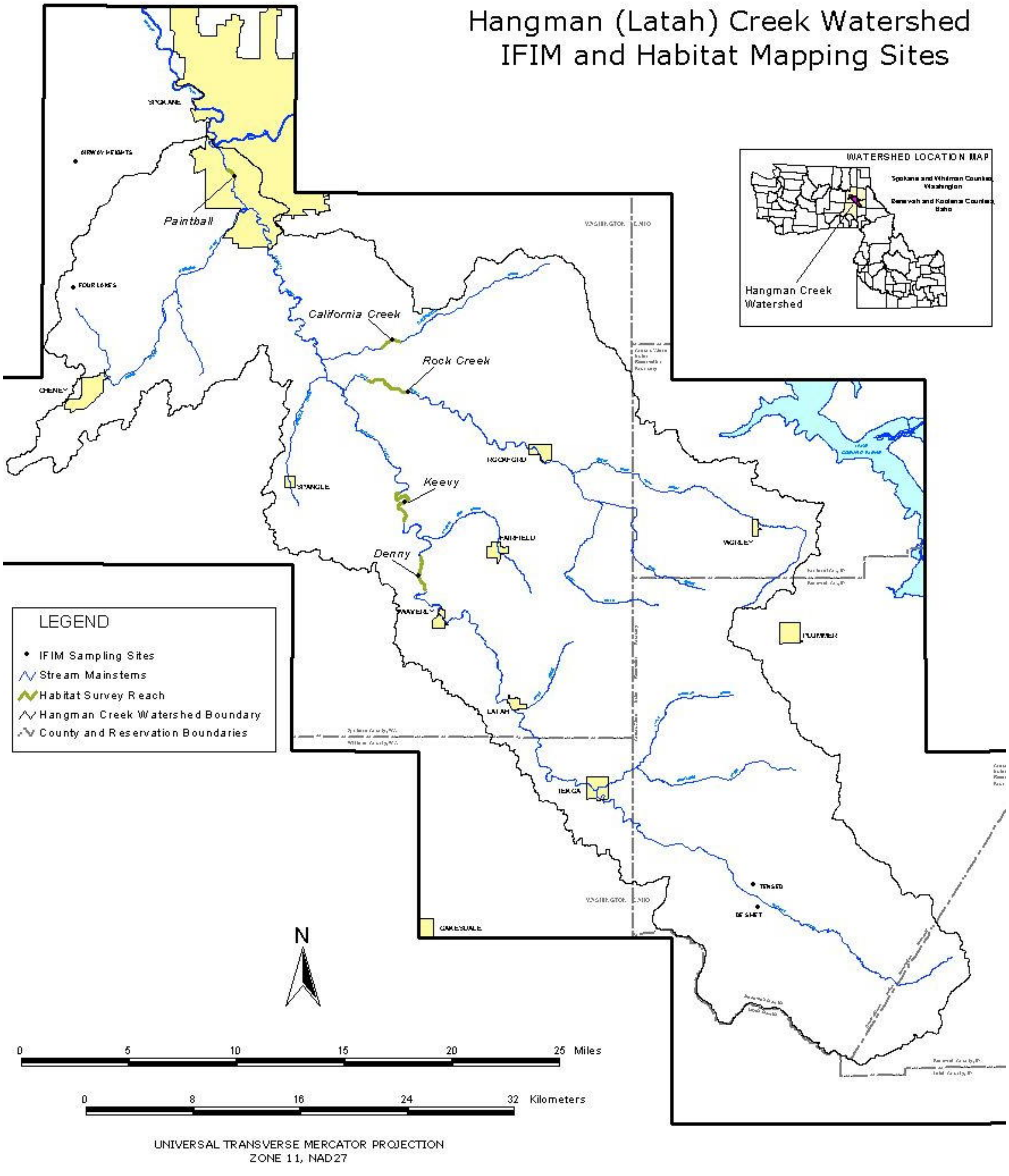

Figure 1. Site location, IFIM sampling sites, and habitat mapping sites.

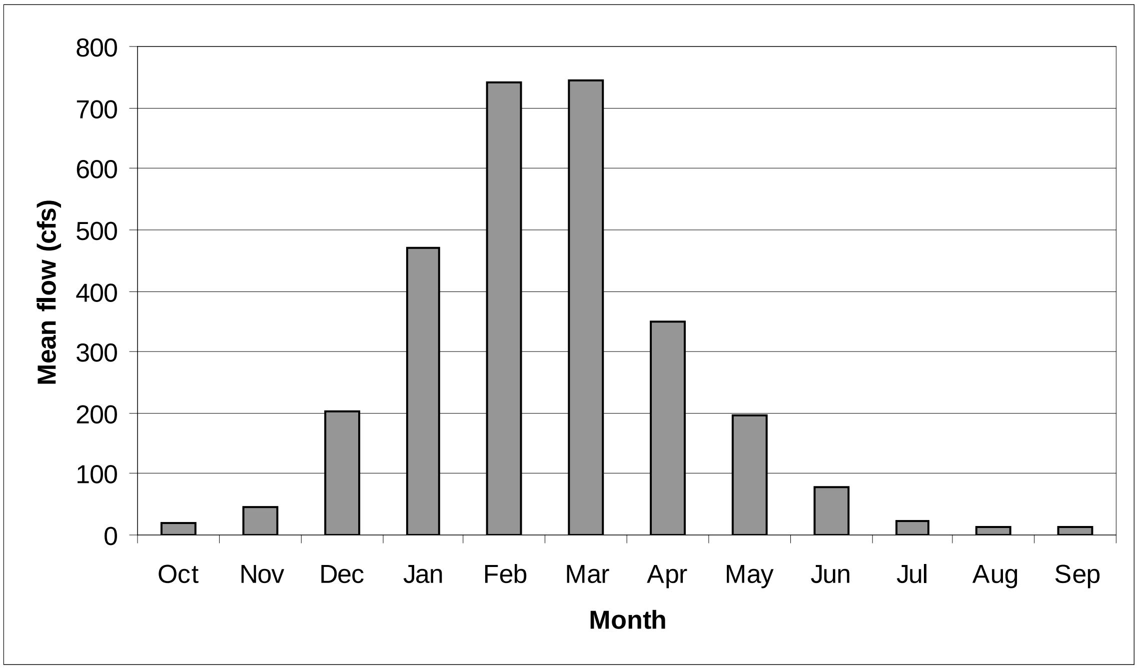

Figure 2. Mean monthly flows in Latah Creek.

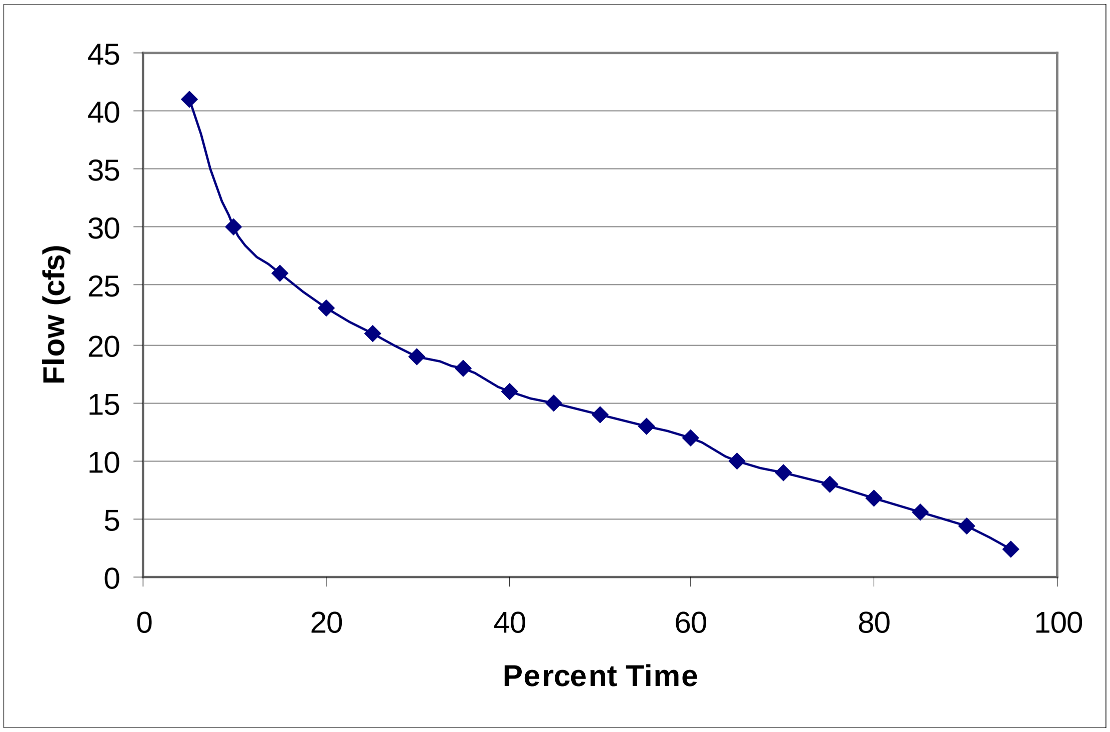

Figure 3. Flow exceedance at USGS gage, July-October (1948-2002 data).

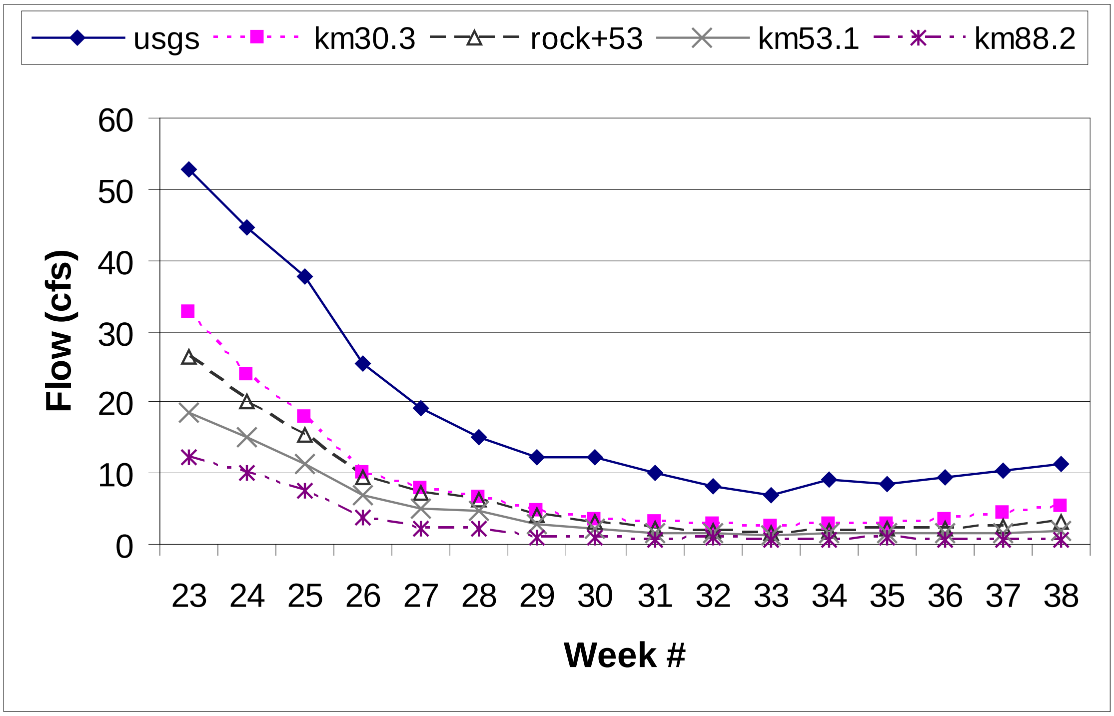

Figure 4. Relationship between gages during low flow period.

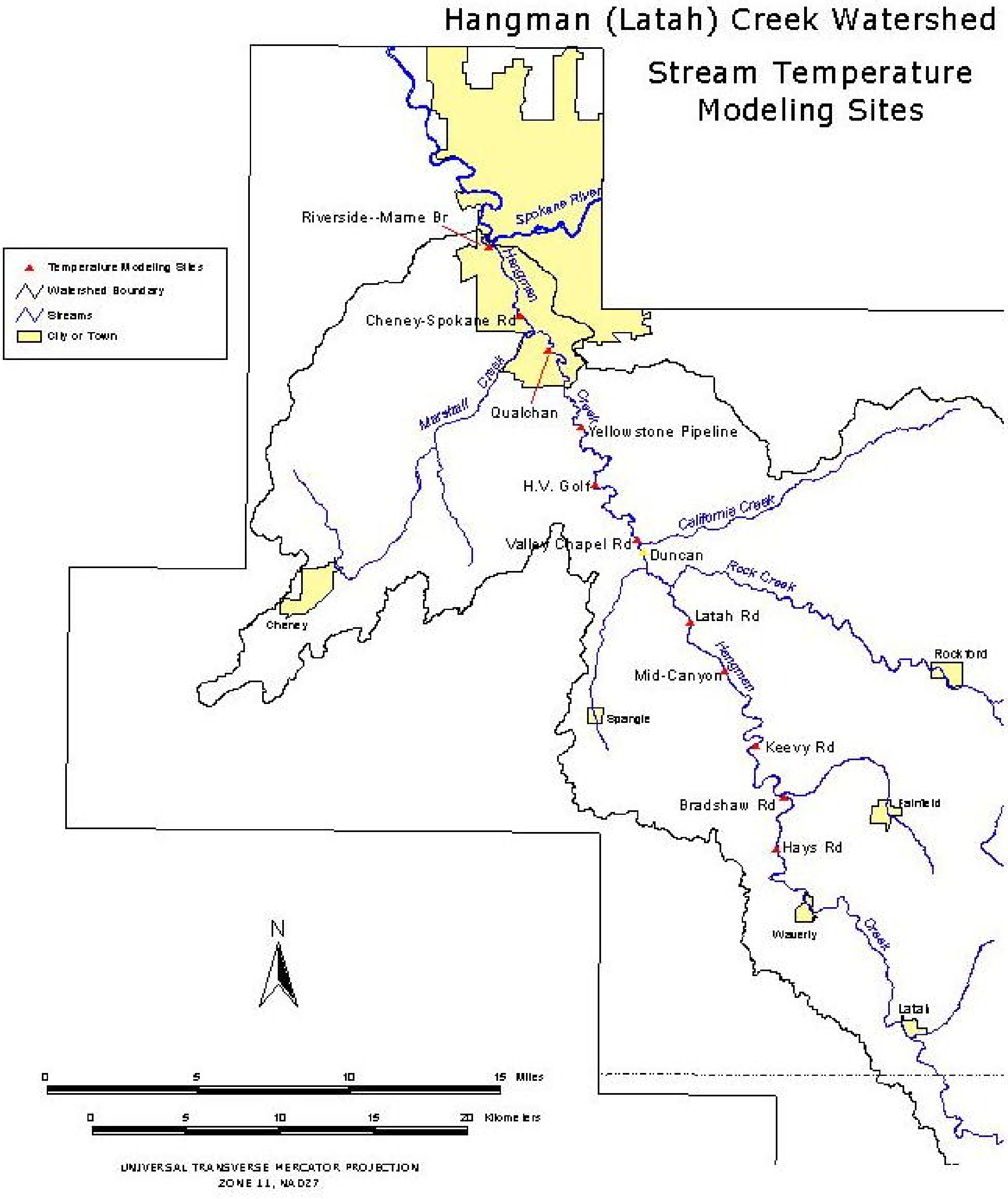

Figure 5. Map of study area with temperature model reference locations.

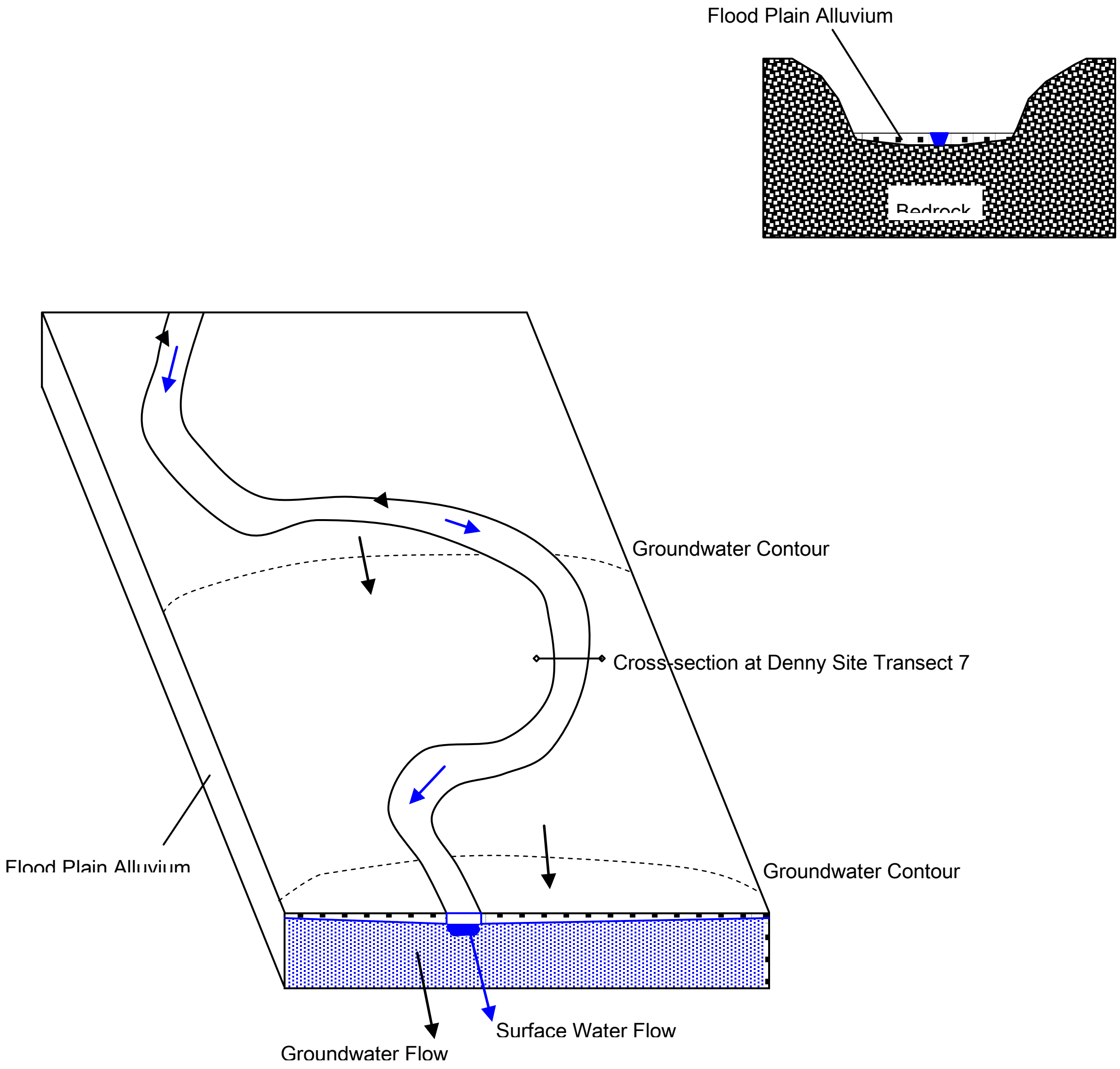

Figure 6. Schematic representation of the hydrological setting of Latah Creek.

