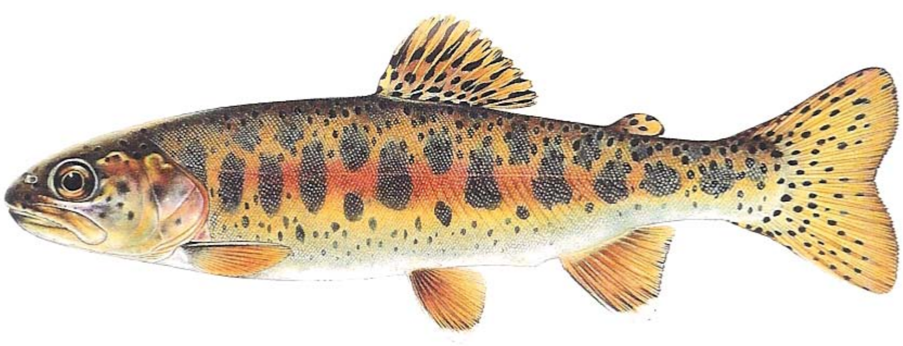
Progress Report
Hangman Creek Fisheries Restoration
BPA Project #2001-032-00
Completed in Contract #52962

Covers data collected for Contracts:
#2508
#6180
#22363
#27859

2004-2007



Redband trout (Oncorhynchus mykiss gairdneri)

Bruce Kinkead- Project Lead

Jon Firehammer-RME Specialist

Coeur d'Alene Tribe-Fisheries Program

401 Annie Antelope Drive

Plummer, ID 83851

8/26/2011

Table of Contents

List of Figures and Tables

EXECUTIVE SUMMARY

The BPA project entitled “Hangman Creek Fisheries Restoration Project”, which began in 2002, mitigates for lost fishery resources that are of cultural significance to the Coeur d’Alene Tribe. This project funds management actions, and research, monitoring, and evaluation (RME) activities associated with these actions, which are carried out by the Coeur d’Alene Tribe’s Fisheries Program to recover populations of redband trout *(Oncorhynchus mykiss gairdneri)* trout in the Spokane basin. This report summarizes RME data collected during 2004-7 that describe the status and trends of redband trout in target sub-watersheds, water quality, hydrology, macro-invertebrate assessment, as well as a summary of initial restoration efforts.

Research, monitoring, and evaluation summary

The entire Hangman Creek watershed within Idaho borders, consisting of 215,097 acres, was assessed for fisheries distribution, genetics, and relative abundance of redband trout, Level 1 Rosgen channel typing, macro-invertebrate population analysis, and water quality during 2004. Those portions of the watershed commonly known as the northern watershed consisting of Rock Creek and its tributaries were eliminated from RM&E efforts after analysis revealed feasibility of restoration is out of the scope of funding for the project and would not be a priority in the near future. The remaining three years was devoted toward evaluation of the area commonly known as the southern watershed consisting of 157,586 acres. Genetic sampling using electroshock methods involved a more concentrated effort for a number of reaches sampled in 2003-4.

Redband trout distribution and abundance

Moderate numbers of redband trout are found in Indian Creek, and short reaches of Mission, Sheep, and tributaries east of the Reservation boundaries. Given that one of the primary objectives of the project identified in the Spokane subbasin plan is to increase the distribution of redband trout, it is imperative that conditions conducive to establishment are restored in those reaches that currently are seemingly restricting the spatial extent of existing remnant subpopulations. Hangman Creek has the morphological characteristics of stream reaches with low gradient mid elevation reaches located in alluvial valleys with prominent floodplain habitats, as well as overwintering habitat with deep, slow moving pool habitats for redband trout. Though pools are scarce in tributary reaches, pools greater than 1m are present in some tributary locations and main-stem reaches.

Improving the suitability of rearing habitats to expand the spatial distribution of redband trout would also likely increase connectivity and promote the exchange of reproductive individuals among tributary sub-populations. Genetic analysis indicated evidence of reproductive isolation for sampled subpopulations in tributary reaches, which may be a result of degraded habitat in areas downstream of sample locations that is inhibiting the movement of adults among subpopulations. Alternatively, the differences in genetic signature may be a result of genetic drift associated with small effective populations, which is shown in significant departures from Hardy-Weinberg equilibrium. Whatever the reason, increasing the connectivity of tributary subpopulations would promote a more robust and resilient population structure and would minimize the adverse consequences (e.g., demographic stochasticity, inbreeding depression) that arise from isolated, small populations. Further, given that the genetic signature from redband

trout in California Creek, a tributary in the lower reach of Hangman Creek, aligned more with fish from upper Hangman than with those downstream in the Spokane subbasin, there is evidence that movement and sub-population connectivity throughout the drainage likely existed in the past and may have been an important mechanism that promoted metapopulation persistence. This suggests that conditions in Hangman Creek have prevented successful colonization of non native rainbow trout found in the Spokane River, and the expected genetic introgression with native redband trout.

Another finding from the genetic analyses is that fish sampled from upper Nehchen Creek were genetically more similar to cutthroat trout, than to redband trout. However, given the low allelic richness detected in these fish and the lack of detectable cutthroat genes in other sampled tributary subpopulations, it confirms a landowner's statement that these fish were transplanted in 1985 from a tributary in the Coeur d'Alene Lake Basin, and not from elsewhere in the watershed.

Not only was the distribution of redband trout limited in the upper Hangman watershed, but estimated densities of age 1 and older fish were typically less than 12 fish/100 m in many of the reaches in which they were found over all years during the reporting period. These densities convert to real densities of 6 fish/100m^2 , and when compared to literature compiled for high desert and montane streams of southern Idaho and eastern Oregon, would be considered low density. Moderate density would be considered 6-19 fish/100m^2 and greater than 20 would be considered high density. Based on this delineation, some of the reaches in the watershed supported moderate to high densities of redband, suggesting that given the appropriate conditions, redband trout can approach rather high densities in the upper Hangman watershed.

Though redband trout densities were low overall across the upper Hangman watershed, the age class structure was apparently stable with one to three year olds consistently well represented in fish collections over reporting years, suggesting high levels of mortality for these age groups would not fully explain the low densities of fish in surveyed reaches. Rather, the lack of fish may partly the results of factors such as insufficient spawning habitat, high mortality rates of fry, or a scarcity of spawners to seed available habitat. However subwatersheds such as Sheep and the South Fork of Hangman may not support older age classes, as age 1 fish dominate the sampled reaches, suggesting either high mortality rates or high rates of emigration out of these tributaries into Hangman main-stem reaches downstream.

Whereas summer monitoring efforts revealed a lack of age 3+ redband in reaches sampled across the upper Hangman watershed, spring migration trapping at two tributary locations and one main-stem location, captured a high proportion of fish over the size of 200mm. Although the numbers of fish caught were small, it may not adequately describe how many spawners are in the system due to trap efficiency compromised by high flows during spring freshets. Alternatively, the lack of large redband trout in summer surveys but their presence in migrant traps could be attributed to seasonal differences in habitat use in the upper Hangman watershed. Large adults may be overwintering in deep main-stem habitat and then intercepted in traps during spring spawning migrations as they ascend tributaries, and then descend back into main-stem habitat when sub-optimal conditions exist during the summer. Migrant trapping will need to continue, but new tagging methods will be needed to describe seasonal use of Hangman main-stem habitats by both adult and juvenile redband trout in order to evaluate the importance in providing summer and overwintering habitat and in providing a potential corridor to permit exchange of individuals among tributaries in the upper watershed. We intend to use visible implant elastomer (VIE) tags to all fish 1+ with unique color and body placement for each tributary and main-stem reach to permit examination of potential movements throughout the upper watershed.

Limiting factors – physical and chemical attributes of surveyed reaches
Much of the disparity in the distribution and density of redband trout among tributaries and among reaches within tributaries could be explained by the dramatic differences in the physical and chemical attributes that constituted habitat suitability in the upper Hangman watershed. Forested reaches in Indian Creek and in upper Sheep and Mission creeks, where redband trout were commonly found, typically had a lower percentage of fines in surveyed riffle substrates, greater canopy cover, and more LWD than in other reaches, such as downriver reaches of Sheep and Mission creeks and main-stem reaches in Hangman creek, where agriculture predominated. In addition, summer temperature profiles, most likely related to the presence of canopy cover, were cooler and more suitable for incubation and rearing in upper forested reaches of monitored sub-watersheds than in downriver agricultural reaches.

Temperature monitoring of the southern portion of the upper Hangman watershed using running 7-day average max were compared to various research on temperature and its impact on redband trout. Data showed that a lack of canopy cover and concomitant high summer temperatures may be a major factor limiting the distribution and abundance of redband trout in many of the stream reaches in the upper Hangman Creek watershed. Both spawning limits of 14 degrees C (May 1st – June 30th), and rearing limits of 20 degrees C (July 1st – August 30th) were examined. The link between stream shading and temperature was especially evident for main-stem reaches in Hangman creek where summer temperatures were documented to sharply increase over relatively short distances downstream as the riparian canopy markedly decreased. Throughout the reporting period, stream temperature metrics in downriver reaches of Mission and Sheep creeks and in the main-stem of Hangman Creek, where canopy cover was lacking, exceeded established temperature thresholds a high percentage of the time. Despite the variety of metrics that have been proposed by the states of Washington and Idaho, our metric seemed to differentiate stream reaches reasonably well where redband trout were found to be present and lacking, and consequently, will continue to be used in future assessments. We intend to examine the availability and distribution of these potential refugia in main-stem habitats of Hangman Creek in future monitoring years following established protocol (Firehammer et al. 2010).

In addition to stream temperature monitoring, the accumulation of several more years of base flow dissolved oxygen and discharge data throughout this reporting period was instrumental in identifying those reaches in the upper Hangman Creek watershed that consistently displayed suboptimal rearing conditions for redband trout. For example, tributaries in the northern part of the Hangman Creek watershed that were heavily impacted by agriculture (e.g., Andrew Springs, Lolo, Tensed, and Rock creeks) either lacked water during baseflow periods or displayed dissolved oxygen profiles that would be insufficient to support salmonids. Low flow (e.g., standing pools) and attendant low levels of dissolved oxygen was also documented repeatedly in monitored reaches of Mission, Sheep, and South Fork of Hangman sub-watersheds.

Furthermore, lower reaches of Nehchen Creek were repeatedly found to be intermittent during summer periods over the reporting period, and is considered critical given that large redband trout have been found to ascend this tributary during spring migratory periods and that they may be using lower reaches as spawning habitat, more information is needed on the fate of fry that would be emerging coincident with the observed dewatering periods. Notwithstanding the high temperatures and low dissolved oxygen levels that are often associated with low flow, lack of discharge can also impact salmonids by decreasing the volume of macro invertebrate drift.