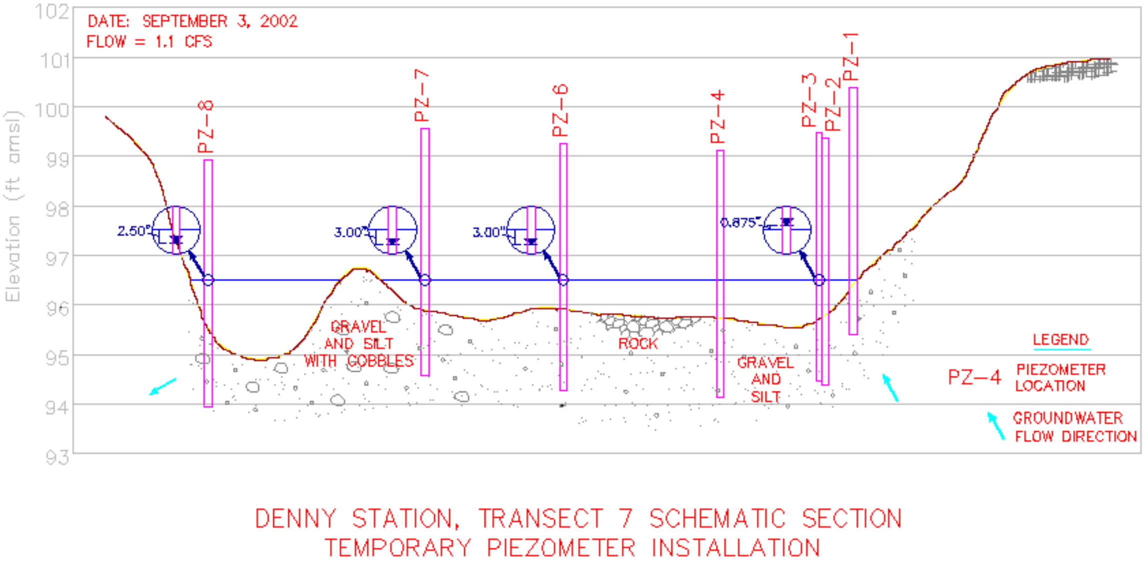

Figure 7. Schematic representation of cross section 7 at RM 35.4 (Denny site).

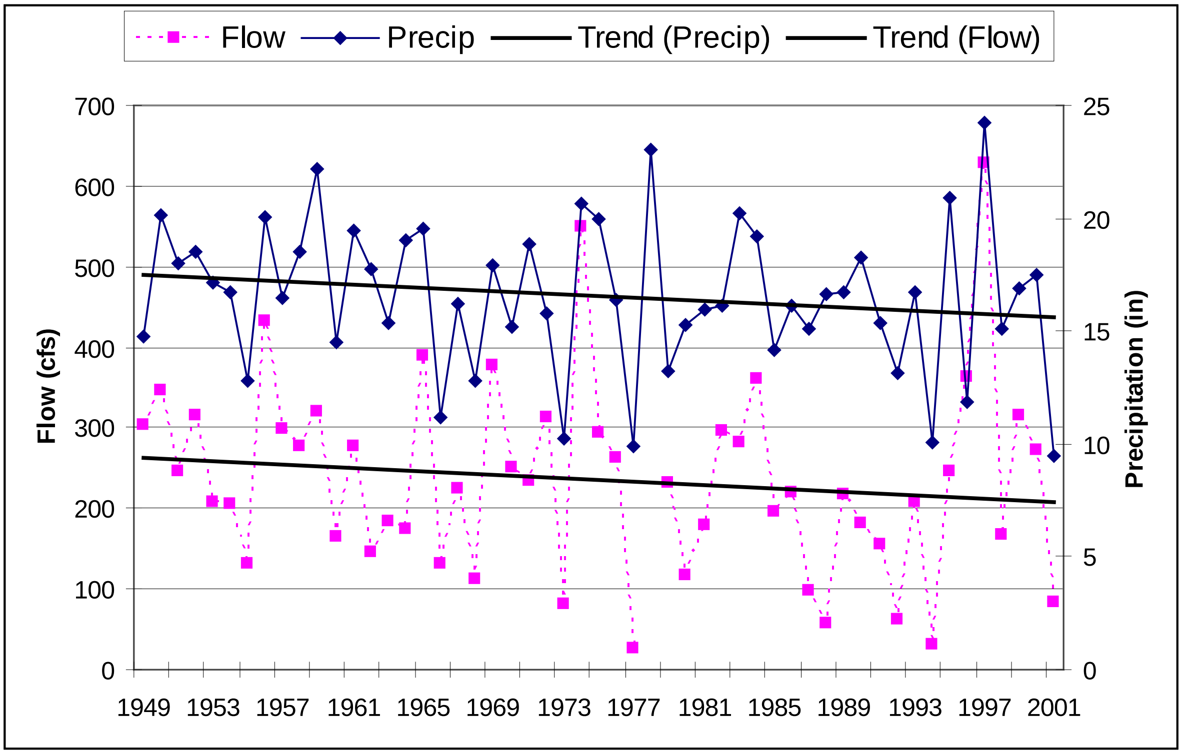

Figure 8. Mean annual discharge and annual precipitation in Latah Creek 1949-2001
(flow data from USGS gage at mouth, precip data from Spokane Airport).

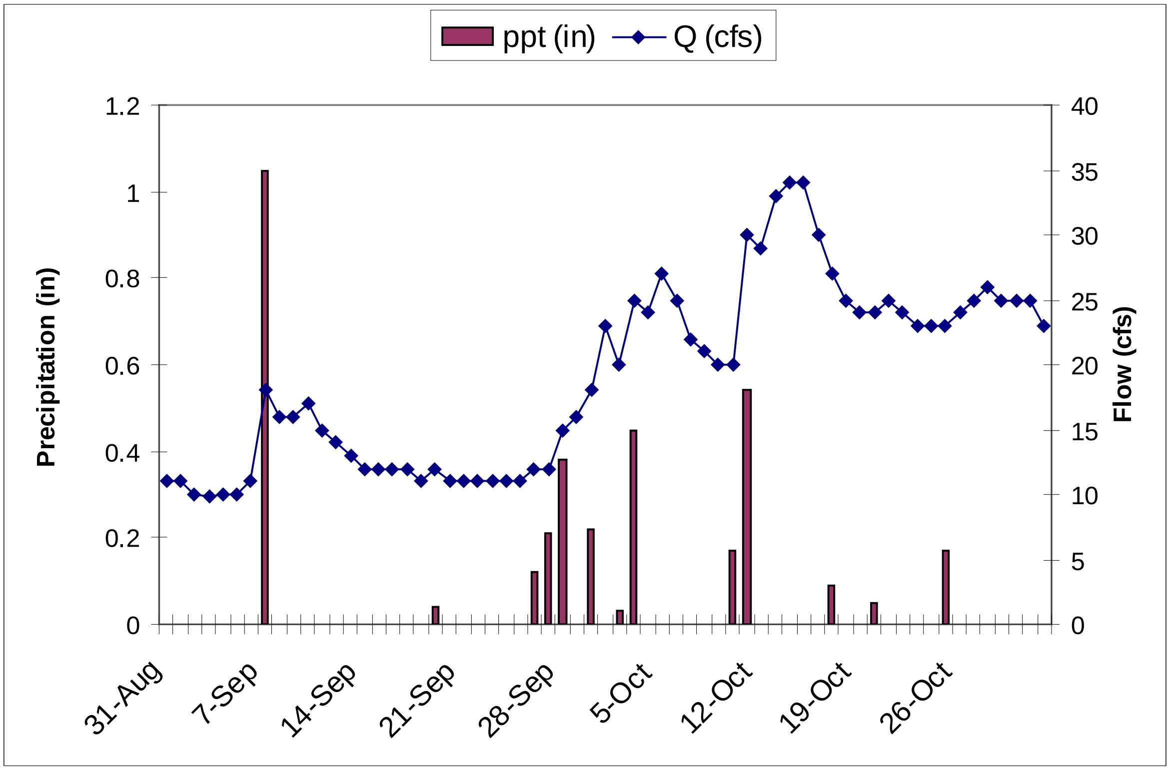

Figure 9. Event-scale hydrograph, September to October, 1995
(flow data from USGS gage at mouth, precip data from Spokane Airport).

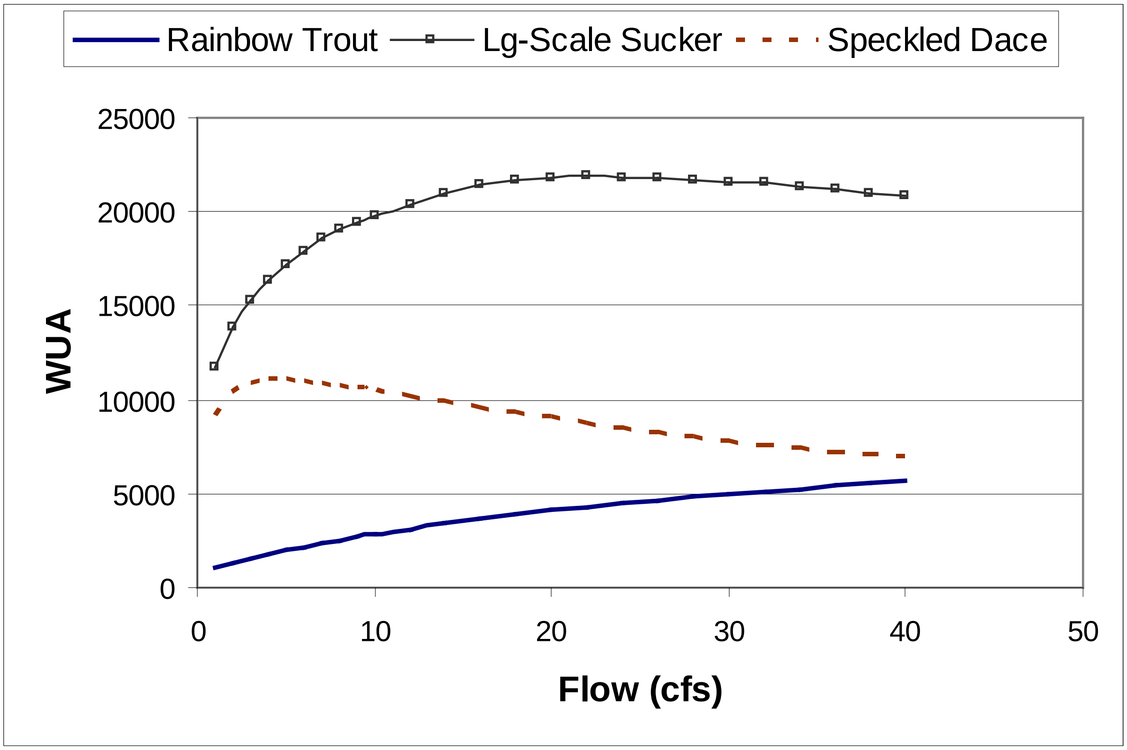

Figure 10. Weighted useable area at RM 35.4 for three species.

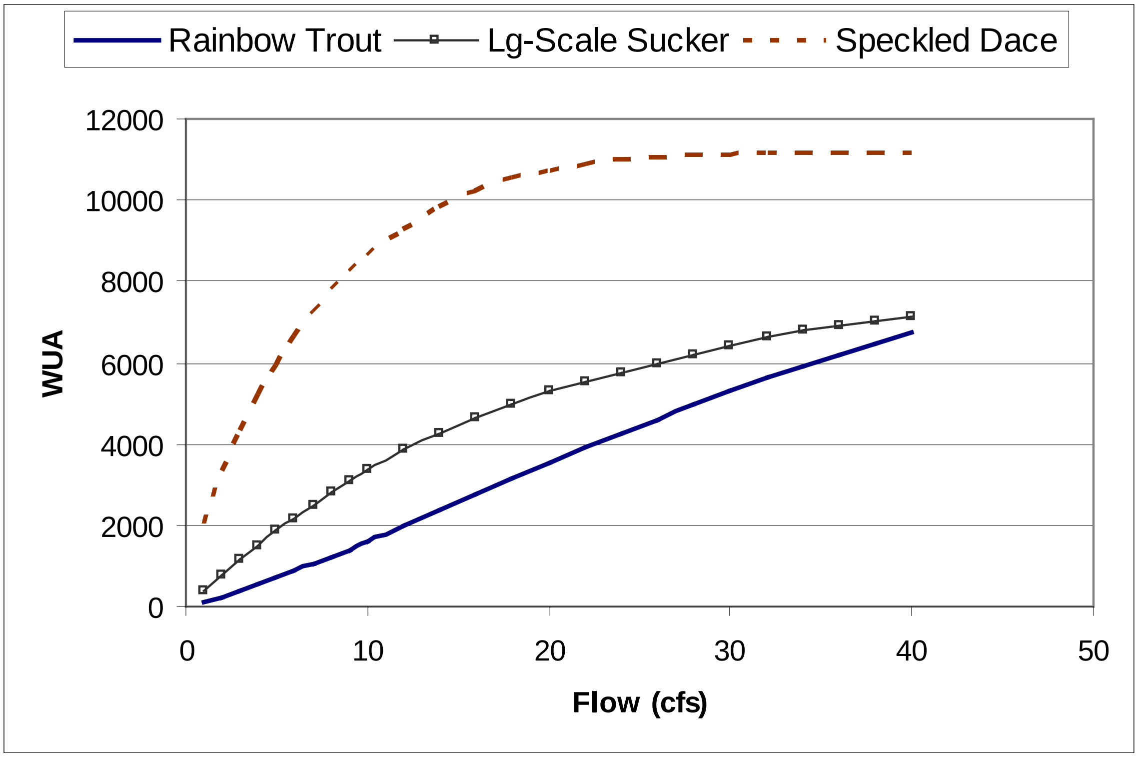

Figure 11. Weighted useable area at RM 29.2 for three species.

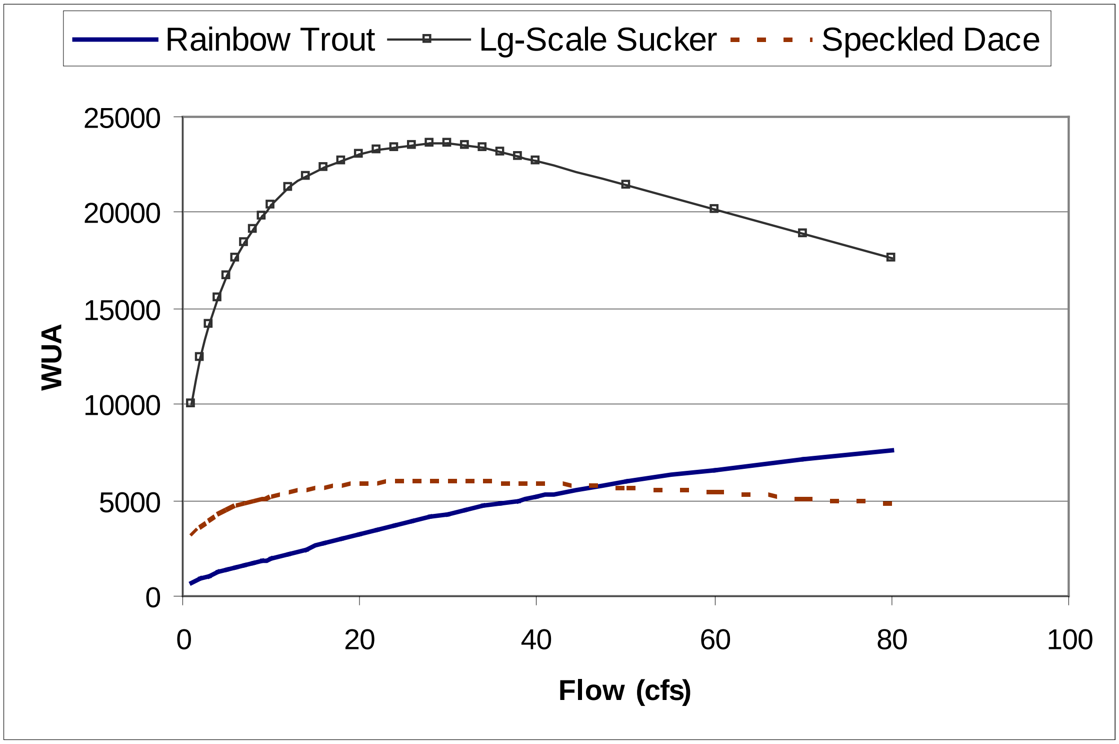

Figure 12. Weighted useable area at RM 2.5 for three species.