Monitoring of discharge, TSS and turbidity during peak flows that occur during peak flow events reveal conditions in Hangman, Sheep, and Mission creeks are more likely to have sub-lethal effects on salmonids compared to Indian and Nehchen creeks. The former have flashier hydrographs and suspended sediment concentrations over the course of several days that would cause increased coughing, increased respiration rates, long term reduction in feeding success, homing impairment, and overall poor condition.

Channel forming processes were also found to be highly impaired in the lower reaches of Mission and Sheep creeks and in main-stem reaches of Hangman creek. As revealed in the Rosgen channel typing surveys conducted during the reporting period, these reaches were in a transitional phase from a Rosgen C to an F classification, and were characterized by deeply incised channels, and a sinuosity that was not consistent with their low gradient of less than 0.5%. Channel incision further reduces the frequency of overbank flows and, as a result, impairs normal functions of a stream-riparian ecosystem. Most of these stream channel changes were likely the result of a combination of factors including historical channel straightening and the installation of tiles on dry land agriculture fields, the removal of riparian vegetation, high road density, and excessive levels of timber harvest.

Though water quality and physical features (e.g., low canopy cover and LWD volume, excessive fine sediments) were typically inadequate to support suitable rearing habitat for redband trout in the main-stem of Hangman creek and in lower reaches of Mission and Sheep creeks, these same reaches were primarily the sole reaches that provided deep pools in surveyed sub-watersheds in upper Hangman. Indian Creek, where canopy, adequate spawning substrate and LWD are more plentiful, the pools did not exceed one foot in residual depth. The absence of pool habitats in surveyed reaches in tributaries of the upper Hangman watershed may in part be the result of an overall lack of large pieces of woody debris that are essential in both channel and pool-forming processes. Given that deep slow moving pools are preferred by redbands for summer rearing and overwintering habitat, it is imperative to develop pool habitat in both the tributaries and the main-stem of Hangman.

Analysis of macro-invertebrate samples collected across sub-watersheds in 2004 reflected the differences in water quality and habitat features, specifically substrate size and stream temperature, observed among reaches. Generally, macro-invertebrate metrics described a trend of decreasing habitat quality (i.e., greater stream temperatures and higher percentages of fine sediments) for salmonid species from upstream to downstream for all tributaries, with the exception of Indian Creek. Regression analysis showed a significant relationship ($P<0.05$) for both temperature and percent fines for the following metrics; EPT Richness, % EPT, Plecoptera

Richness, % Plecoptera, Fine Sediment Biotic Index, % Diptera, % Chironomidae, Intolerant Taxa Richness, Long-Lived Taxa Richness, DEQ MBI. In many cases it was very significant ($P<0.0001$), such as percent plecopterans (stoneflies) and plecopteran richness. Plecopterans were not only useful to assess temperature and fine sediments, but also effective in assessing the quality of feeding habits for redband trout since they are significantly larger prey items. Hayes et al. (2000) has shown that while growth was limited in their modeling analysis mostly by costs of reproduction, growth was also related to the increased foraging costs associated with feeding on small invertebrate prey.

In summary, of all the surveyed sub-watersheds in the upper Hangman watershed, Indian Creek, a primarily forested tributary, though lacking in quantity of deep pool habitat, had the most suitable perennial flows and annual discharge regimes, the lowest temperatures, the highest level of dissolved oxygen, high levels of canopy cover, and suitable substrate size. Not unexpectedly, Indian Creek was also the one sub-watershed that supported the most robust distribution and density of redband trout, even though it was one of the relatively smaller sub-watersheds in upper Hangman. Similar comparative results were reported by Dambacher and Jones (2007) for several streams in the Crooked River basin in Oregon. The authors found that the stream that supported the highest densities of redband trout also provided the best available habitat with respect to the greatest volume of LWD, lowest temperatures, perennial flows, and lowest level of imposed disturbances (e.g., cattle grazing, logging). As such, it is imperative to protect and preserve the quality and quantity of suitable rearing habitats that were evident in Indian Creek.

Restoration priorities

Restoration efforts during the reporting period focused on enhancing the quality of degraded rearing habitats in main-stem reaches of Hangman Creek to address documented deficiencies and to improve the suitability of migratory corridors that would increase the connectivity of sub-populations in tributaries in the upper Hangman watershed and promote both genetic interchange and colonization potential. Based on the modeling analysis conducted by Hardin-Davis (2005), the most effective method to expedite the increase in usable habitats in the main-stem of Hangman would be to improve the suitability of rearing temperatures by increasing the amount of stream shading. Consequently, much of our restoration activities were devoted to riparian plantings that would address this. Based on experimentation with various techniques and the lessons learned therein, we intend to focus on planting larger plants with maximum protection methods using larger cones, hogs panels and watering during the periods of above average air temperatures.

In addition, future restoration priorities should be focused on protecting and enhancing the availability of suitable habitat in Indian Creek, where the most robust remnant sub-population of redband trout is currently found. Preservation and enhancement of such refugia for redband trout in the upper Hangman watershed would support the goal of connectivity among tributaries by having sufficient numbers of redband to colonize elsewhere after restoration has occurred. Hardin-Davis (2005) concluded in their IFIM report that additional useable fish habitat can be gained in tributaries by additional flow, which in turn increases pool depth. We intend to install pool-forming large woody debris structures in Indian Creek to increase residual pool depths.

1.0 PROJECT BACKGROUND

The Coeur d'Alene Tribe has depended on runs of anadromous salmon and steelhead during aboriginal times, and centered their fishing activities along the upper reaches of the Spokane River and in Hangman Creek (Scholz et. al. 1985). It is generally acknowledged that the Coeur d'Alenes shared Spokane Falls with the Spokane People, but Hangman Creek at the confluence with the Spokane River and the fishing site near what is now Tekoa, Washington are recorded as being primarily used by the Coeur d'Alene People (Scholz et. al. 1985). Several estimates have been made of the amount of the anadromous fish resource that was consumed by the Coeur d'Alene People. These estimated annual per capita consumption rates for the Coeur d'Alenes ranged from 100 pounds per year to 700 pounds per year, with the average per capita for Plateau Tribes in general ranging from 300-365 pounds per year (Scholz et. al. 1985).

Construction and operation of the Federal and non-Federal hydropower system during the 20th century directly led to the complete extirpation of all anadromous and some resident fish populations as well as the permanent destruction of thousands of acres of critical fish and wildlife habitat throughout portions of the Upper Columbia River and its tributaries. Such is the case with Chief Joseph, Grand Coulee, and Albeni Falls dams as well as additional hydro facilities constructed along the Spokane River. Simultaneously, rapid changes in land management practices further altered the fish species composition in Hangman Creek and the availability of native terrestrial wildlife habitat (Edelen and Allen 1998). From the World War II era to the present, streams were straightened and channelized to provide more arable lands, with the greatest modifications occurring during the 1950s and 1960s. By 1996, the predominant use of the land within the Hangman Watershed on the Coeur d'Alene Reservation was agriculture (65.1%), followed by forest (37.9%), grassland (0.2%), developed (0.3%) and wetland (0.006%) (Redmond and Prather 1996). Because of the land modifications to Hangman Creek, the watershed was listed in the Environmental Protection Agency's 303d list in 1998 for habitat alteration, sediment, nutrients, and bacteria. Moreover, tributaries to Hangman Creek within Idaho were also listed in 2002 for elevated levels of temperature.

To address the losses attributed to the establishment of the Federal Columbia River Power System (FCRPS), the Pacific Northwest Electric Power Planning and Conservation Act (Act) of 1980 explicitly gives the Bonneville Power Administration (BPA) the authority and responsibility "to protect, mitigate, and enhance fish and wildlife to the extent affected by the development and operation of any hydroelectric project of the Columbia River and its tributaries in a manner consistent with the program adopted by the Northwest Power Planning Council (NWPPC) and the purposes of this Act." The Hangman Watershed's reduced capability to support native fish and wildlife and its historical importance to the Coeur d'Alene Tribe prompted the Coeur d'Alene Tribe to submit an resident fish substitution project proposal to the Northwest Power Planning Council to begin a coordinated effort to protect and restore fish and wildlife habitats along with the natural function of wetlands, riparian areas, and streams within the Project Area. The projects proposed were intended to restore the native resident fish to Hangman Creek to provide alternate subsistence resources for extirpated salmon. The *Hangman Restoration Project* (BPA Project #2001-033-00) was submitted in conjunction with this Project, *Implement Fisheries Enhancement on the Coeur d'Alene Indian Reservation: Hangman Creek*

(BPA Project #2001-032-00). These proposals were submitted during the fall of 2000 for inclusion in the FY2001 – FY2003 budget cycle for the Spokane River Subbasin of the Intermountain Province. These projects were funded as part of the Bonneville Power Administration's commitment "to rebuilding healthy, naturally producing fish and wildlife populations by protecting and restoring habitats and biological systems within them" (Northwest Power Planning Council 2000a).

The primary goal proposed in the original project submittal included:

> Protect and/or restore stream habitats throughout the Hangman Watershed on the Coeur d'Alene Indian Reservation in order to support the restoration or reintroduction of native fish populations that are reduced from their original abundance.

This goal was to be attained through a stepwise process to:

- Conduct baseline investigations to determine native and resident fish stock composition, distribution, and relative abundance in the Subbasin by year 2010 (Priority 1) (Intermountain Province Subbasin Plan 2004).
- Describe biological, physical, and chemical attributes of habitat of Hangman Creek and its tributaries that either support or limit the distribution and abundance of native redband trout.
- Protect and enhance native redband trout populations by implementing habitat restoration measures
- Create a holistic approach to restoration through a public outreach program.
- Create a fishery to support traditional and recreational harvest.

The project began in 2002 with an initial coarse assessment of the spatial distribution of fish assemblages across the upper Hangman watershed, with a particular emphasis on delineating reaches where native and non-native salmonids were present and absent (Peters et al. 2003). Sampling in 2002 also focused on collecting water quality data across the upper watershed to aid in evaluating factors that may be limiting the suitability of habitat for, and consequently the observed spatial distribution of, redband trout. Water quality data collected included discharge, oxygen, pH, conductivity, nutrients, total suspended solids (TSS), turbidity, bacteria, alkalinity, and continuous temperature profiles.

Results from the initial assessment conducted in 2002 indicated that native redband trout were found in low numbers and only captured in Indian creek, in lower reaches of Nehchen creek, and in upper reaches of Sheep, Mission, and Hangman creeks. The presence of redband trout was often associated with forested reaches; redband trout were not captured in those tributary reaches encompassed predominantly by agricultural land. In addition, non-native cutthroat trout were found to be present in relatively high numbers in upper reaches of Nehchen creek. Results from the assessment also indicated water quality was often sub-optimal in those reaches that lacked redband trout. High temperatures, elevated TSS concentrations, low levels of dissolved oxygen, and extremely low discharge levels (e.g., dewatering) were documented during baseflow summer rearing periods in most of the agriculturally-dominated tributaries, in lower reaches of the fish-bearing tributaries, and in the lower mainstem of Hangman Creek. Total suspended solids were also found to be highly variable in the lower Hangman mainstem with extremely high levels recorded during peak discharge periods.

To supplement the initial assessment conducted in 2002, this report summarizes four additional years of monitoring to characterize water quality and relative fish abundance and distribution across the upper Hangman Creek watershed. Given that the prior assessment included only one year of data collection, additional years were deemed necessary to capture typical levels of annual variability in the monitored variables and provide a clearer picture of the range of values observable in the watershed. In addition, additional years of baseline data will permit more robust statistical models to be constructed (e.g, before and after comparisons, trend analyses) when analyzing the effectiveness of projected restoration actions or evaluating changes over time.

Furthermore, this report summarizes additional monitoring activities to address data gaps that were evident in the 2002 fisheries assessment. First, many of the redband trout captured in 2002 summer surveys in tributary habitats were classified as juvenile fish from aging analyses. Apparently, large adult redband trout, which were rarely captured in the surveys, may only be using these tributaries seasonally (i.e., during spring spawning periods). As a result, migrant traps were deployed during spring spawning seasons during this reporting period to evaluate the distribution and relative abundance of adult redband trout. In addition, the 2002 surveys indicated that redband trout were sparse and spatially isolated in upper reaches of tributaries, and that sympatric populations of cutthroat trout also existed in one of the sampled tributaries. Consequently, a genetic analysis was conducted on Hangman Creek redband trout to evaluate both introgression with cutthroat trout and their genetic relatedness to other redband populations in the Spokane subbasin.

In addition to the water quality data that were collected from 2004 to 2007, other habitat assessments were conducted during this reporting period to provide a better understanding of the suitability of habitats for redband trout. These included Rosgen channel typing surveys to describe baseline physical habitat conditions in representative reaches across the upper watershed, a macro-invertebrate survey to better understand food availability and linkages to physical and chemical processes, and a modeling analysis that used temperature and physical habitat data collected in the field to evaluate the potential for improving habitat suitability in tributary and mainstem reaches. Lastly, partly in conjunction with the recommendations suggested by the modeling analysis, this report summarizes the effectiveness of restoration actions (i.e., riparian plantings) that were implemented to address sub-optimal habitat conditions in the upper Hangman Creek watershed.

STUDY AREA

Hangman Creek drains 430,000 acres of northern Idaho and eastern Washington. The study area consists of the portion of Hangman Creek watershed that lies within the Coeur d'Alene Reservation and east into the headwaters outside of the reservation (Figure 1). The Washington-Idaho State border, which corresponds to the border of the Coeur d'Alene Indian Reservation, marks the western boundary of the project area. The total acreage is 215,097 (Kinkead 2011), with 205,504 of that within the reservation. Elevations range from 754 meters in the northwest corner of the Project Area where Hangman Creek flows west into Washington to 1,505 meters at the top of Moses Mountain on the southeastern end of the Hangman/Coeur d'Alene Basin watershed divide. The named tributaries within the basin include NF Rock, Rose, and Rock Little Hangman, Moctilimne (a tributary of Little Hangman), Mission, Lolo, Tensed, Sheep, Smith, Mineral, Nehchen, Indian, the SF Hangman and its' tributaries Conrad, Martin, Tenas, and Papoose, and the upper part of Hangman Creek east of the Reservation along with its' named tributaries Hill and Bunnel (Figure 3). All of these tributaries except Little Hangman were thought to be home to trout in the 1940's (Aripa 2003). In 2005 the northern part of the project area was excluded from the study, and left 157,586 acres in the southern project area.

The climate in the Project Area is sub-humid temperate with cool, wet winters and warm, dry summers. Annual precipitation at DeSmet, Idaho for the years 1963-1983 was estimated to range from 70 to 90 cm (WRCC 2008). A distinct precipitation season typically began in October or November and continued through March. Approximately two-thirds of annual precipitation occurred during this period and rain-on-snow events generated by moisture laden Pacific air masses were common in late winter months (Bauer and Wilson 1983). Temperatures in the watershed are mild overall. The average daily maximum for August of the 1963-1983 reporting period was 82.2° F. The average daily minimum for January, which was the coldest month of the year, was 20.9° F. Snows in the lower elevations of the Study Area do not persist throughout the winter and in the higher elevations the snows are usually completely melted by April or May. Weather and land management practices such as tilling, tiling, grazing, riparian vegetation removal, stream channelization, logging, and road building have all contributed to stream sediment pollution and a flashy hydrologic cycle (Spokane County Conservation District 1994, Isaacson 1998). Rain-on-snow events in particular swell streams, contribute to the erosion of lands and cause a pulse of stream sediment pollutants (Bauer and Wilson 1983). The lack of an adequate wetland water storage capacity within the watershed results in little to no base flow during the dry season of August and September.

The original vegetation patterns within the Project Area included the eastern edge of the Palouse Steppe, mesic mountain forests, open woodland transition forests, (Bailey 1995, Lichthardt and Mosely 1997, Black et al. 1998) and wetland/riparian habitats (Jankovsky-Jones 1999). Currently the major vegetation coverage is agriculturally derived (Redmond and Prother 1996) and native habitats have been greatly altered to channel water off the landscape to facilitate agricultural production (Black et al. 1998, Jankovsky-Jones 1999). Forest habitat series' within the Project Area include western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), grand fir (*Abies grandis*), Douglas fir (*Pseudotsuga menziesii*), and ponderosa pine (*Pinus ponderosa*) (Cooper et al. 1991). White pine *(Pinus monticola)* cover type has been eliminated by a combination of harvest and white pine blister rust (Hagle et al. 1989, Maloy 1997). Since settlement of this region, the ponderosa pine and Douglas fir cover types have been greatly reduced, while grand fir, cedar and hemlock cover types have greatly increased (Gruell 1983).

Riparian/wetland plant communities within the Project Area can be divided into five general categories: coniferous forest, deciduous forest, deciduous shrub, graminoid wetlands (Jankovsky-

Jones 1999) and camas marsh (Daubenmire 1988). The coniferous forest communities include mountainous riparian communities that are dominated by western red cedar, or mountain hemlock, with alder (*Alnus incana*) populating areas of disturbance from timber harvest. In the lower elevations, a mosaic of riparian communities exists directly from land management practices where the dominant native vegetation includes ponderosa, alder (*Alnus incana*), and hawthorne (*Cretaegus douglasii)*, along with invasive weeds, such as hawkweed (*Hieracium sp.*), reed canarygrass (*Phalaris arundinacea*), and common tansy (*Tanacetum vulgare*). Other plants present in less than historical density include; aspen (*Populus tremuloides*) black cottonwood (*Populus trichocarpa*), red-osier dogwood (*Cornus sericea*), willow (*Salix sp.*). The graminoid wetlands are dominated by grasses (*Agropyron*), sedges (*Carex sp*.) and various rushes (*Eleocharis, Glyceria, Juncus, Scirpus, and Sparganium*), and Camas (Camassia spp).

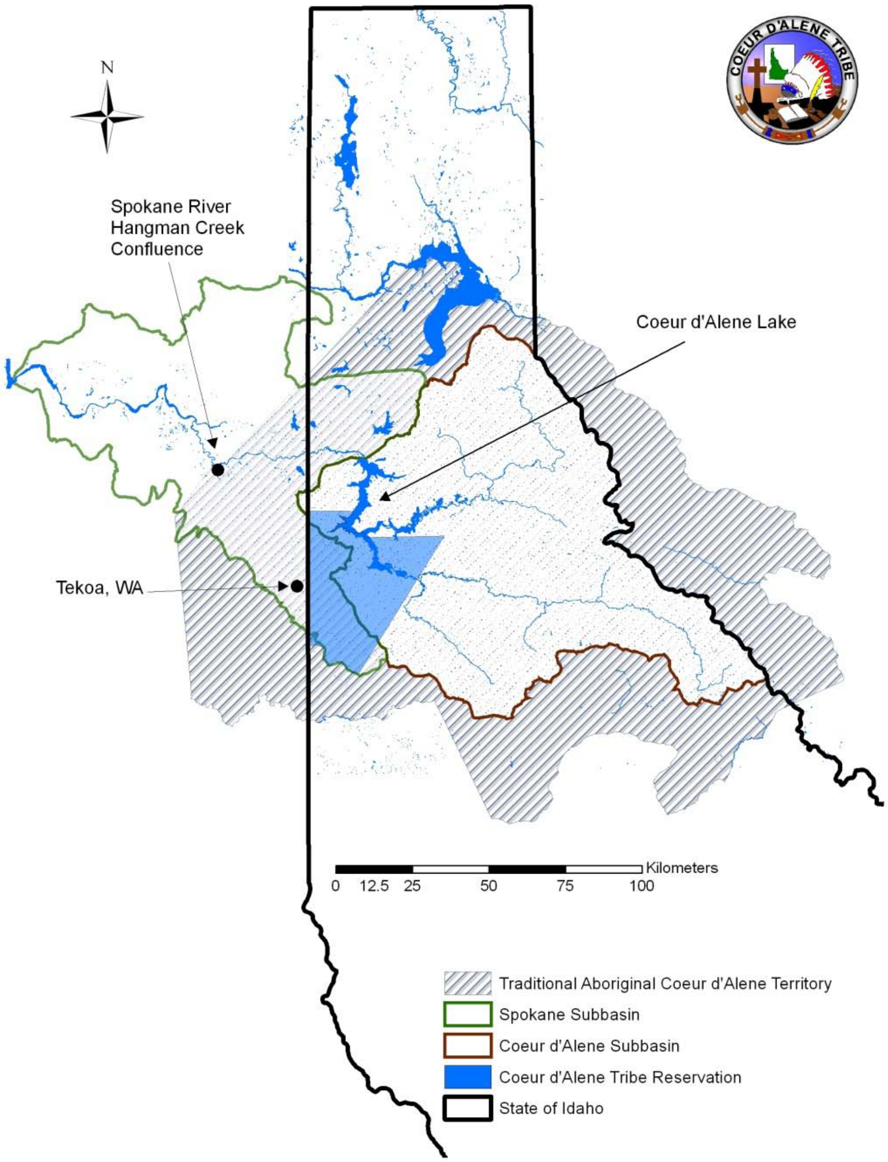


Figure 1. The aboriginal territory of the Coeur d'Alene People encompassed the Coeur d'Alene Subbasin and roughly half the Spokane Subbasin. The major fisheries sites for salmon and steelhead within the aboriginal territory included Spokane River and Hangman Creek. Major fishing sites in Hangman Creek were at the confluence with the Spokane River and near, what is now, the current town of Tekoa, Washington.