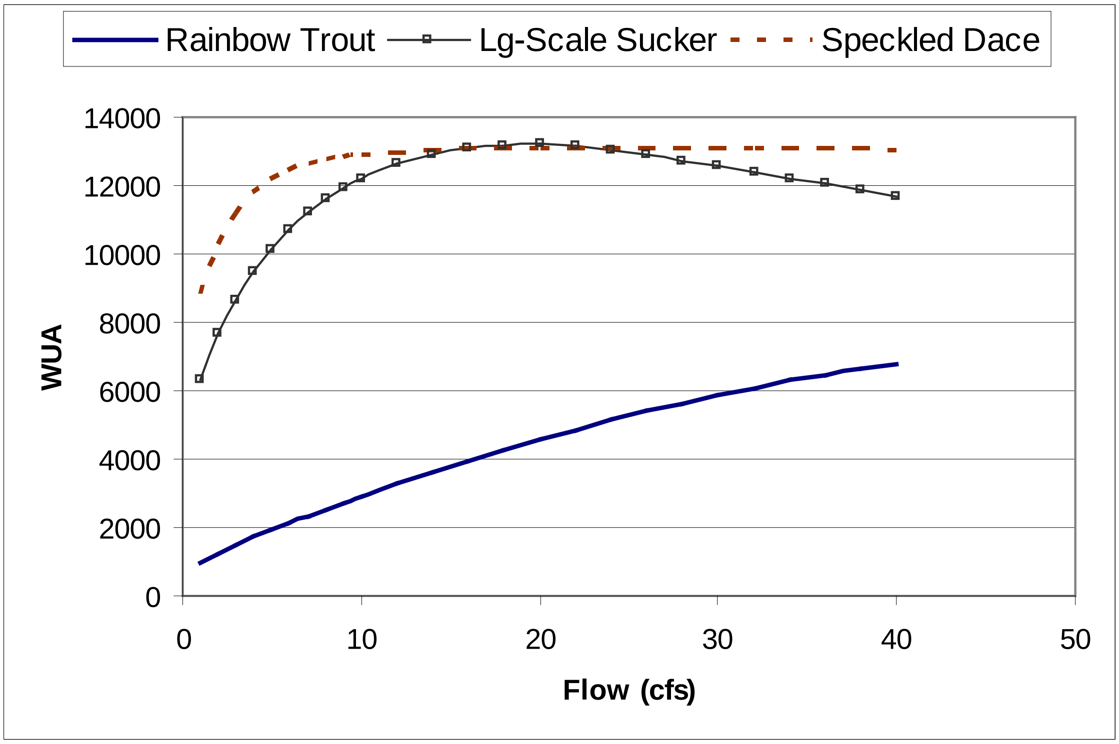

Figure 13. Weighted useable area at the Rock Creek site for three species.

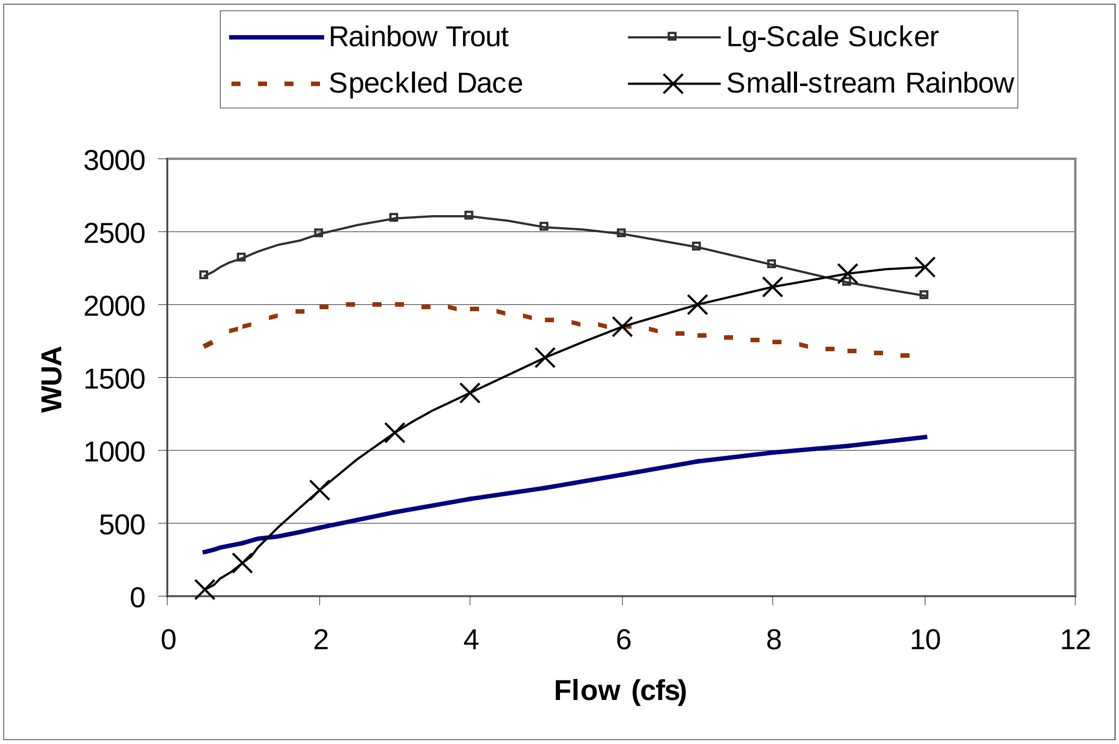

Figure 14. Weighted useable area at the California site for three species.

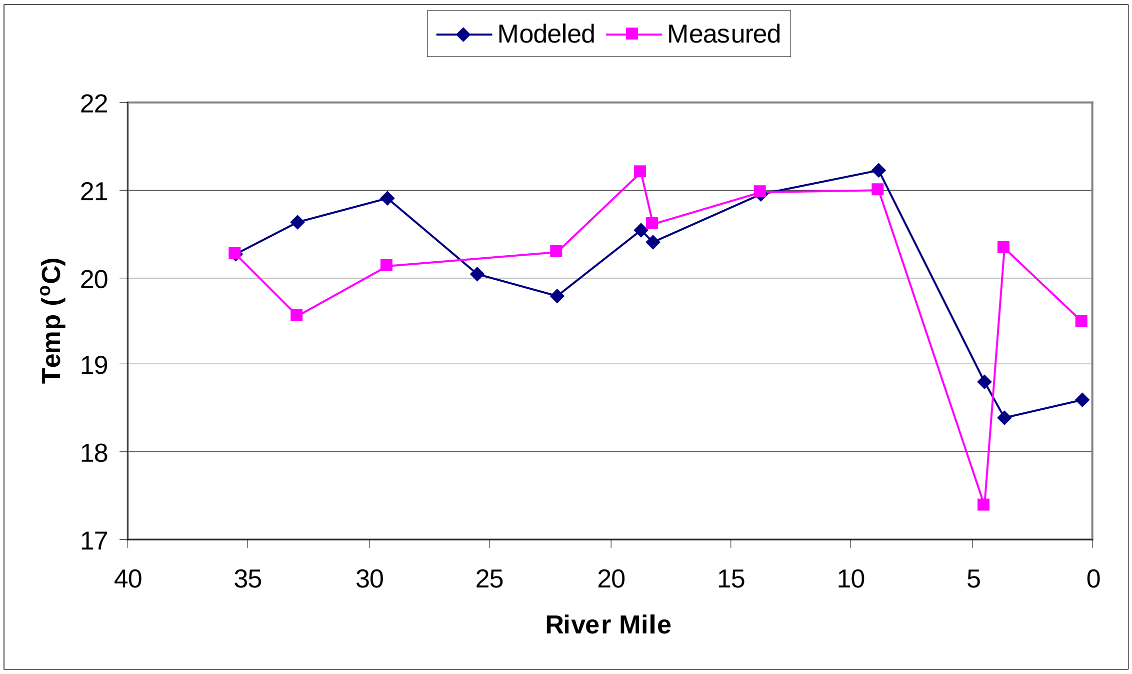

Figure 15. Measured and modeled stream temperatures for week 24.

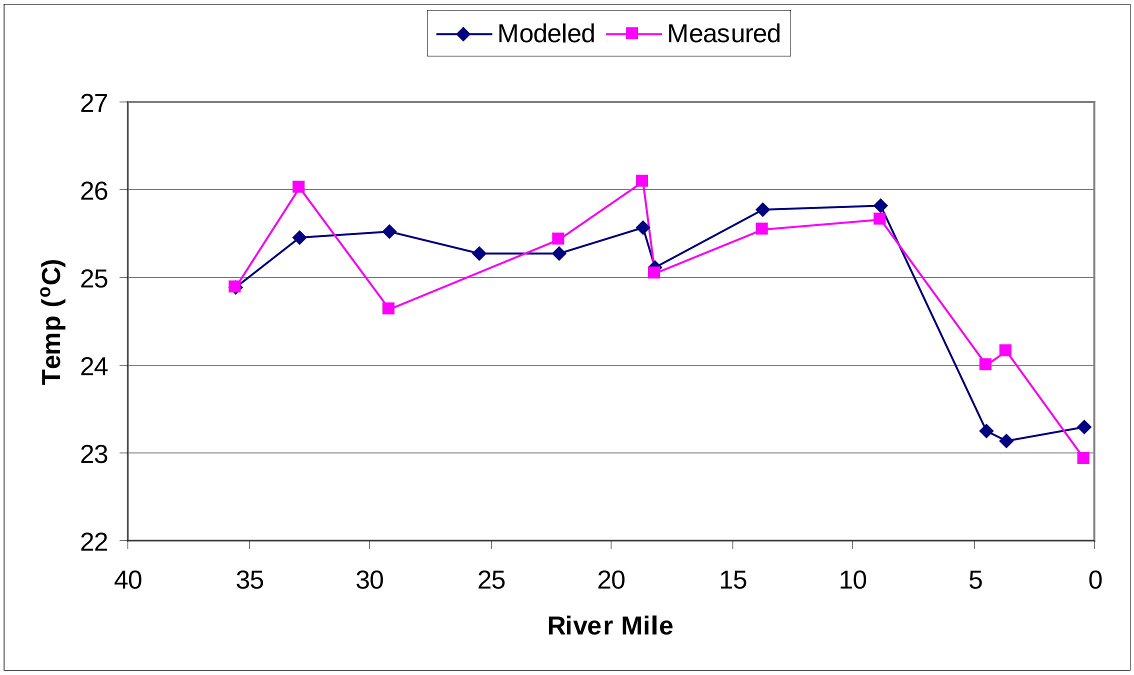

Figure 16. Measured and modeled stream temperatures for week 28.

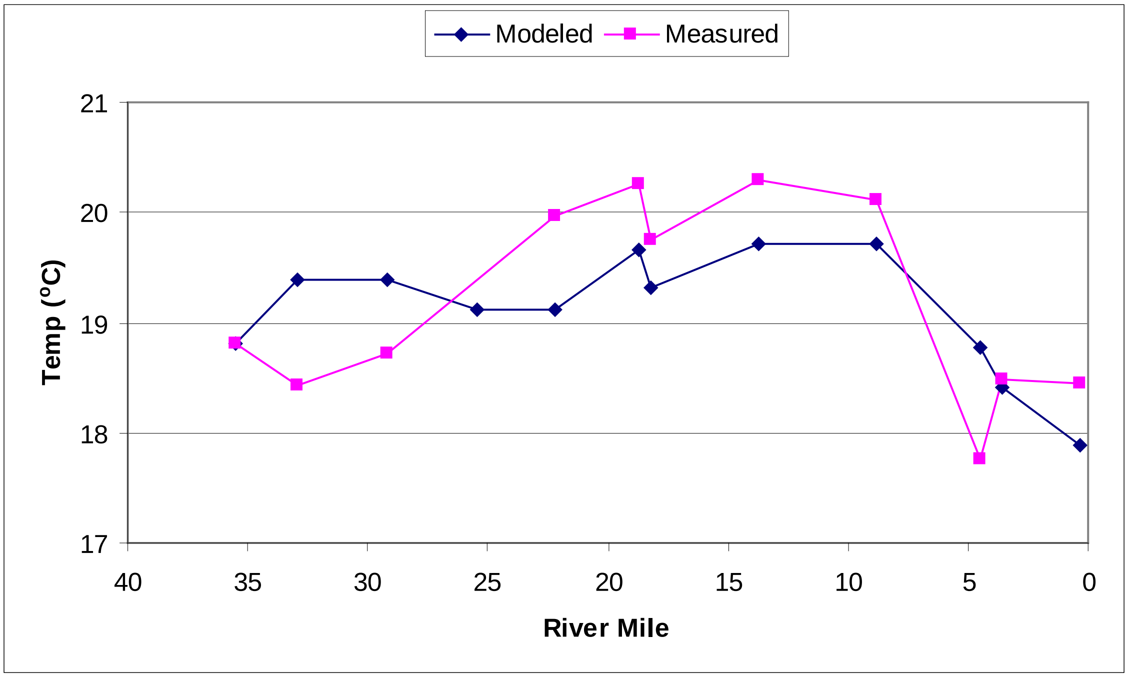

Figure 17. Measured and modeled stream temperatures for week 32.

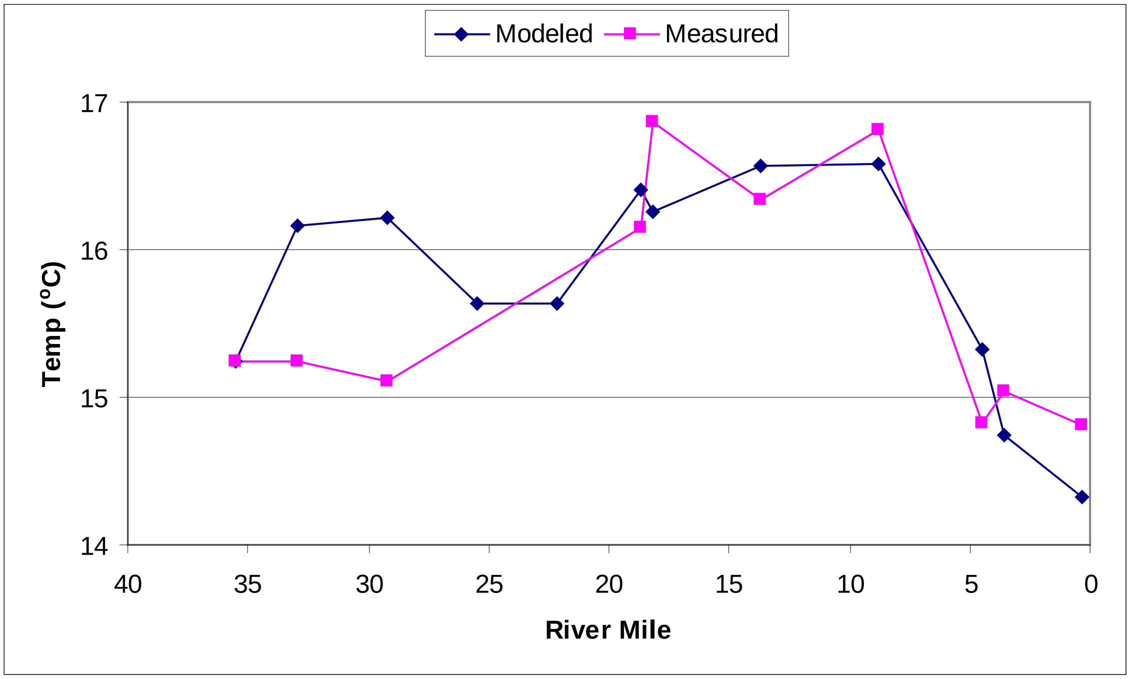

Figure 18. Measured and modeled stream temperatures for week 36.