3.0 MATERIALS & METHODS

3.1 Biological Assessment

3.1.1 Trout Abundance and Distribution during Summer Rearing Periods

Sample sites for evaluating fish abundance and distribution were selected using a stratified-randomization scheme based on Rosgen Level 1 survey methodology (Rosgen 1996). Stream reaches were first stratified into relatively homogeneous types according to broad geomorphologic characteristics, such as valley slope, channel sinuosity, and channel pattern (Figure 2). Stream reaches were further stratified by basin area to ensure that both main stem and tributary habitats were represented in the stratification scheme. Sample sites were then randomly placed within each stratum with the number of sites selected in proportion to the total reach length of each stratum (Appendix D). The length of each sample unit was 200 ft, which, in most cases, typically encompassed a stream length that was 20 times the mean channel width. In 2004, a total of 78 sites were selected with 69 and 9 of the sites located in the southern (Figure 3) and northern part of the watershed (Figure 4), respectively. Fewer sites were located in the northern portion of the watershed, which included Rock Creek, NF Rock Creek, and Rose Creek, given that this area will not be part of any restoration in the near future, though a sufficient amount of data were still needed to capture baseline information. In 2005 and 2006, the sampling scope was limited to those portions of the watershed that were targeted for projected restoration actions, and as a result, only 38 sites were sampled (Figure 5). Thirty six of the 38 sites were those that were previously sampled in 2004.

Sites were electrofished to estimate fish distribution and abundance during base flow conditions in June and early July before dewatering occurred in intermittent stream reaches and before temperatures increased to stressful levels. Electrofishing was conducted using a Smith-Root Type VII pulsed-DC backpack electrofisher, and followed established guidelines and procedures to standardize capture efficiency (Reynolds 1983). Block nets were placed at the upstream and downstream boundaries of each site to prevent immigration and emigration during sampling. Two electro-fishing passes were made for each sample site as the standard procedure. A third pass was conducted if the number of salmonids captured in the second pass was more than 50% of that captured in the first pass. Captured salmonids, including redband and cutthroat trout, were identified, enumerated, measured (TL to nearest mm), and weighed (g). Trout greater than 200 mm in length were tagged with a Floy FD-6B numbered anchor tag. Fish aged 1+ and older and less than 200 mm were tagged with a fingerling tag which was inserted with a needle under the dorsal fin and tied with an elastic thread that would allow 1-2 years of growth (Picture 1 and Picture 2). Other species such as longnose dace, redside shiner, longnose sucker, and sculpin were considered incidental catch and were only counted.

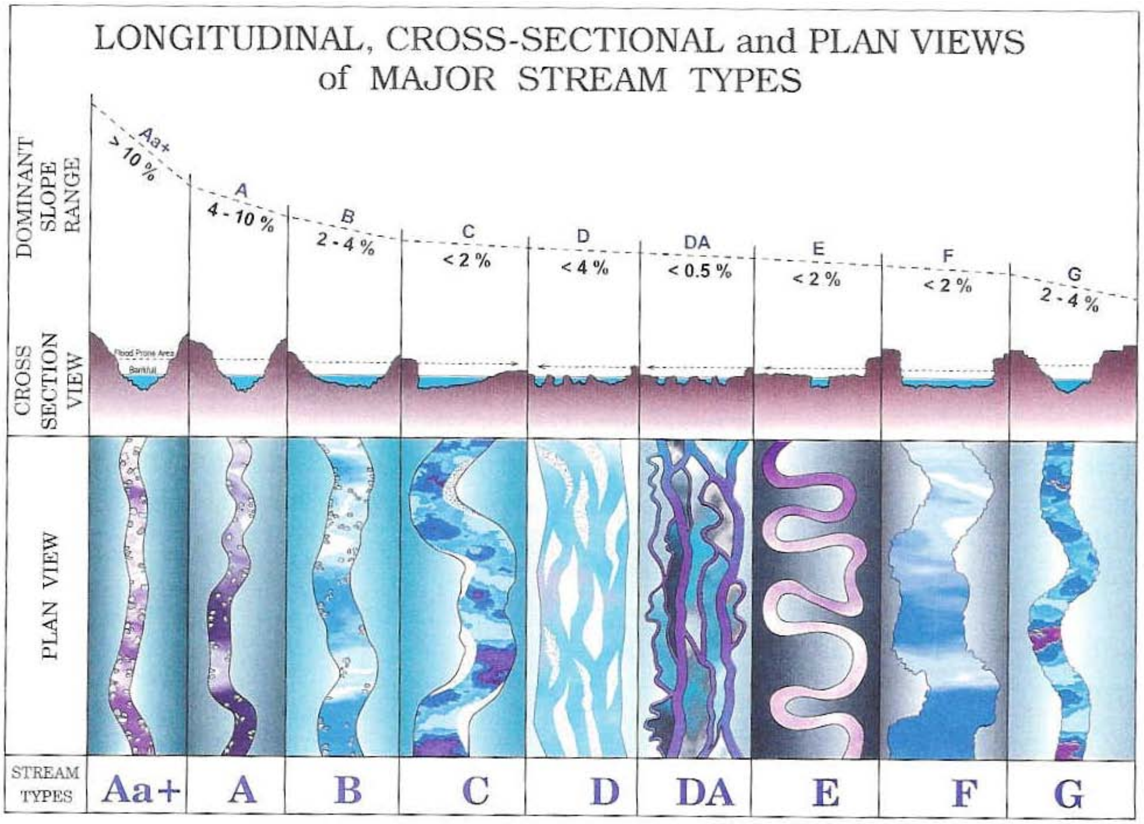
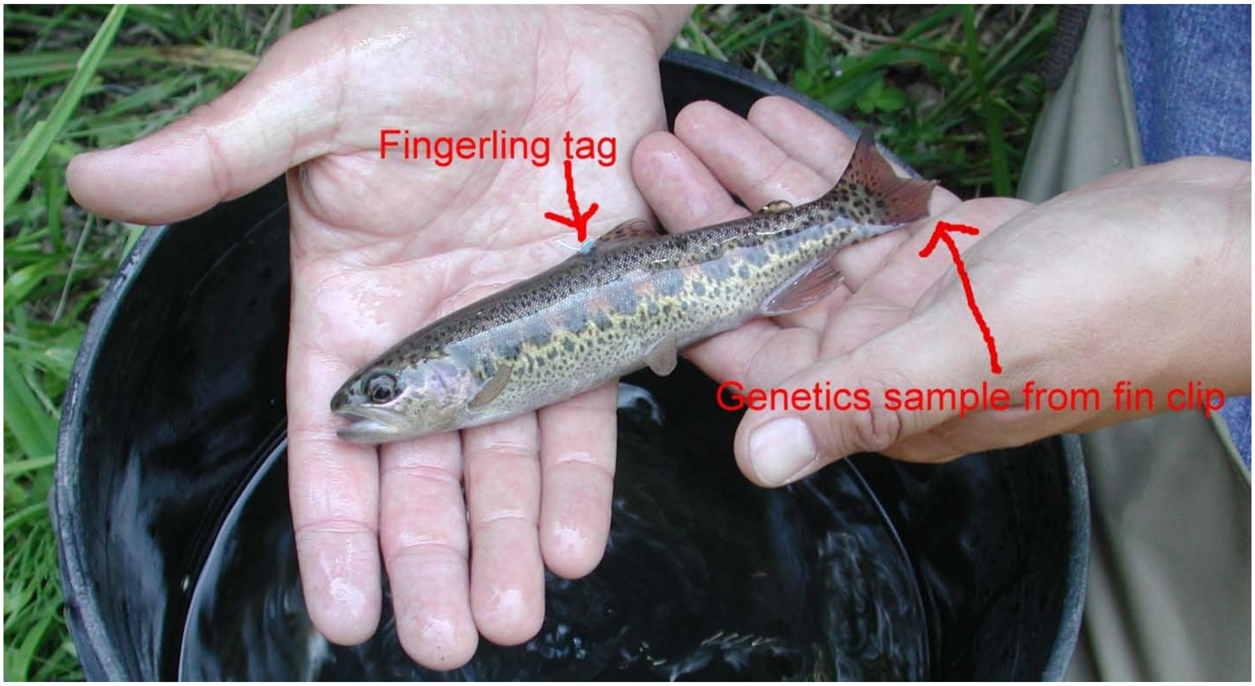


Figure 2. Geomorphic characteristics of Rosgen's channel types.



Picture 1. Processing of fish in 2004 consisted of fin clips for genetics analysis, and installation of fingerling tags on fish less than 200mm in length.

Picture 2. Tying on a fingerling tag

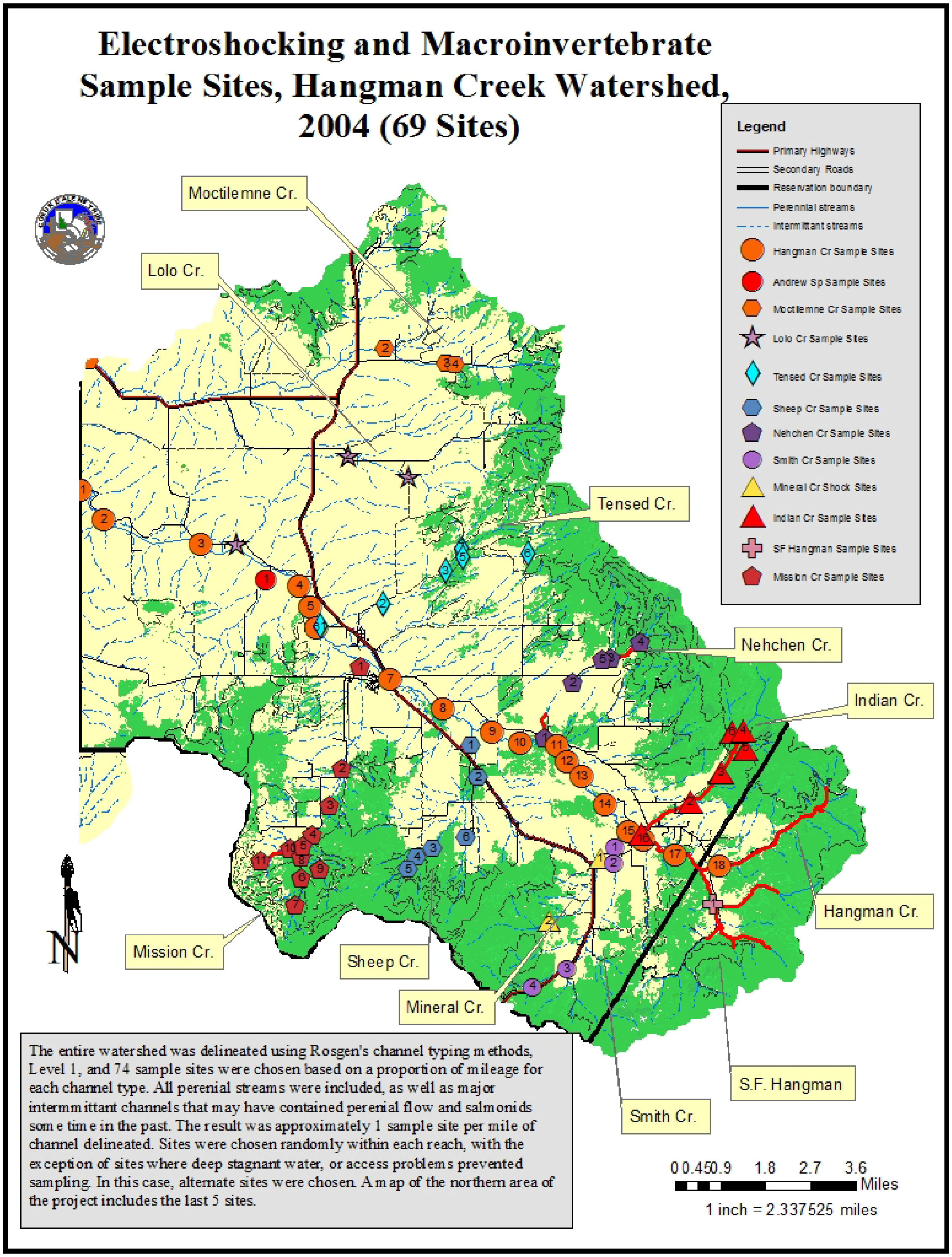


Figure 3. Sample locations for electro-shocking, macro-invertebrates and pebble counts in 2004 in the southern area of Hangman Creek.

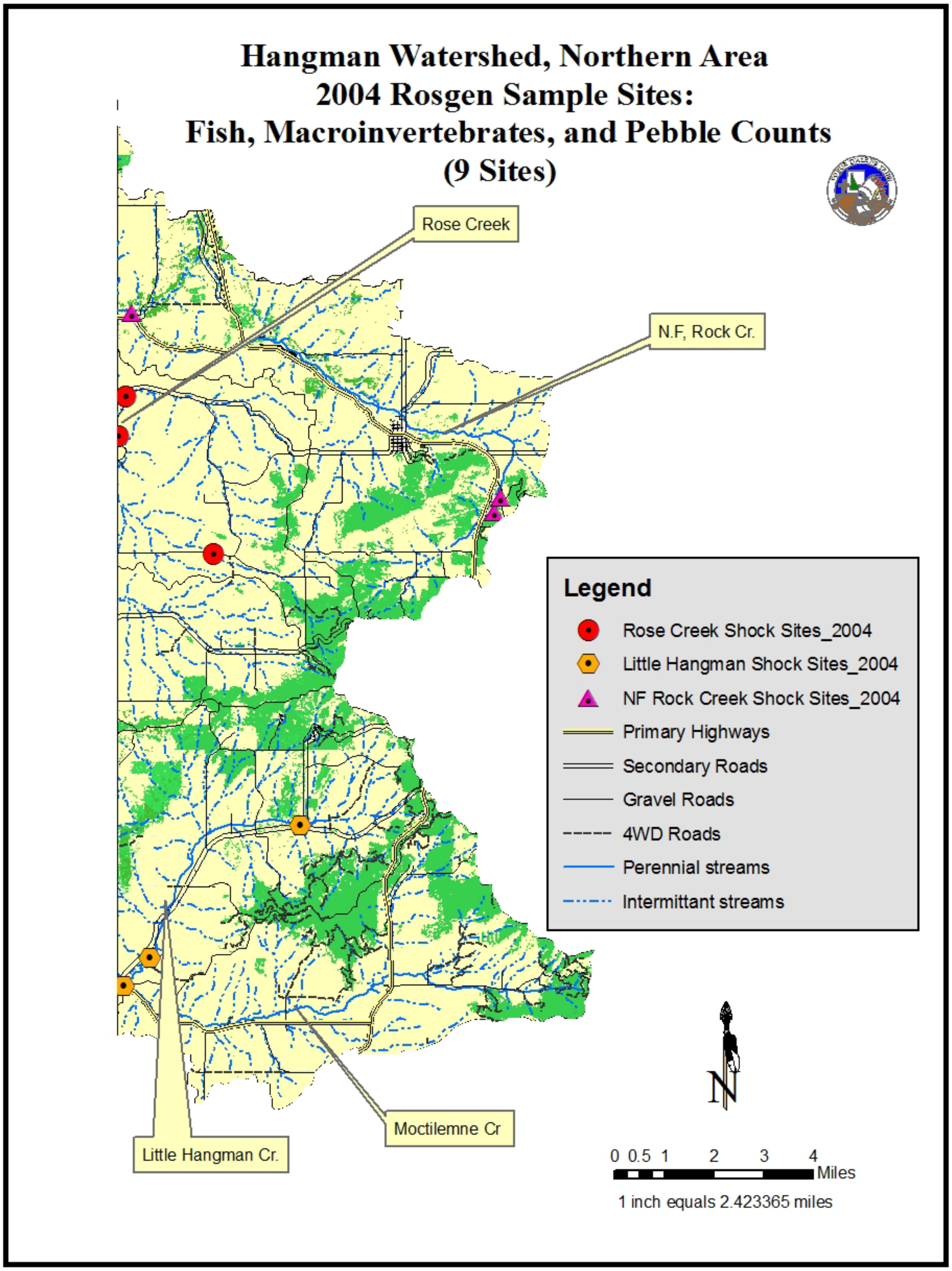


Figure 4. Sample locations for electro-shocking, macro-invertebrates, and pebble counts in the northern section of Hangman Creek in 2004.

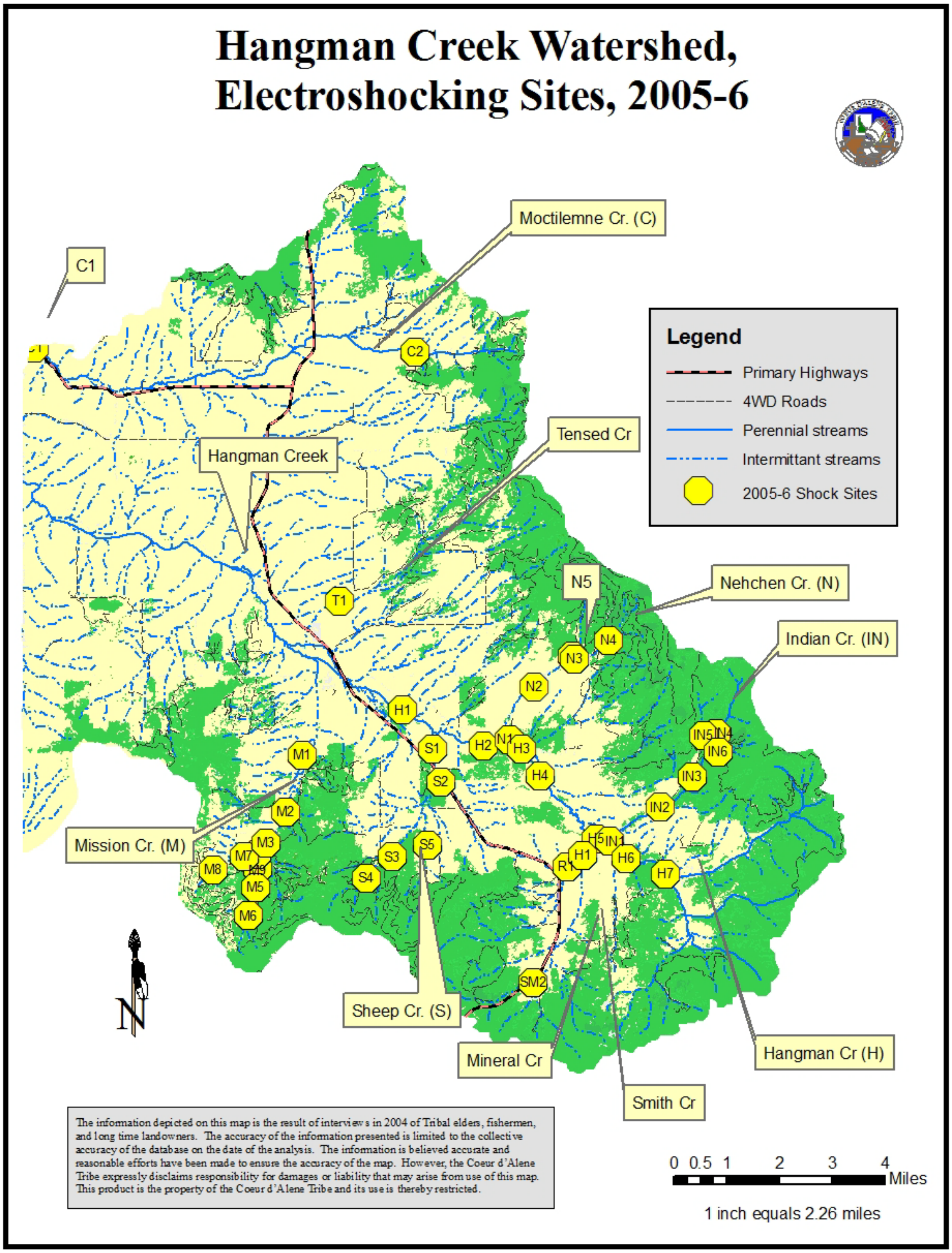


Figure 5. Thirty eight sample locations for electro-shocking in the southern section of Hangman Creek, 2005-6.

Index site abundances were estimated for fish considered at least one year of age (hereafter referred to as age 1+) separately for each salmonid species using the removal-depletion method (Zippen 1958; Seber and LeCren 1967). Site estimates were calculated using the following equation for two pass removals (Armour et al. 1983):

$$N = \frac{U_1}{1-(U_2/U_1)}$$

where:

N = estimated abundance;
U_1= number of fish collected in the first pass; and
U_2= number of fish collected in the second pass.

The standard error of the estimate was calculated as:

$$se(N) = \sqrt{\frac{M(1-M/N)}{A-\left[(2p)^2(U_2/U_1)\right]}}$$

where:

se(N) = standard error of the estimate;
M= $U_1 + U_{2;}$
A= $(M/N)^2$; and
p= $1-\frac{U_2}{U_1}$.

Abundance estimates when more than two passes were necessary were calculated using the following equation (Armour et al. 1983):

$$N = \frac{M}{1-(1-p)^t}$$

where:

N = estimated population size
M = sum of all removals ($U_1 + U_2 + \ldots U_t$)
t = the number of removal occasions
U_i = the number of fish in the i^{th} removal pass
C = $(1)U_1 + (2)U_2 + (3)U_3 + \ldots(t)U_t$
R = (C-M)/M
p = $(a_0)1 + (a_1)R + (a_2)R^2 + (a_3)R^3 + (a_4)R^4$
a_i = Polynomial coefficient from Table 8 (Armour et al. 1983).