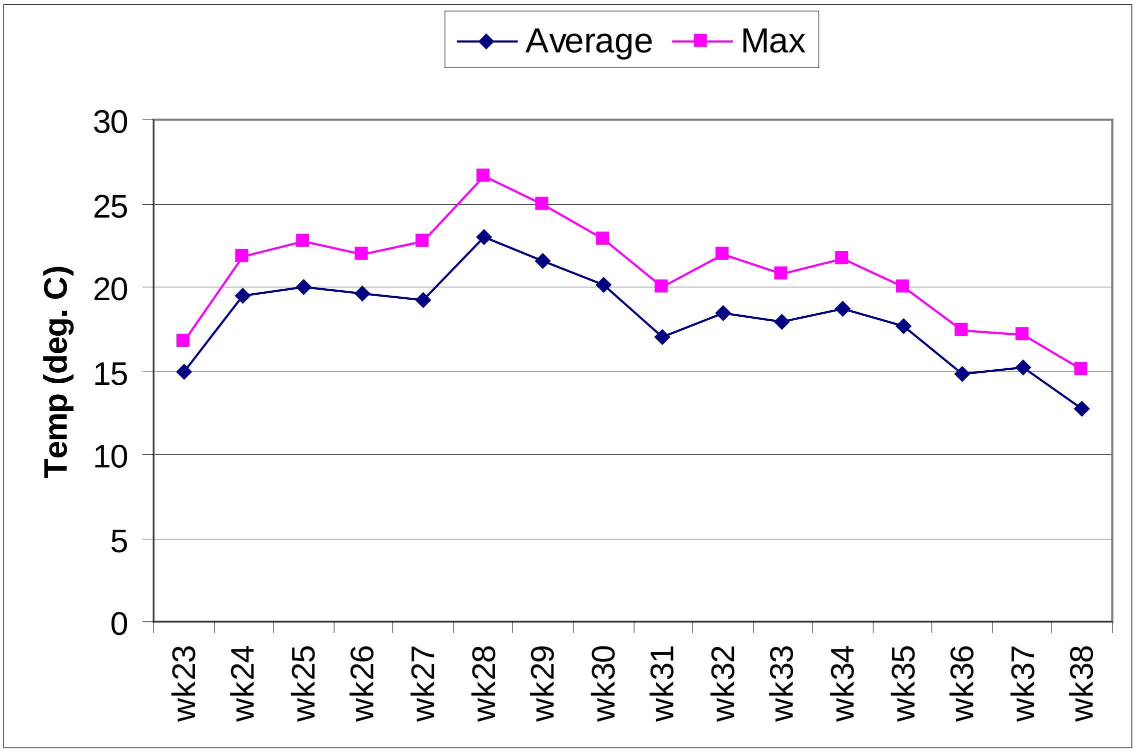

Figure 19. Measured weekly mean and maximum stream temperatures, RM 0.4.

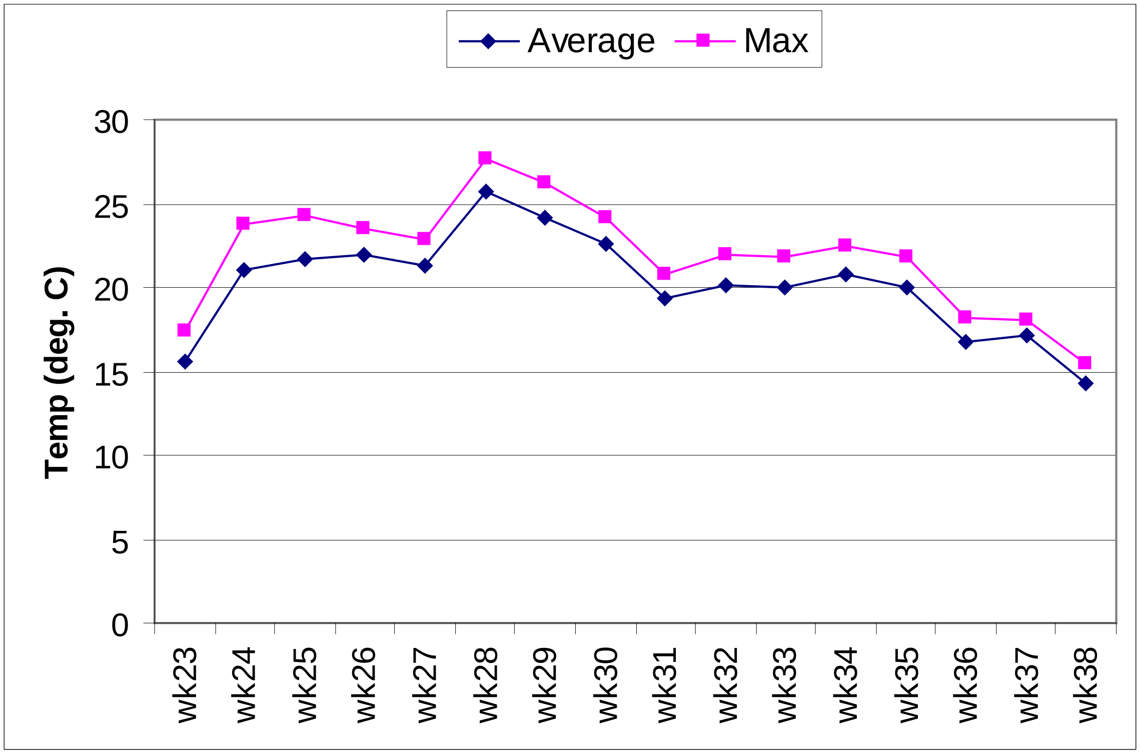

Figure 20. Measured weekly mean and maximum stream temperatures, RM 8.8.

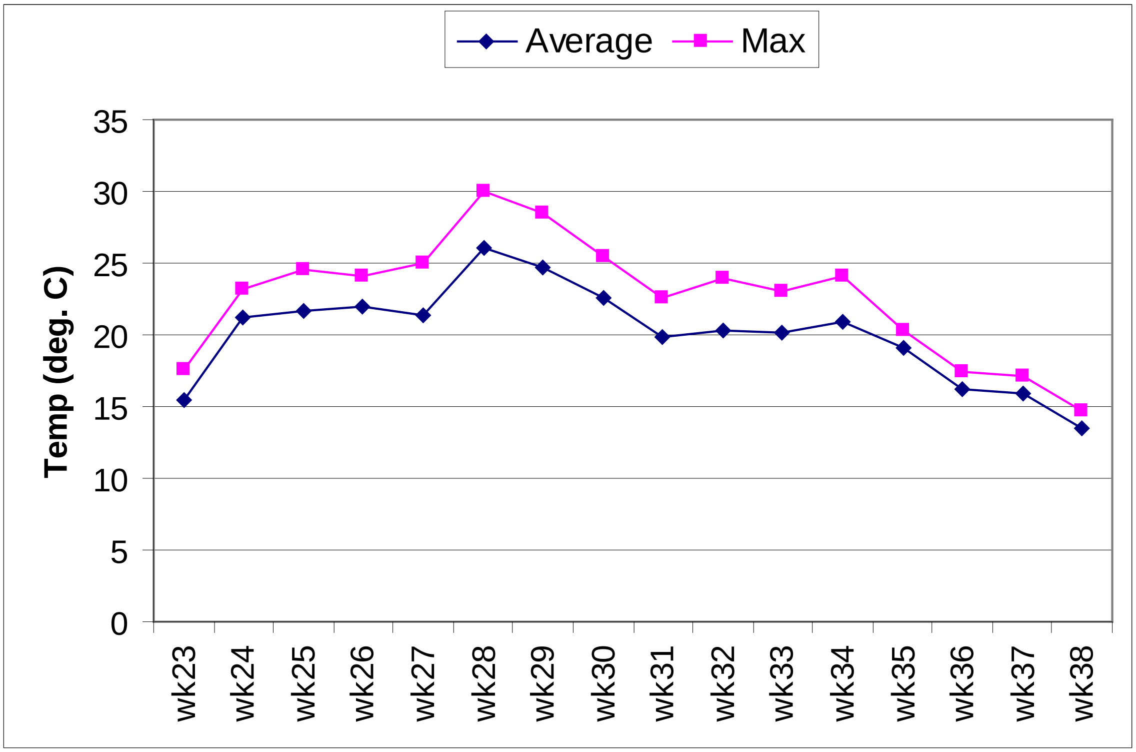

Figure 21. Measured weekly mean and maximum stream temperatures, RM 18.7.

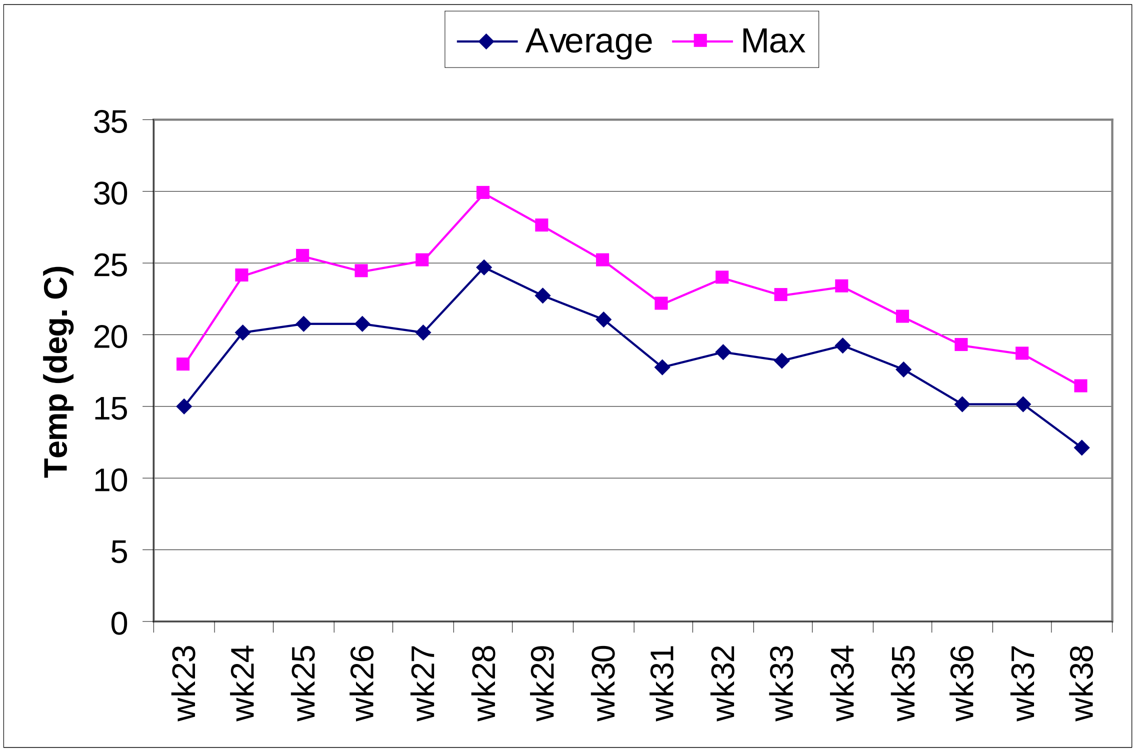

Figure 22. Measured weekly mean and maximum stream temperatures, RM 29.2.

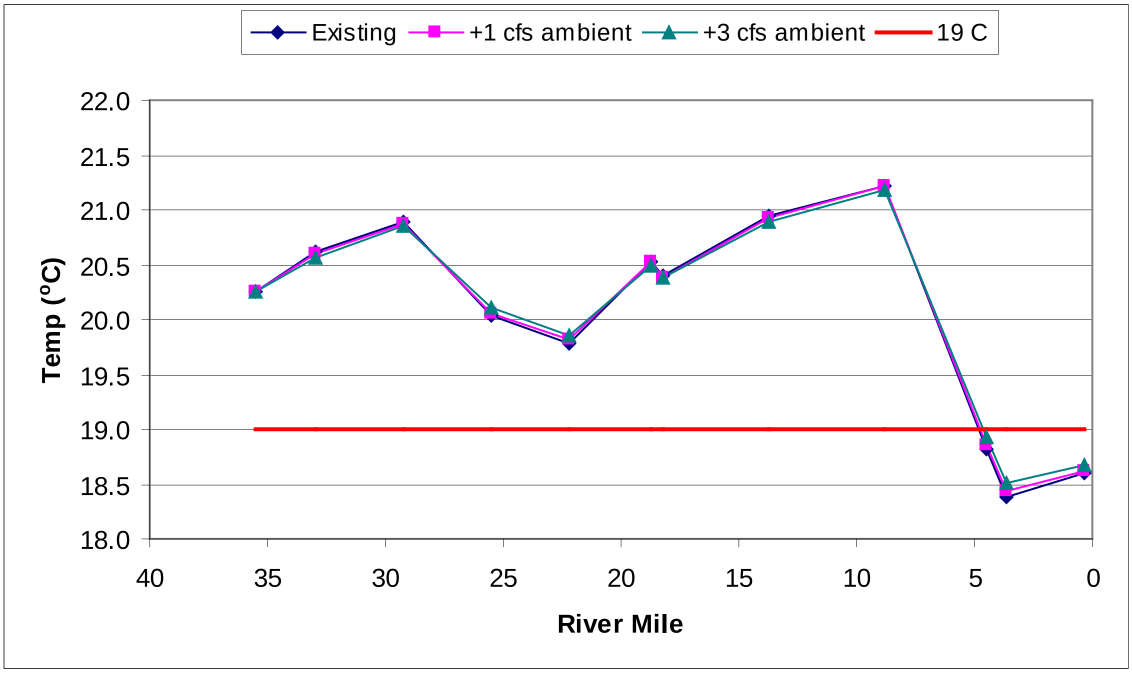

Figure 23. Longitudinal Temperature Comparison, Week 24 – simulated ambient inflow.

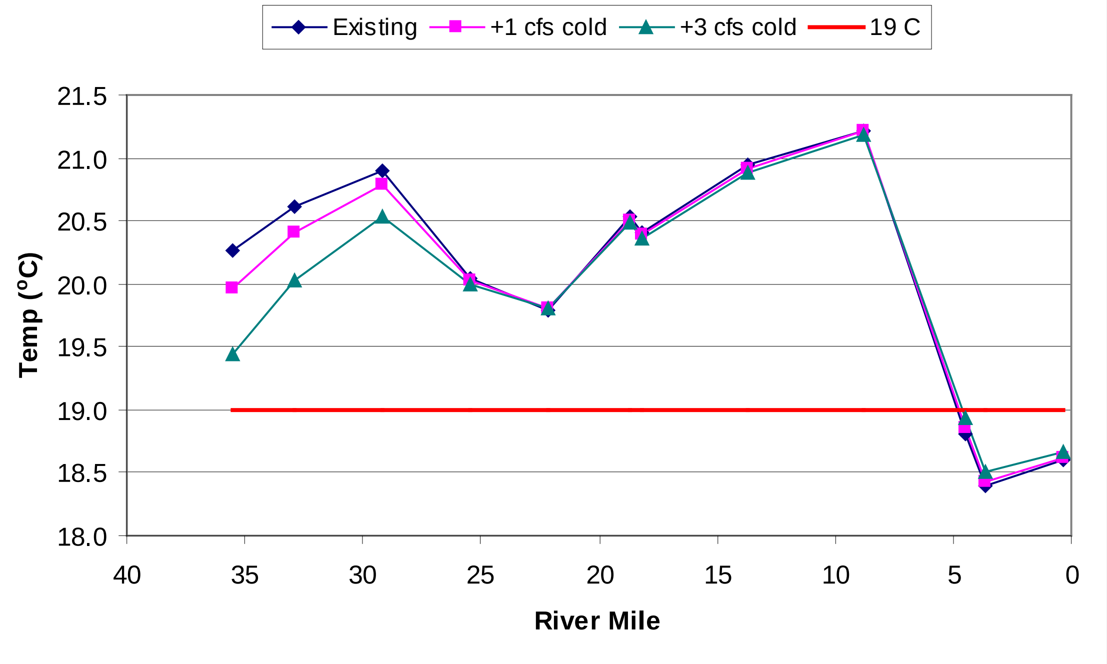

Figure 24. Longitudinal Temperature Comparison, Week 24 – simulated cold inflow.

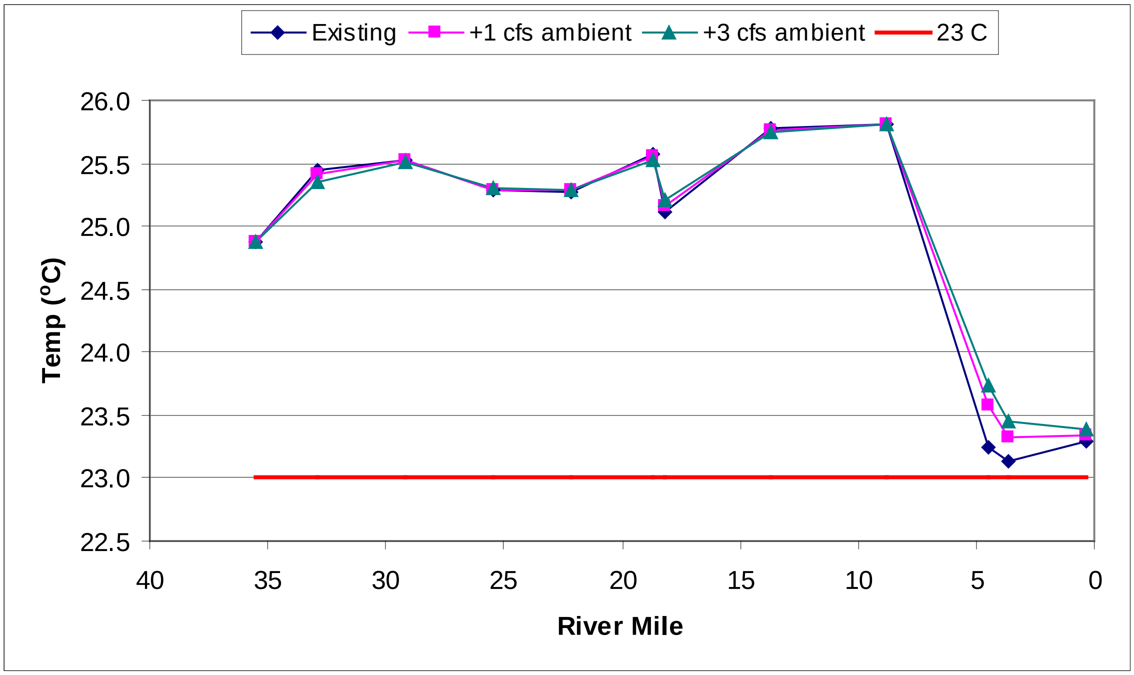

Figure 25. Longitudinal Temperature Comparison, Week 28 – simulated ambient inflow.