The standard error was calculated as:

$$se(N) = \sqrt{\frac{N(N-M)M}{M^2 - \frac{N(N-M)(tp)^2}{(1-p)}}}$$

The approximate 95% confidence interval for the site abundance estimate was calculated as follows (Armour et al. 1983):

$$95\%CI = N \pm 2 * \sqrt{\mathrm{var}(N)}$$

3.1.2 Trout Age and Condition

Raw scales were used for age determination and calculating growth rates. Salmonid scales were taken from the side of the body just behind the dorsal fin and above the lateral line (Jearld 1983). Scale samples were sorted by watershed to allow for independent determination of age and growth rate. In the laboratory, several dried scales were mounted between two glass microscope slides and viewed using a Realist, Inc., Vantage 5 microfiche reader. Age was determined by counting the number of annuli (Lux 1971, Jearld 1983). Simultaneous to age determination, a measurement was made from the center of the focus to the furthest edge of the scale. Along this line, measurements were made to each annulus under a constant magnification. These measurements can later be used for back calculations, but were not done so at this time.

Relative weights were calculated for all redband trout at least 120 mm in length using a standardized weight at length regression developed for rainbow trout (Anderson and Neuman 1996). A calculated value of 1.0 indicates an average weight for a fish of a given length, with values less than and greater than 1.0 indicating that fish were respectively thinner and plumper than normal. Condition factors were also calculated for redband trout less than 120 mm to permit comparison of fish of this size among sub-watersheds.

3.1.3 Trout Migration

Migration traps were installed near the mouth of Nehchen, and Indian Creeks in 2006 and 2007 to assess migratory life history patterns, length and age frequency distribution, and relative abundance of migrating trout. In the past, both the feasibility of installing and maintaining traps and the ultimate efficiency of trapping efforts have largely been determined by the runoff patterns of the respective watersheds. The periodic, low duration peaks in the hydrograph related to rain-on-snow events and/or heavy rains generally have resulted in very low trapping efficiency. Traps were installed March 1st and were monitored and maintained until May 30th.

The design was a modification of the juvenile downstream trap used by Conlin and Tuty (1979). Traps consisted of a weir, runway and a holding box (Picture 3). Traps boxes were made by welding rebar, chicken wire, and aluminum sheet metal for the cover. The barrier fences were made from a combination of rebar/chicken with rebar hammered into stream banks for support. Paired upriver and downriver traps were placed approximately 10 meters apart and installed at each location to capture fish moving upstream from the mainstem of Hangman and fish moving downstream from the upper watershed, respectively. Beginning in 2006, a resistance board weir, modified after the design used by Stewart (2002), was used to trap upstream migrants in the mainstem of Hangman Creek, and was located below the confluence of Nehchen Creek (Picture 4). The weir was built with spacing between the PVC pickets to accommodate the size of redband trout age 2 and older in Hangman Creek. Traps were checked and cleaned at least once daily during peak spawning periods from April through the mid-May. Fish captured in the traps were identified, counted, measured, and weighed. A scale sample was taken to assess the age and condition of the fish. Fish were tagged in the same manner as in summer electroshocking.

Picture 3. Standard upstream trap used at Nechen and Indian creeks.

Picture 4. Resistance Board Weir installed in winter of 2005 and maintained March 1st till mid June of each year.

3.1.4 Salmonid Genetics

In order to evaluate the conservation potential for native interior redband trout in the upper Hangman Creek watershed, a genetic study was conducted in 2003-2004 to examine population structure and potential hybridization in populations distributed across priority sub-basins. Genetic introgression was investigated given that cutthroat trout have been putatively introduced into Nehchen Creek in the upper Hangman Creek, and that hatchery fish of the non-native coastal strain of rainbow trout have been repeatedly stocked throughout the Spokane drainage in the past. Genetic samples were collected from redband trout sampled during electrofishing surveys in Indian Creek, Nehchen Creek, Martin Creek, Sheep Creek, Mission Creek, and main stem reaches in upper Hangman Creek. Given the low number of fish sampled in Mission and Sheep creeks, samples were combined to provide the necessary requirements for statistical analysis. Briefly, individual fish were sampled by clipping the lower half of the caudal fin and preserving the fin clip in alcohol until all samples could be delivered to the Washington Department of Fish and Wildlife Genetics Lab. Samples were screened for 16 microsatellite DNA loci as primary genetic markers to show levels of genetic variation. Samples were also screened for pine markers as evidence of inter-specific hybridization. A complete description of the protocol is provided in Appendix G.

3.1.5 Macro-Invertebrate Communities

Macro-invertebrate samples were collected at 75 of the78 sites sampled for trout distribution and abundance (Figure 3 and Figure 4). At each of the sites, samples were collected from riffles given that previous research has documented significant relationships between invertebrate assemblages in riffles and land use impacts (Roy et al. 2003). Field samples were collected using a Hess sampler and preserved in 70% ethanol according to methods outlined in Idaho Department of Environmental Quality's Beneficial Uses Reconnaisance Project (BURP). In addition, pebble counts were conducted and current velocities measured at sampled sites to draw relationships with invertebrate assemblage indices. Invertebrates were identified and enumerated in the lab by EcoAnalysts, Inc (Appendix H).

Various invertebrate metrics were selected to examine their relationship to habitat variables that were measured at each of the sample locations (Table 1). The habitat variables that were chosen were those that would differentiate the sampled sites and would also reflect the quality of the stream habitat. The two variables that were selected were percent fines in tailpool and riffle habitats and a 7-day moving average of maximum daily water temperature. Linear regressions were developed to relate invertebrate metrics to selected habitat variables, and significance was examined at $\alpha = 0.05$.

Table 1. Macroinvertebrate metrics that were selected for analysis (X) to examine their relationship with measured habitat metrics.

Metrics Calculated	Analyzed	Metrics Calculated	Analyzed
Functional Group Composition		**Dominance Measures**	
% Filterers		1st Dominant Taxon	
% Gatherers		1st Dominant Abundance	
% Predators		2nd Dominant Taxon	
% Scrapers		2nd Dominant Abundance	
% Shredders		3rd Dominant Taxon	
% Piercer-Herbivores		3rd Dominant Abundance	
% Unclassified		% 1 Dominant Taxon	
Filterer Richness		% 2 Dominant Taxa	
Gatherer Richness		% 3 Dominant Taxa	
Predator Richness			
Scraper Richness		**Richness Measures**	
Shredder Richness		Species Richness	
Piercer-Herbivore Richness		EPT Richness	X
Unclassified		Ephemeroptera Richness	
		Plecoptera Richness	X
Diversity/Evenness Measures		Trichoptera Richness	
Shannon-Weaver H' (log 10)	X	Chironomidae Richness	
Shannon-Weaver H' (log 2)		Oligochaeta Richness	
Shannon-Weaver H' (log e)	X	Non-Chiro. Non-Olig. Richness	
Margalef's Richness		Rhyacophila Richness	
Pielou's J'			
Simpson's Heterogeneity		**Community Composition**	
		% Ephemeroptera	
Biotic Indices		% Plecoptera	X
% Indiv. w/ HBI Value		% Trichoptera	
Hilsenhoff Biotic Index		% EPT	X
% Indiv. w/ MTI Value		% Coleoptera	
Metals Tolerance Index		% Diptera	X
% Indiv. w/ FSBI Value		% Oligochaeta	
Fine Sediment Biotic Index	X	% Baetidae	
FSBI - average		% Brachycentridae	
FSBI - weighted average		% Chironomidae	X
% Indiv. w/ TPM Value		% Ephemerellidae	
Temp. Pref. Metric - average		% Hydropsychidae	
TPM - weighted average		% Odonata	
DEQ MBI	X	% Perlidae	X
		% Pteronarcyidae	
Karr BIBI Metrics		% Simuliidae	
Long-Lived Taxa Richness	X		
Clinger Richness			
% Clingers			
Intolerant Taxa Richness	X		
% Tolerant taxa	X		

3.2 Chemical Assessment

3.2.1 Water Quality

Sample stations were spatially distributed to provide a representative coverage across the watershed using geomorphology, steam order, riparian and upland vegetation, and fish presence/absence as classification variables. Forty-one stations in the southern and northern sections of the Hangman Creek watershed were monitored for water quality in 2004 which included 12 primary and 29 secondary sample sites (Figure 6 and Figure 7). During 2005-2007, sampling continued at the 12 primary and 25 secondary sites in the southern portion of the watershed, though the sites in the northern watershed were omitted. Sampling was conducted monthly at primary sites and at least three times per year for secondary sites to capture data related to significant physical and chemical changes in the water quality throughout the year. The three critical times of flood stage, spawning and incubation, and baseline flows were used to prioritize when the three samples would be taken for the secondary sites. A complete list of sample site locations and water quality variables can be found in Appendices A and B, respectively.

Temperature, dissolved oxygen, pH, and conductivity were monitored at each station using a Hydrolab® DataSonde 4 multi-probe transmitter. Quality control was maintained through strict adherence to the standard operating procedures outlined in the Hydrolab® manual (Hydrolab Corporation 1997). Instrument calibration took place at the beginning of each day of monitoring. A calibration log was used to record the date and time of calibration, the analyst performing calibration, the calibration parameters, and other comments. At the end of the monitoring run, the instrument was checked for drift. All readings were recorded in the calibration log. All standards used for calibration were traceable to NIST Aqueous Electrolytic Conductivity Standard, or other comparable standards. Reagents used for calibration were accompanied by the following documentation: manufacturer, lot numbers, expiration dates, and date opened. A logbook was kept which contains all information related to preparation of reagents and standards.

Water samples were also collected at each station for the analysis of various water quality variables that included total suspended solids (TSS), turbidity, total alkalinity, and nutrients (see Appendix B for list of all nutrients analyzed). Samples were collected using a certified water collection device, and transferred to the appropriate containers for transportation to the contract laboratory. Transportation containers were specially cleaned and prepared by the contract laboratory. Water samples were also analyzed for concentrations of the bacterium E. coli as part of Idaho DEQ’s Beneficial Use Reconnaissance Project (BURP). Sampling and laboratory procedures can be found in <u>2001 Beneficial Use Reconnaissance Project: Work plan for Wadeable Streams</u> (IDEQ 2002). Additional sampling for E. coli was performed by the Coeur d’Alene Tribe. Water samples were collected as close as practical to mid-stream and mid-depth using a clean sterile container provided by the analytical laboratory. Samples were stored immediately in an ice bath for preservation and delivered to the contract laboratory within 6 hours of collection. Collection and handling of samples, including chain of custody protocol, was strictly followed according to standardized methodologies (APHA 1992). Additional information regarding sampling locations and laboratory procedures may be found in Appendix A.

At each station, discharge was also collected at the time of water sampling whenever possible. Discharge measurements were taken in accordance with standard IFIM methodologies (Bovee 1982). The wetted stream channel was divided into 20 equal cells and water velocity was measured in each cell using a Price model 622 digital flow meter. Discharge for each cell was calculated by multiplying the cell width by depth and velocity. All individual cell discharges were summed to determine total discharge in cubic feet per second. Discharge measurements at eleven sampling locations are being used to develop a stage/discharge relationship, with more locations planned in the future. Discharge measurements were collected at low, medium, and high flows in order to complete the rating curve. Staff gauge heights were recorded to the nearest 0.002 ft. The rating curve will be used to determine the annual water budget for each stream sampled.

3.2.2 Continuous Temperature Monitoring

HOBO temperature loggers (Onset Computer Corp.) were installed at 26 locations in 2004, which was increased to 29 locations by 2007. These were distributed across the upper Hangman Creek watershed to develop stream temperature profiles over the years from 2004 to 2007 (Figure 8). Loggers were typically deployed over the period from March/April to October and programmed to record water temperatures hourly (accurate to ± 0.6^{o}C). Loggers were retrieved and data downloaded on average three times a year. Daily minimum and maximum water temperatures were computed for each logger, and seven-day moving averages were calculated for each daily temperature metric.

Moving averages for maximum daily temperatures were compared to a threshold limit of 14^{o}C, which was selected by the Idaho Department of Environmental Quality (IDDEQ) to identify suitable spawning and incubation temperatures for coldwater fish, over the time period from May 1 to June 30. In addition, moving averages for maximum daily temperatures were compared to a threshold limit of 20^{o}C, which was selected internally to identify suitable rearing temperatures for redband trout, over the time period from July 1 to August 31. The number of days in which moving averages exceeded these time period specific thresholds were enumerated and expressed as percents to permit comparisons over years and across sampled reaches.

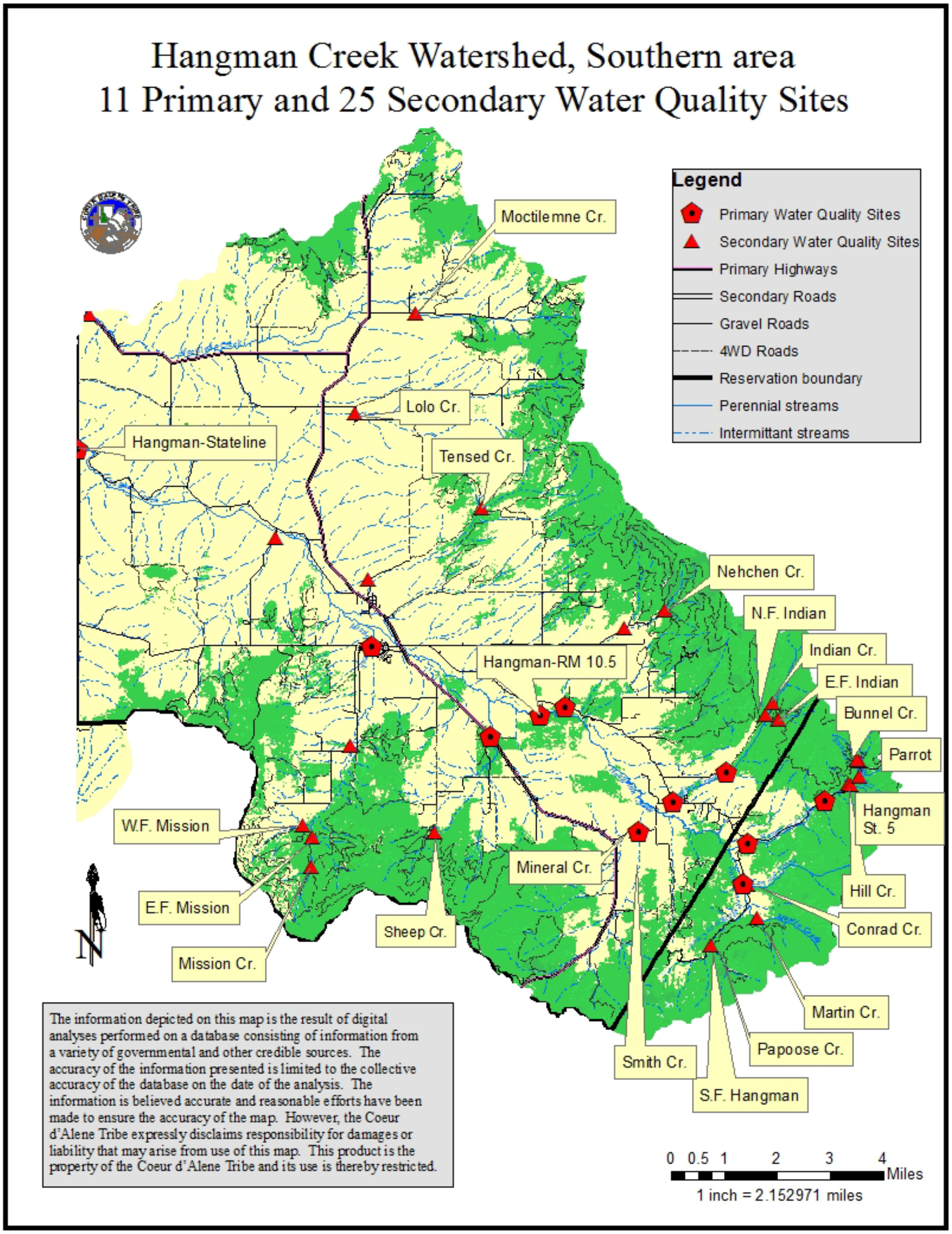


Figure 6. Locations of water quality sampling stations in the southern section of Hangman Creek for 2004-2007. The yellow areas are agriculture, and green are areas of forest management.

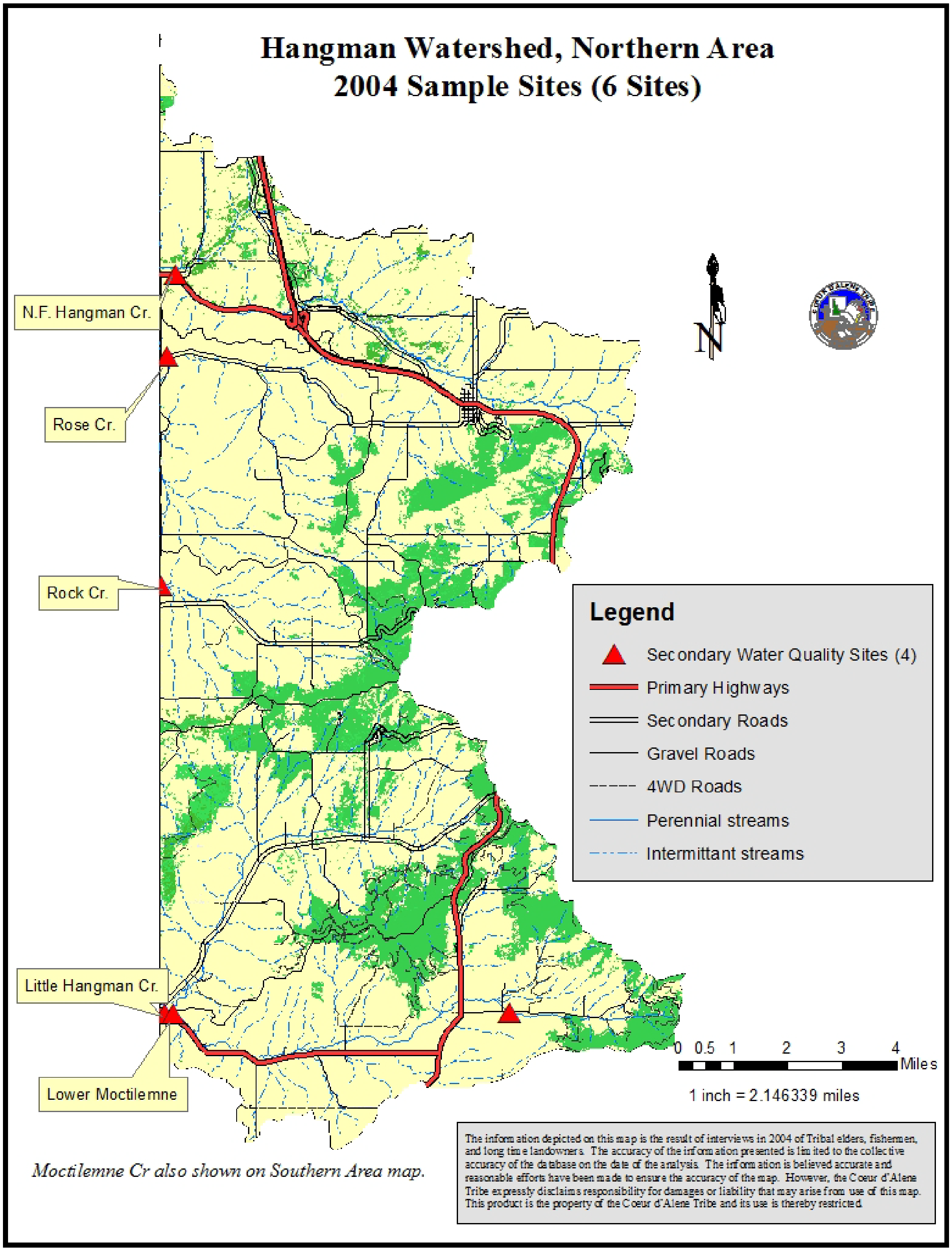


Figure 7. Locations of water quality sampling stations in the northern section of Hangman Creek in 2004.