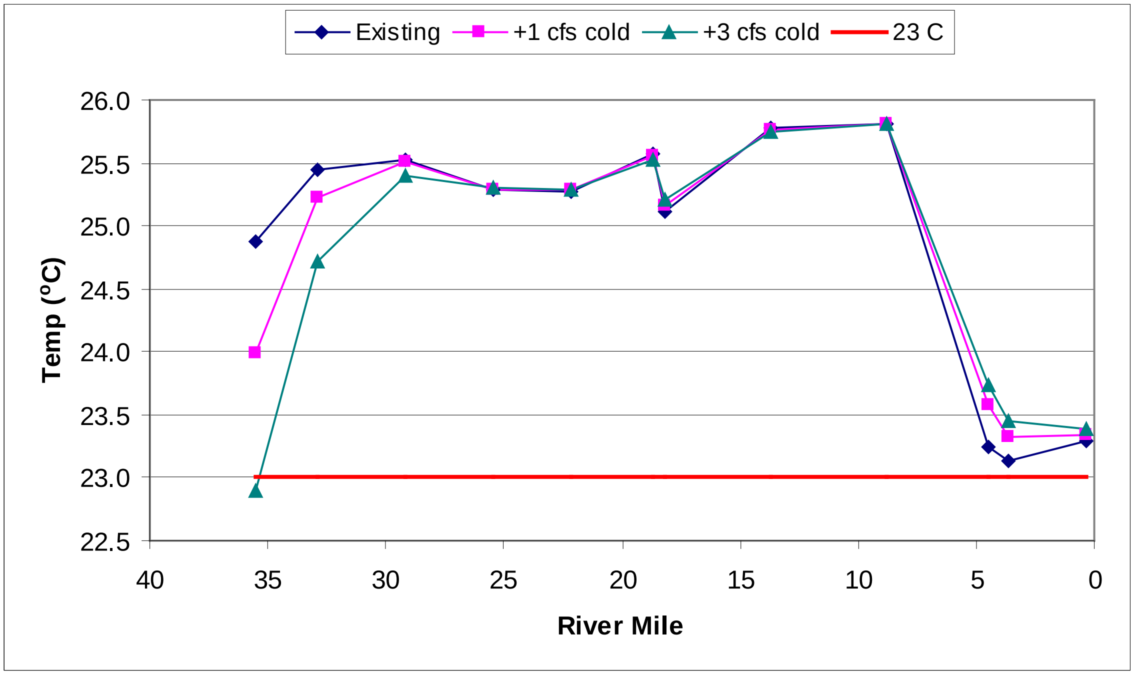

Figure 26. Longitudinal Temperature Comparison, Week 28 – simulated cold inflow.

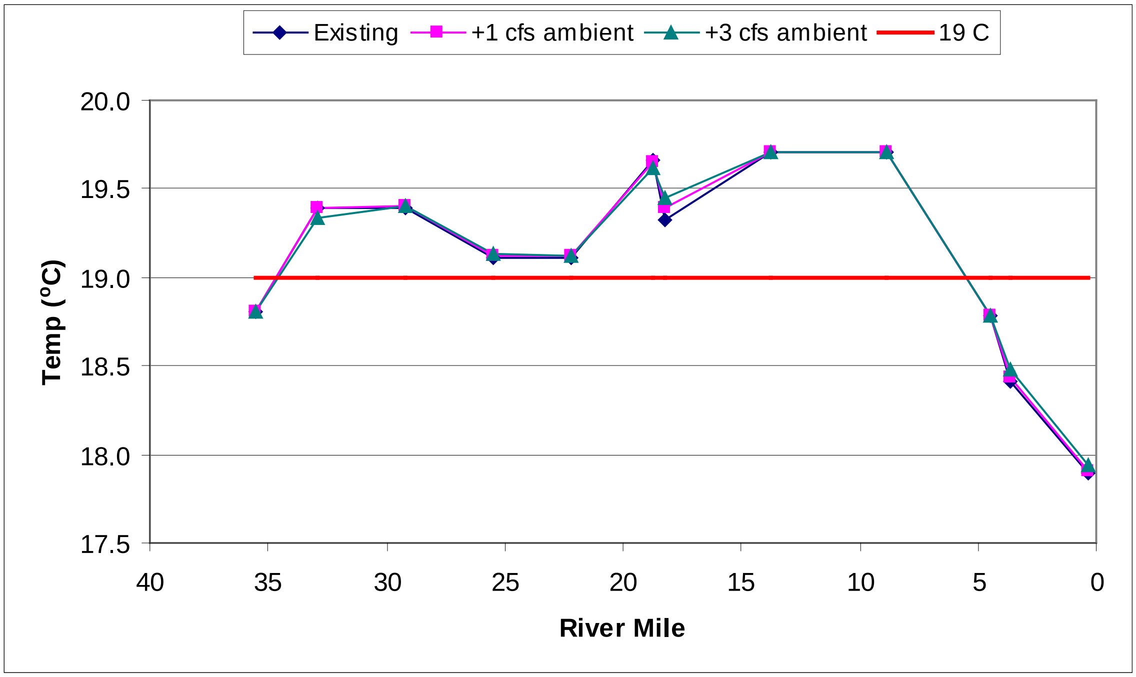

Figure 27. Longitudinal Temperature Comparison, Week 32 – simulated ambient inflow.

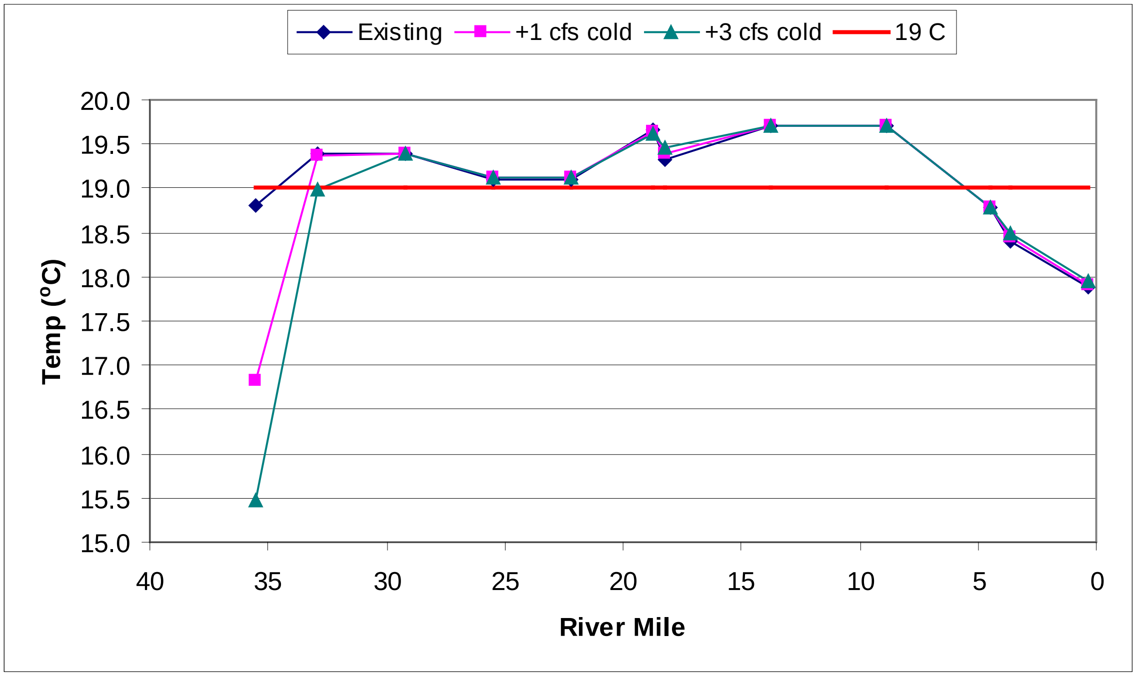

Figure 28. Longitudinal Temperature Comparison, Week 32 – simulated cold inflow.

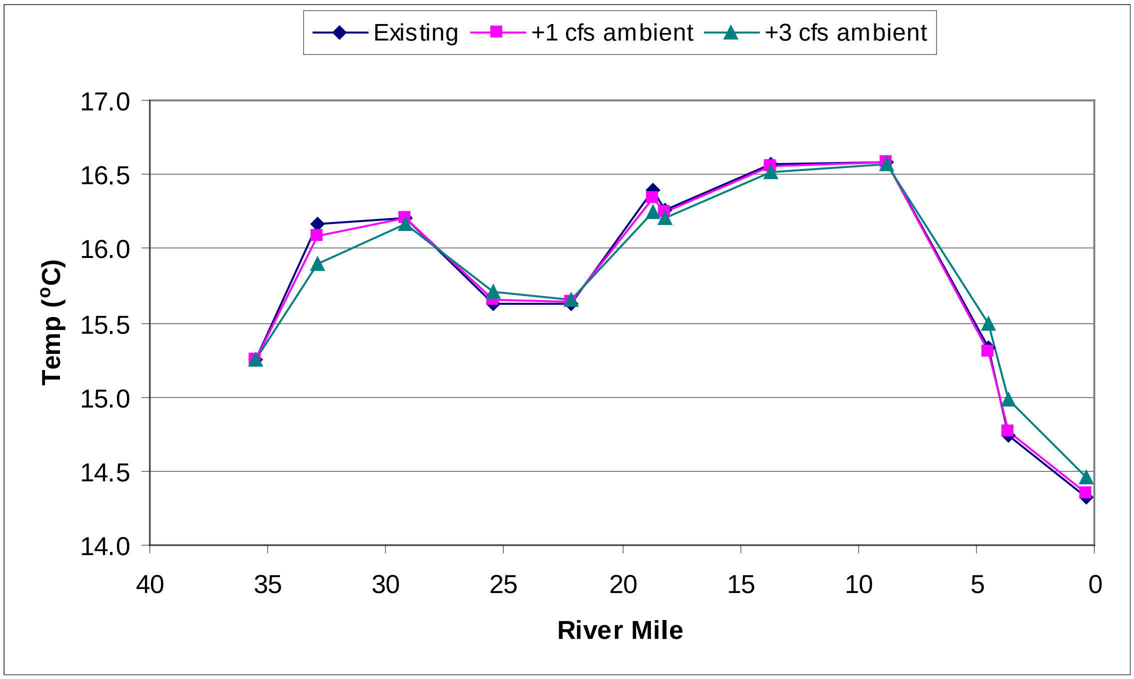

Figure 29. Longitudinal Temperature Comparison, Week 36 – simulated ambient inflow.

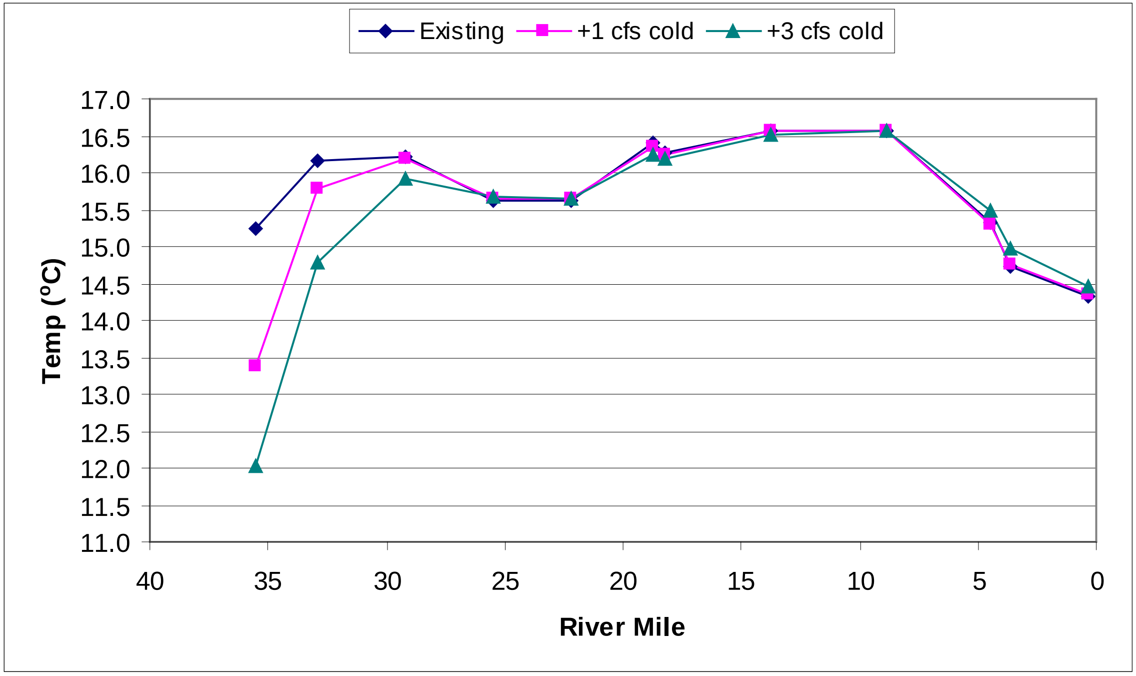

Figure 30. Longitudinal Temperature Comparison, Week 36 – simulated cold inflow.

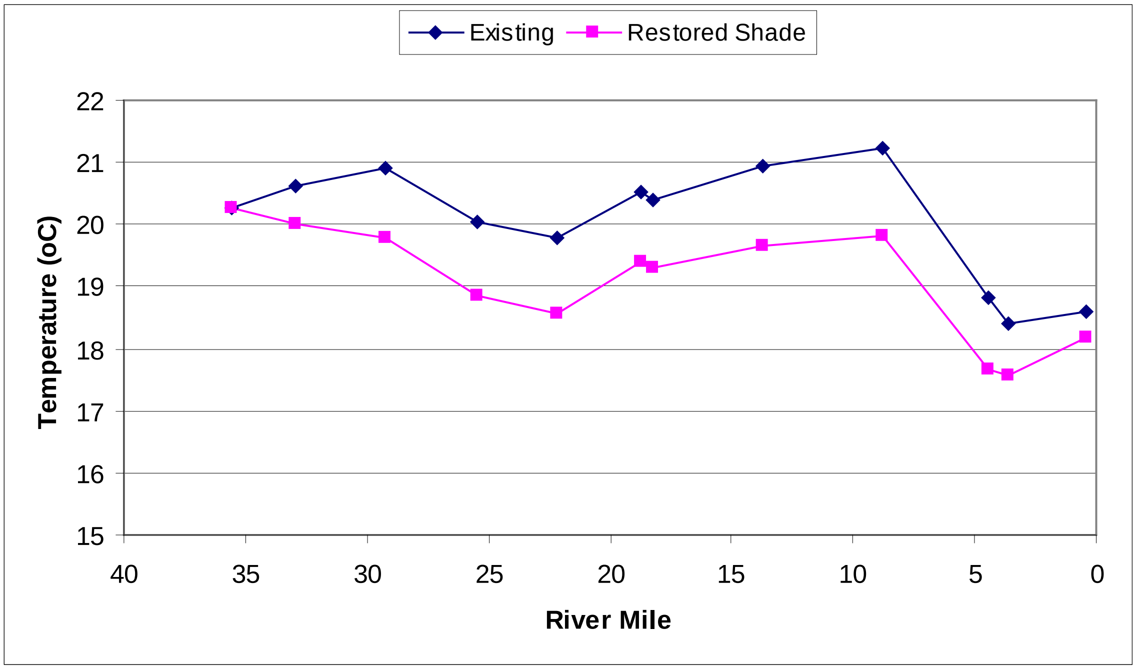

Figure 31. Mean Temperature Comparison, modeled existing conditions and restored shade, Week 24.

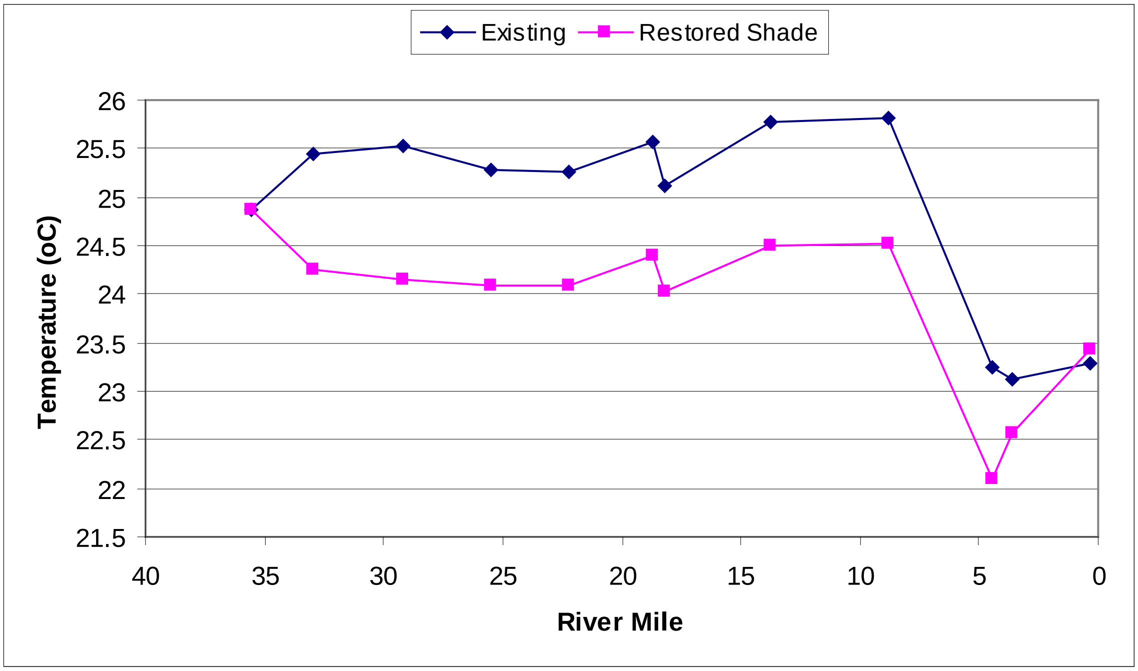

Figure 32. Mean Temperature Comparison, modeled existing conditions and restored shade, Week 28.

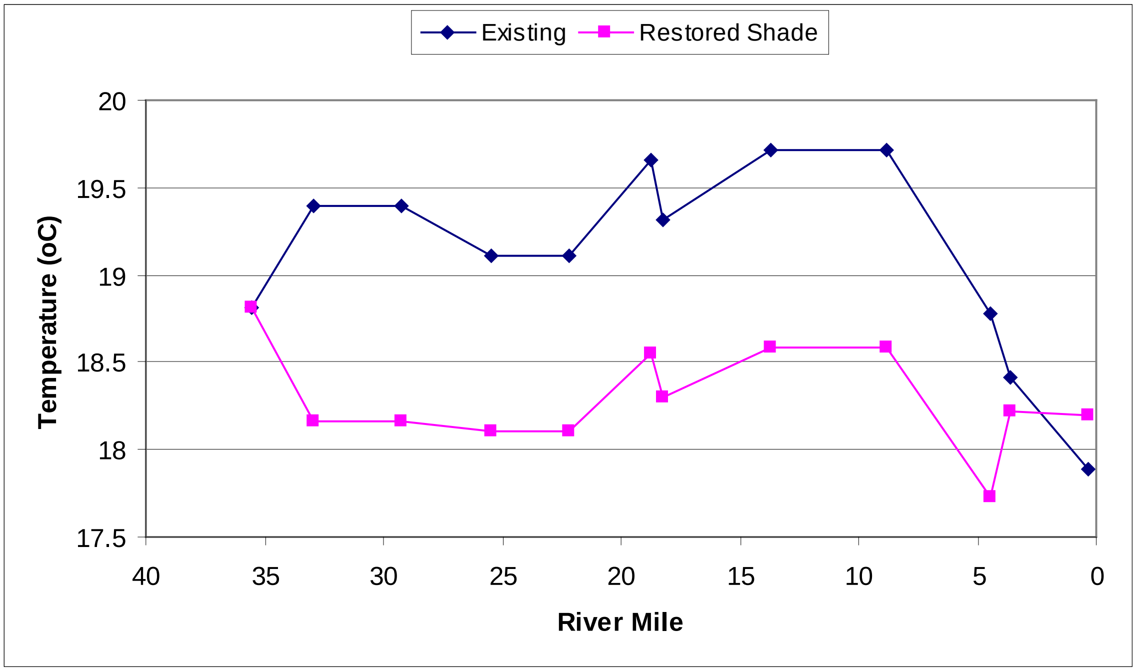

Figure 33. Mean Temperature Comparison, modeled existing conditions and restored shade, Week 32.

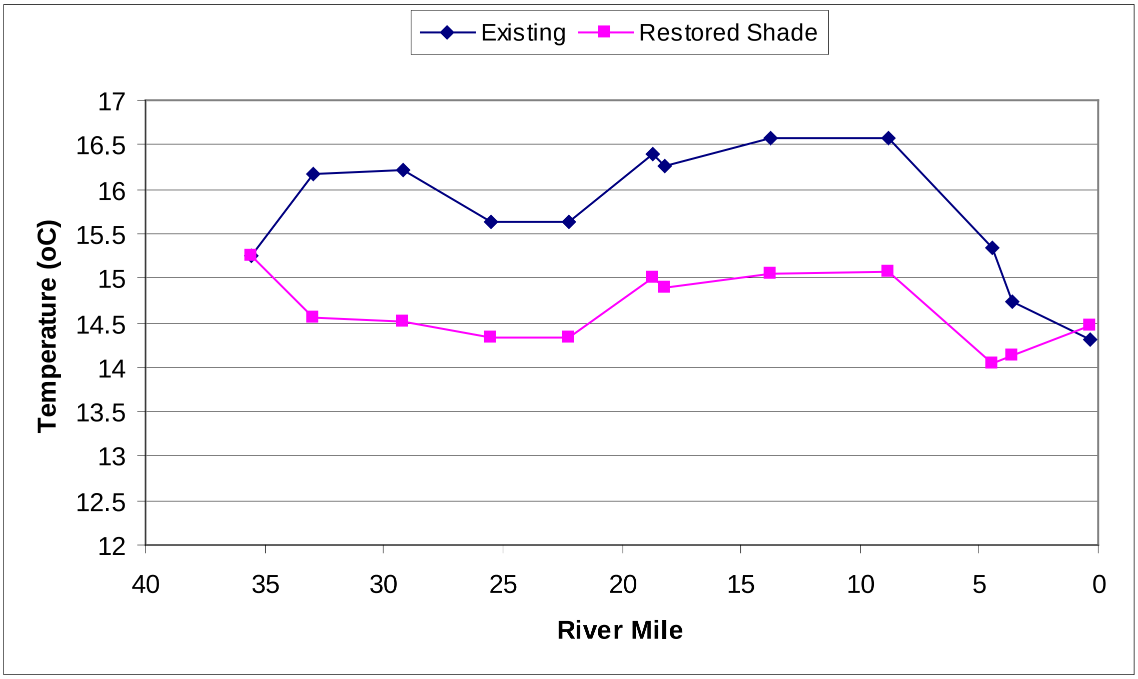

Figure 34. Mean Temperature Comparison, modeled existing conditions and restored shade, Week 36.

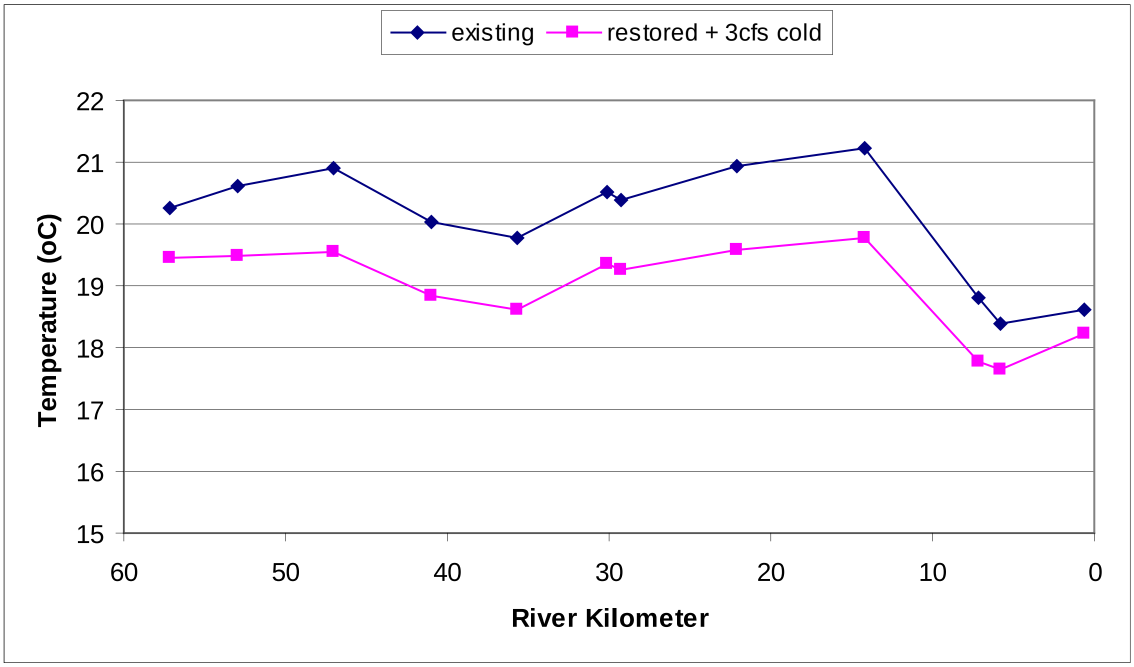

Figure 35. Mean temperature comparison, existing conditions and restored shade and flow, Week 24.

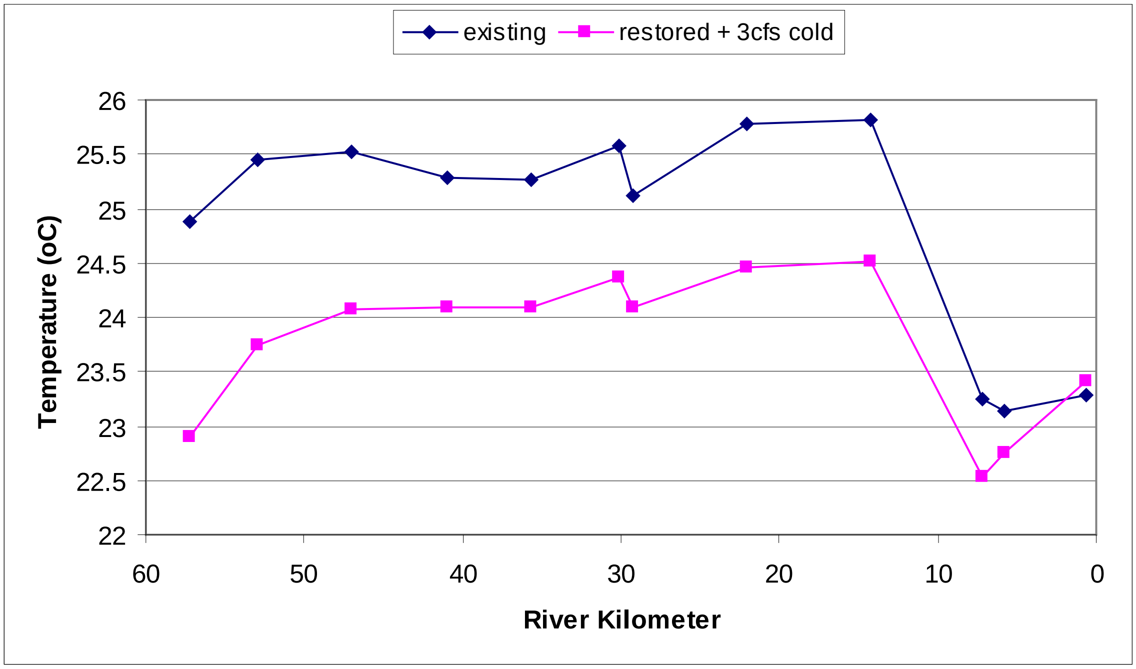

Figure 36. Mean temperature comparison, existing conditions and restored shade and flow, Week 28

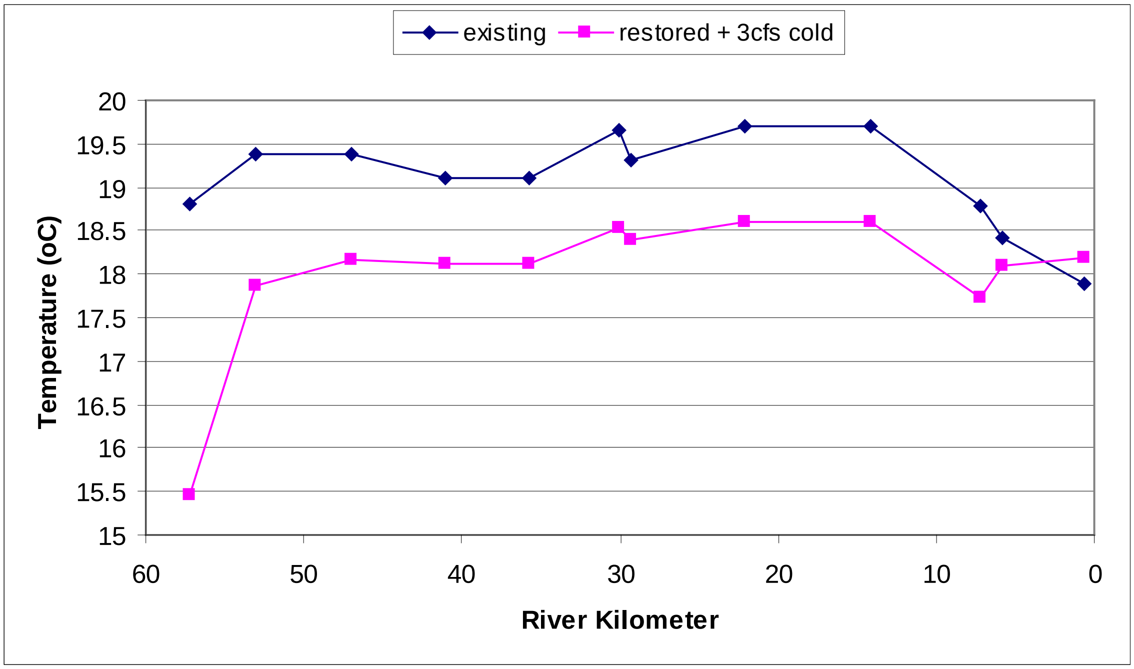

Figure 37. Mean temperature comparison, existing conditions and restored shade and flow, Week 32

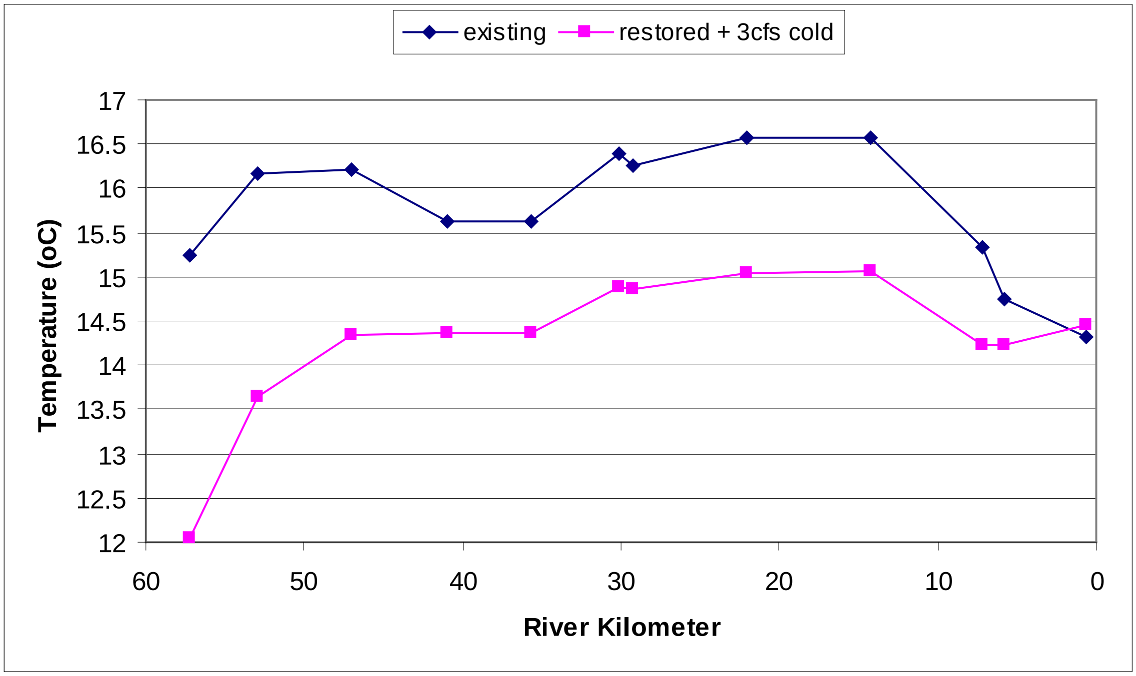

Figure 38. Mean temperature comparison, existing conditions and restored shade and flow, Week 36

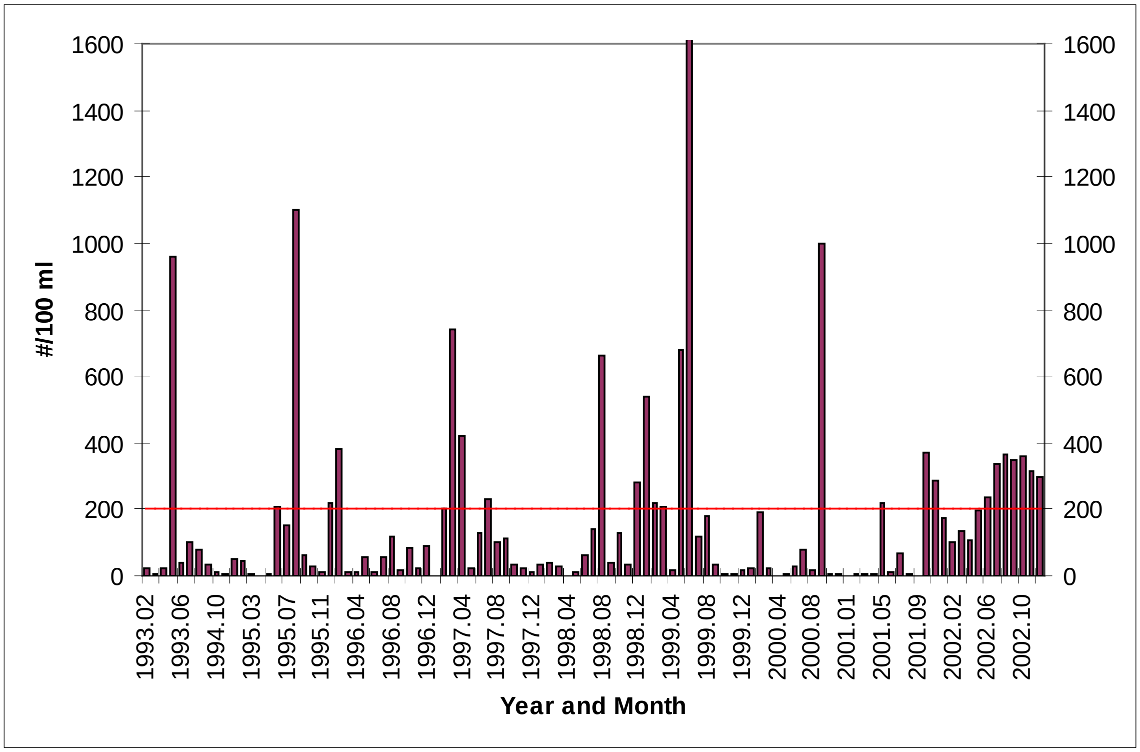

Figure 39a. Fecal coliform levels measured one day per month in Latah Creek near the mouth; 26 out of 103 measurements exceed maximum recommended level (DEQ data, 1993-2002).

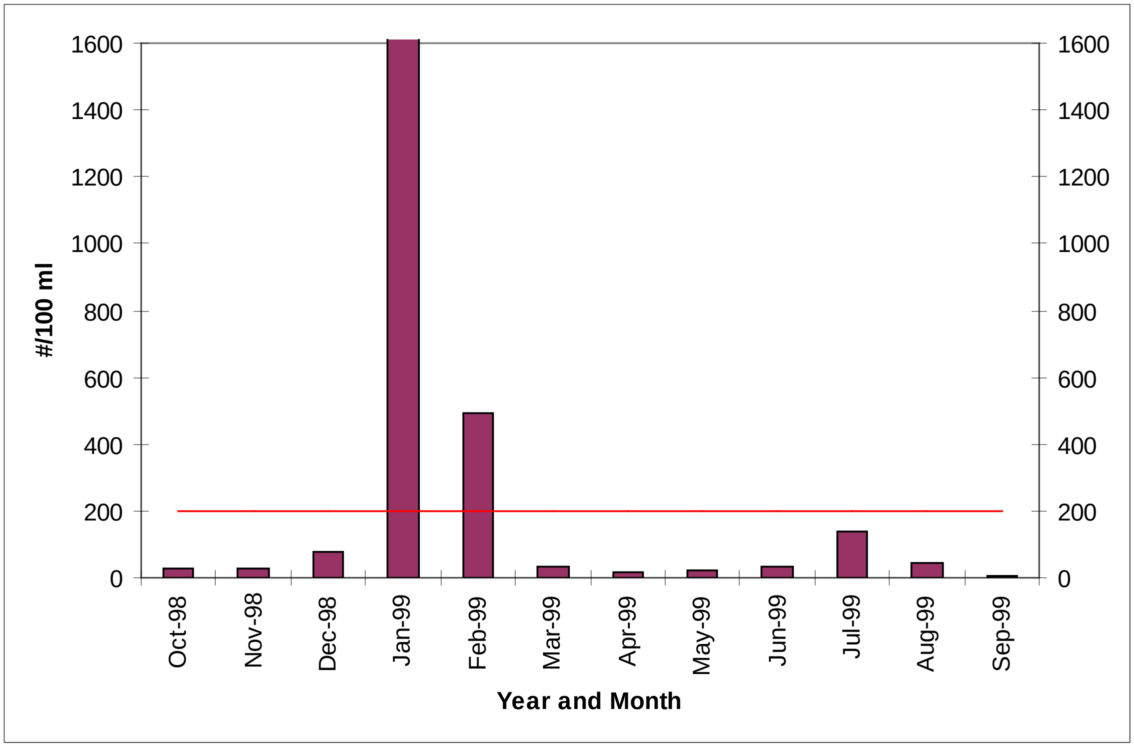

Figure 39b. Fecal coliform levels measured one day per month in Latah Creek near Bradshaw; 2 out of 12 measurements exceed maximum recommended level (DEQ data, 1998-1999).

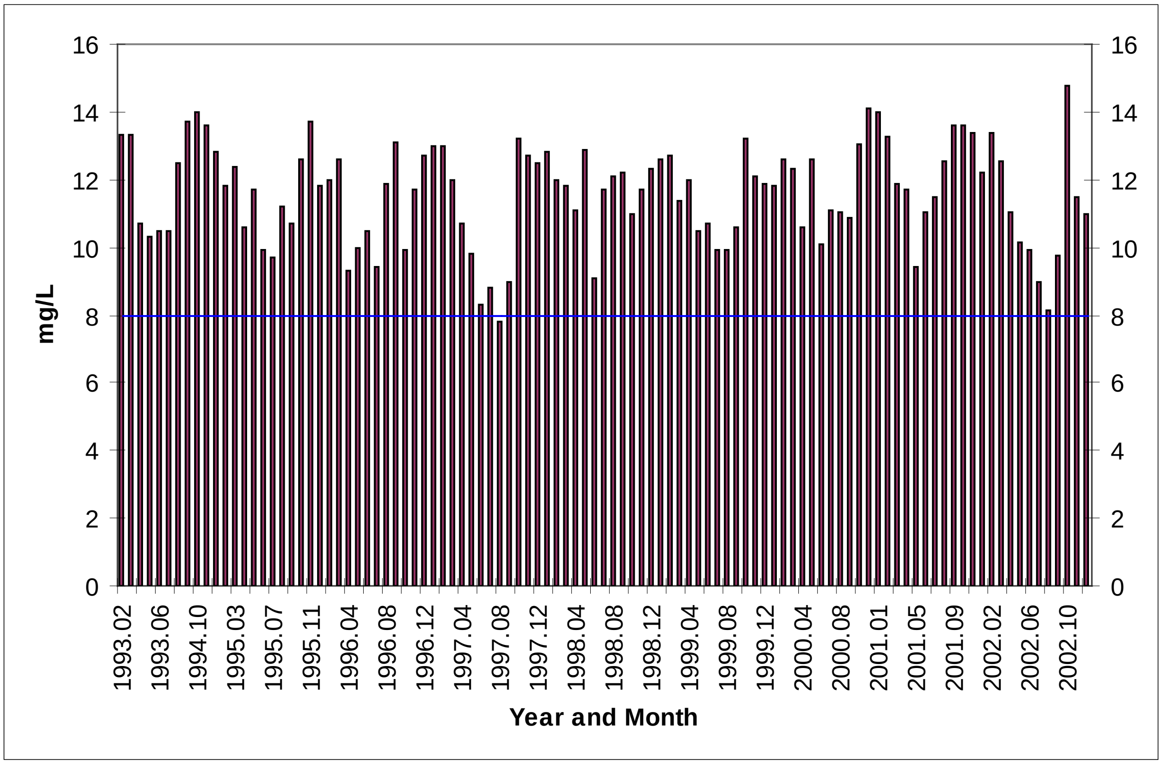

Figure 40a. Dissolved oxygen levels measured one day per month in Latah Creek near the mouth; 1 out of 103 measurements exceed minimum recommended level (DEQ data, 1993-2002).

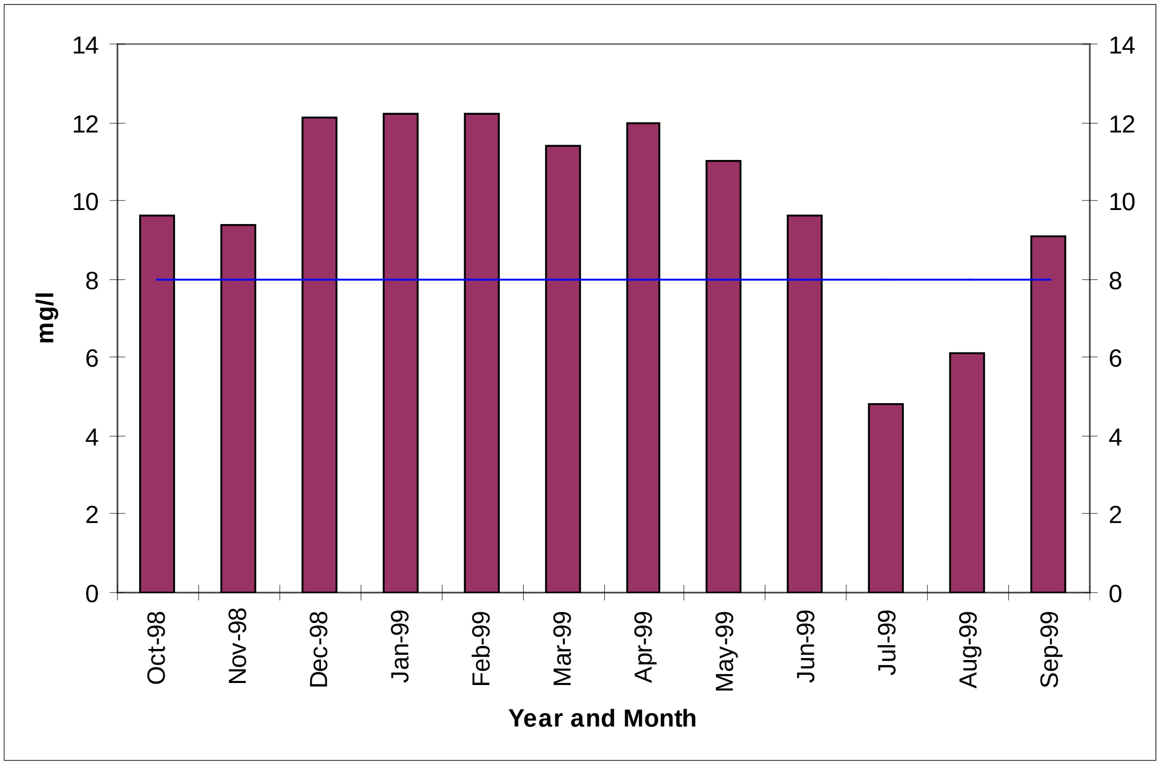

Figure 40b. Dissolved oxygen levels measured one day per month in Latah Creek near Bradshaw; 2 out of 12 measurements exceed minimum recommended level (DEQ data, 1998-1999).

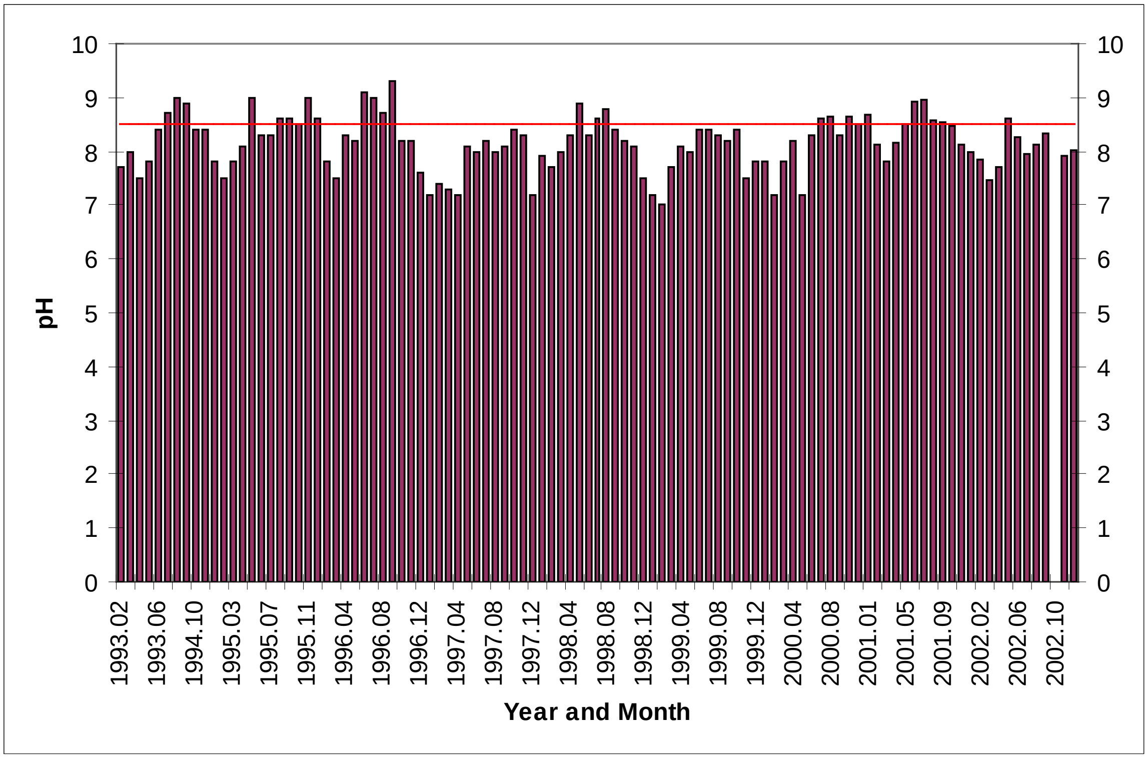

Figure 41a. PH levels measured one day per month in Latah Creek near the mouth; 25 of 103 measurements exceed maximum recommended level (DEQ data, 1993-2002).

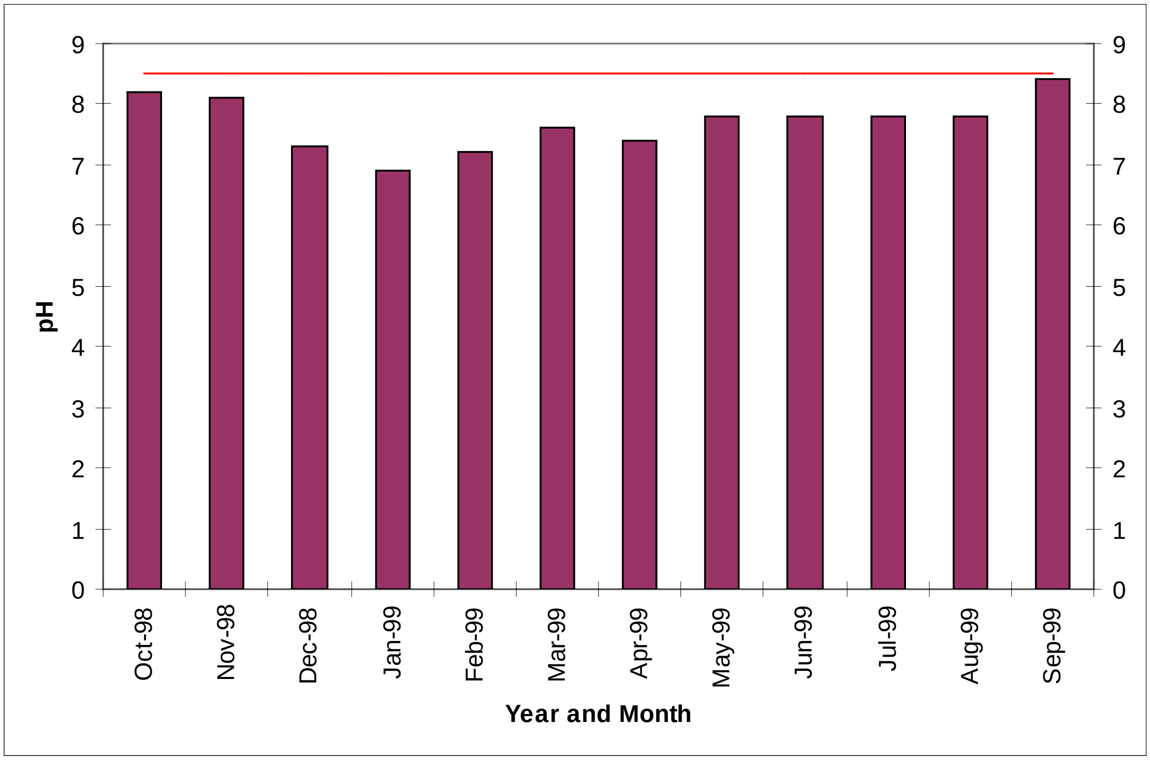

Figure 41b. PH levels measured one day per month in Latah Creek near Bradshaw; 0 of 12 measurements exceed maximum recommended level (DEQ data, 1998-1999).

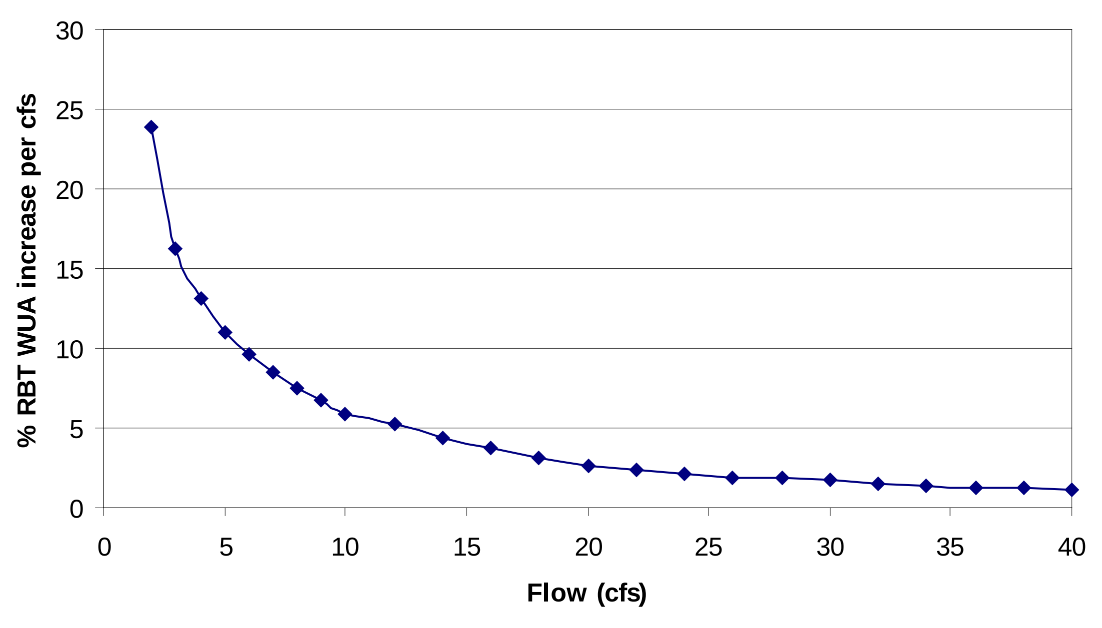

Figure 42. Percent rainbow trout WUA increase per 1 cfs, RM 35.4.

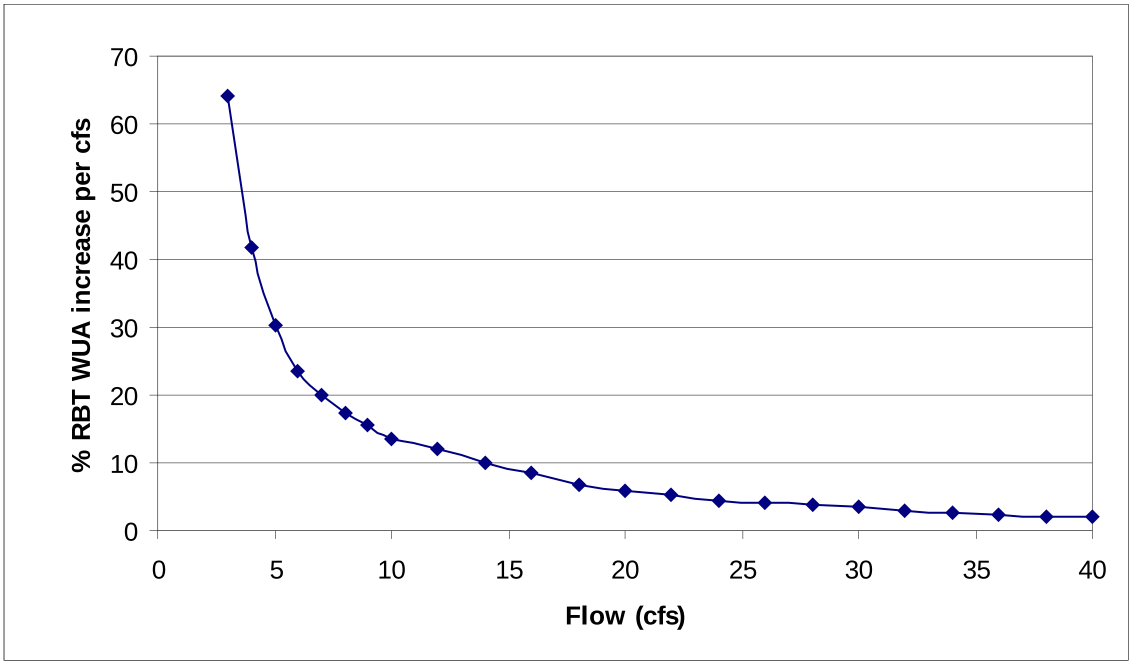

Figure 43. Percent rainbow trout WUA increase per 1 cfs, RM 29.2.

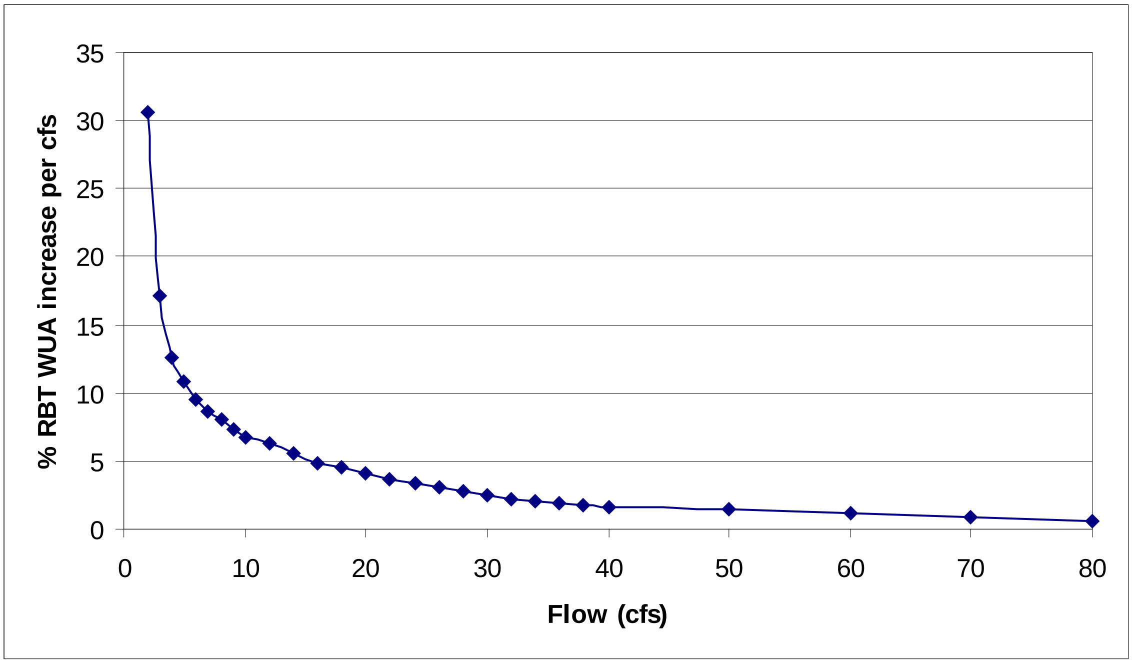

Figure 44. Percent rainbow trout WUA increase per 1 cfs, RM 2.5.

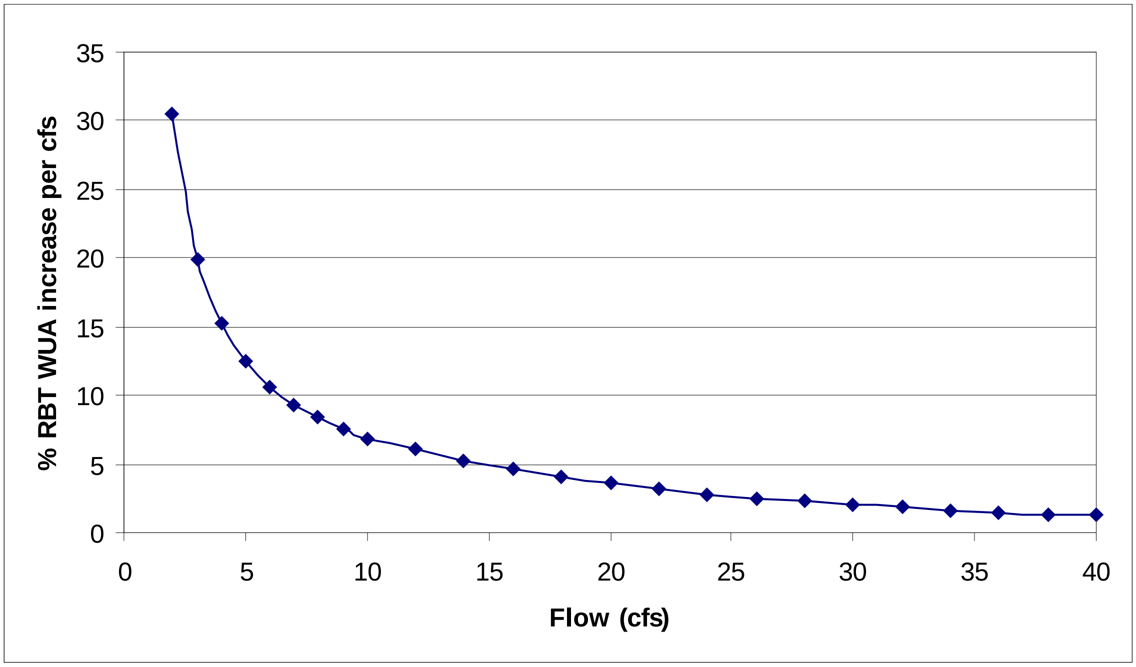

Figure 45. Percent rainbow trout WUA increase per 1 cfs, Rock Creek site.

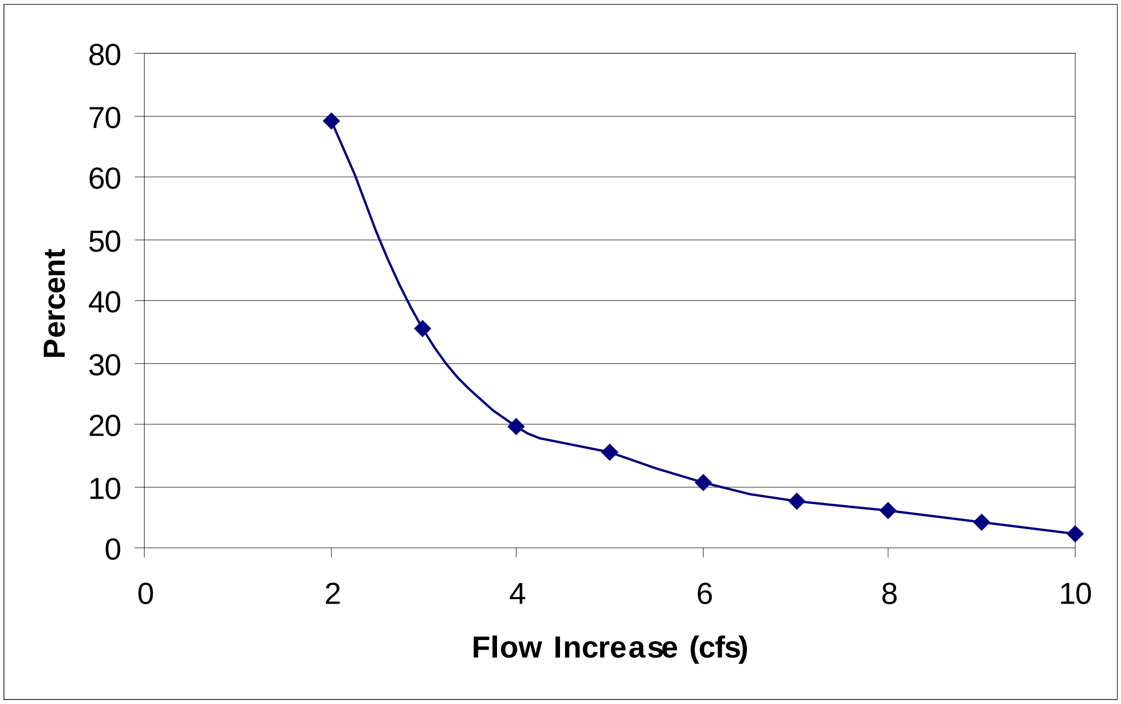

Figure 46. Percent rainbow trout WUA increase per 1 cfs, California Creek site.

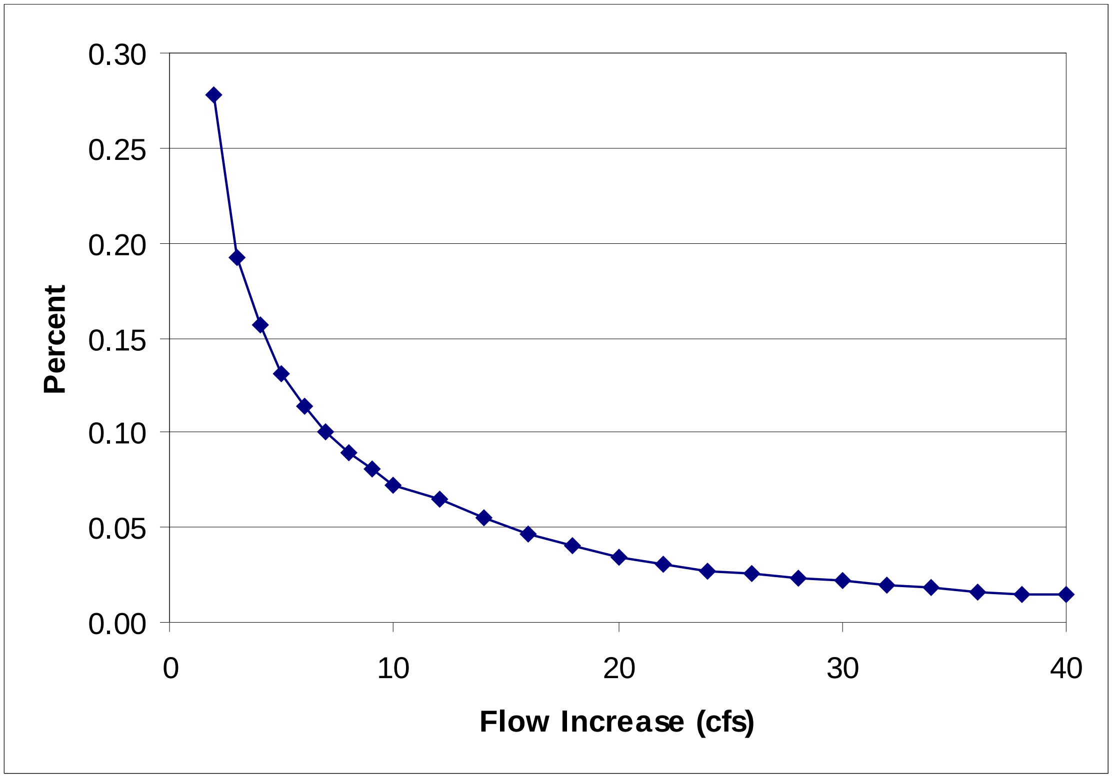

Figure 47. Percent rainbow trout WUA increase per 1 cfs, Latah Creek above Marshall Creek.

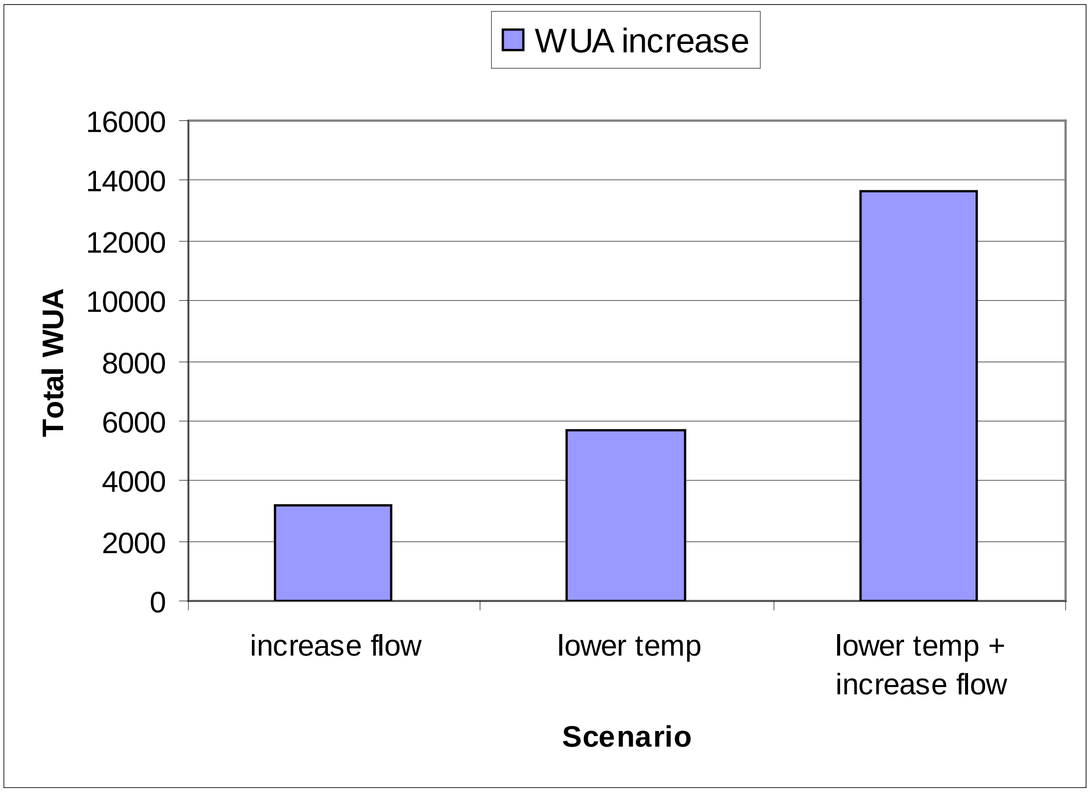

Figure 48. Example of WUA increase with improvements in flow and temperature individually, and combined (based on data from site at RM 29.2).