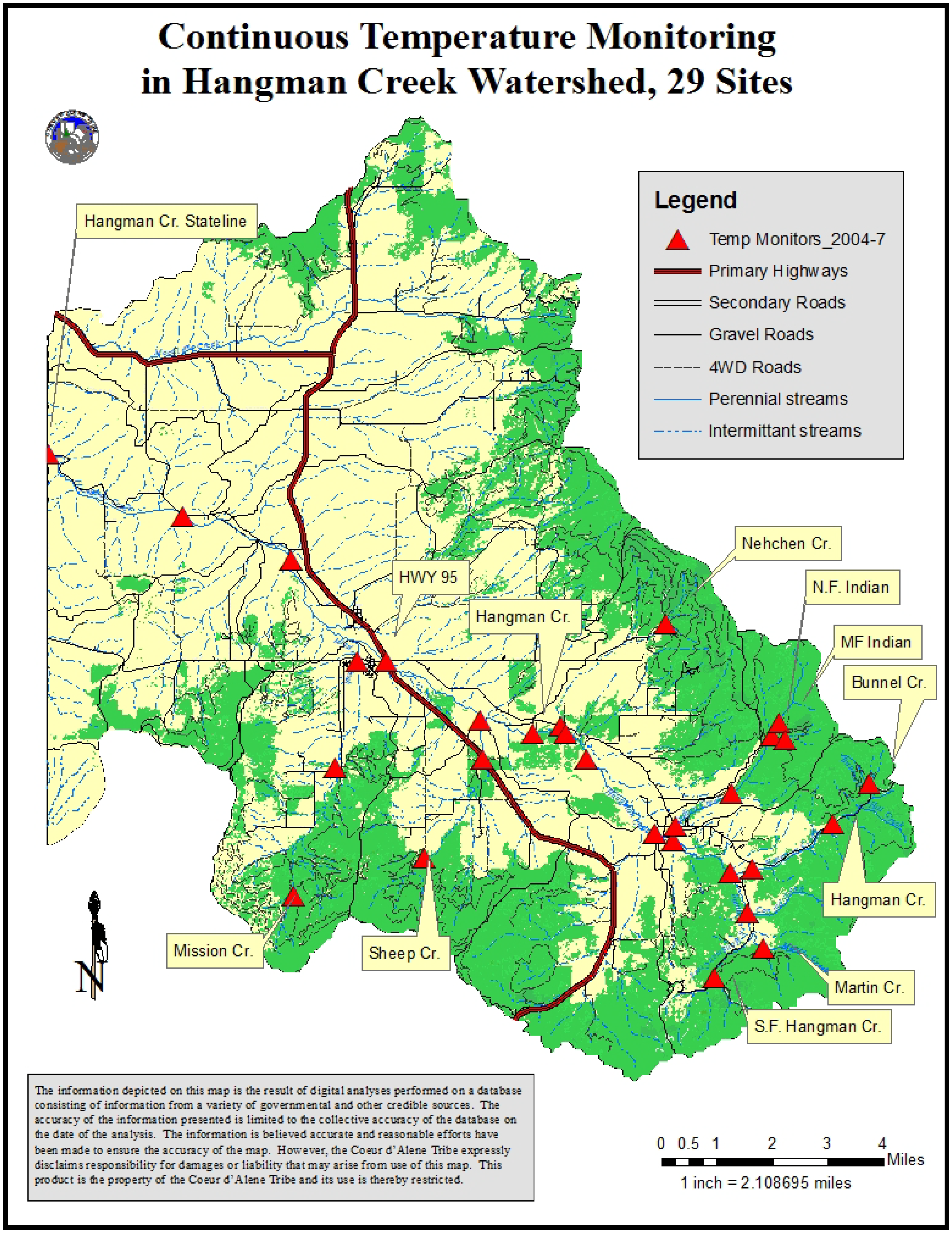


Figure 8. Locations of continuous temperature monitoring in the southern section of Hangman Creek watershed.

3.3 Physical Habitat Asssessment

3.3.1 Rosgen Channel Typing

Sample sites were distributed across the upper Hangman watershed in those reaches that are currently receiving or projected for habitat enhancement to evaluate the response of physical habitat metrics to implemented actions. In addition, sites were also located in control reaches to permit comparisons between treated and untreated reaches to evaluate if measured responses were the result of the implemented restoration actions. Rosgen Level 1 survey methodology was used to ensure that paired control and treatment sites shared similar geomorphological characteristics (see section 3.1.1 Trout Abundance and Distribution During Summer Rearing Periods for description of methodology). Paired monitoring sites for restoration actions are presented in tabular format (Table 2), with 9 of the sites surveyed during 2004-2007. There was an additional six sites surveyed to describe general conditions across the watershed (Figure 9).

Rosgen Level II survey methodology was used to determine channel type at each of the survey sites, and to measure various physical attributes to characterize the reach. The first task in Level 2 channel typing upon arrival at a monitoring site was to determine the location of the downstream end of the surveyed reach. Once this was found, the location was flagged with surveyor's flagging. A 500-foot tape (zero end) was then attached near the water surface and spooled out along the thalweg with the 500 ft mark denoting the upstream end of the reach. This location was also marked with flagging. The following physical attributes were then surveyed or measured along the 500 ft reach. Basic survey methods followed those used by Harrelson et al. (1994).

Longitudinal "Thalweg" Profile

The slope of the water surface is a major determinant of river channel morphology, and of the related sediment, hydraulic, and biological functions (Leopold 1994). A longitudinal profile surveyed along a selected channel reach is recommended for slope and channel typing determinations (Rosgen 1996). This effort (modified from Peck et al. 2001) involved the determination of the water surface and channel bottom elevations along the "thalweg" of each 500-foot study reach. "Thalweg" refers to the flow path of the deepest water in a stream channel. The longitudinal thalweg profile, therefore, is a survey of the lowest stream bottom elevations (and associated water depths) along the reach. Measurements require the use of a surveyor's level and rod, and the 500-foot measuring tape described above. Since most reaches are longer than could be seen from a single level setup, it was necessary to use "turning points" to move the level through the reach.

Profile surveying was begun once a back site shot to a previously established benchmark was completed. This permanent reference point (top of a section of one-inch rebar driven firmly into the ground) was given the assumed elevation of 100.00 feet. From the benchmark, the level was set up and shots taken along the thalweg. A sufficient number of shots were taken to capture all changes in channel bottom slope and habitat types along the reach, generally every 4 feet or so. Collected survey data was input into River Morph V. 3.1, a software package for Rosgen stream typing, for each site, which automatically graphed the profiles and also calculated pertinent descriptive criteria such as water surface slope.

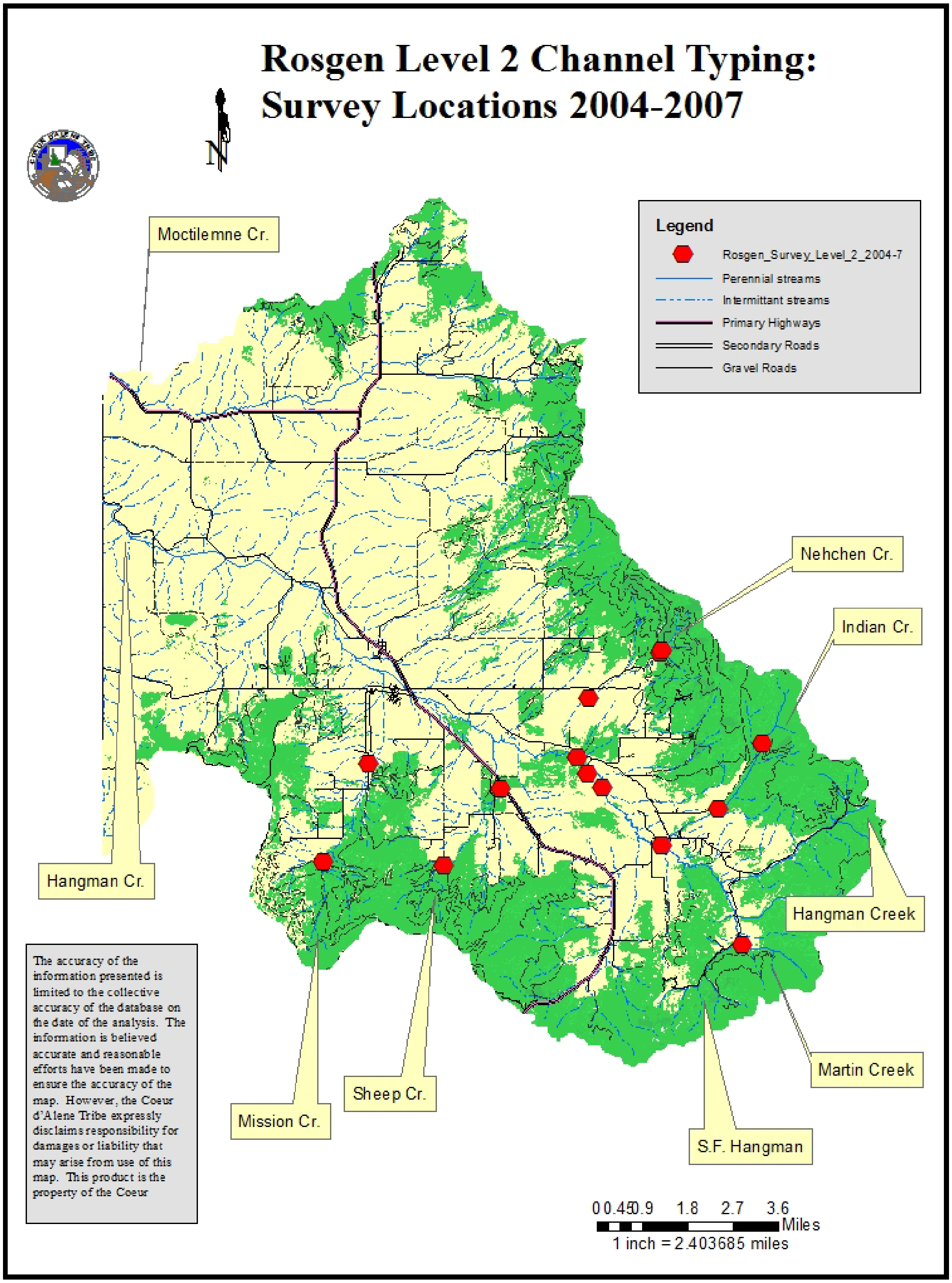


Figure 9. Sample sites for Rosgen channel typing surveys in Hangman Creek during 2004-2007.

Table 2. Projected restoration/enhancement projects in upper Hangman Creek watershed with associated paired treatment and control monitoring sites.

Future Project Site	Project Category Treatment Type	Treatment Monitoring Site #	Control Monitoring Site #
Indian R2 (Pow Wow Grounds)	In-stream structures & Riparian plantings	Indian R2.b*, R2.c	R2.a, R2.d
Nehchen R1 Nehchen R2	Riparian plantings Riparian plantings	R1 Nehchen R2*	Conrad R1
Upper Nehchen R4	In-stream structures & Riparian plantings	Nehchen R4a*	Nehchen R4b*
Hangman R11 (Sweatlodge)	Streambank Stabilization & Riparian Plantings	Hangman R11*	Hangman R12*
Hangman R13	Channel Reconstruction Riparian plantings	Hangman R13*	Hangman R12*
Sheep R2	Streambank Stabilization & Riparian Plantings	Sheep R2*	Tensed R1
Martin R1	Riparian plantings	Martin R1*	Martin R2

*Surveyed in 2004-2007

Cross Section Profiles

The cross section profiles were measured using a surveyor's level and rod at six locations along each studied reach. All cross sections were monumented with permanent pins (rebar), stakes, lathe and flagging to allow for repeat surveying of the profiles in the future. In some cases, survey pins had to be reset because they had been moved or “lost”. The Bench Mark established for the thalweg profile surveying was also used as the reference point for each of the six cross sections.

The cross section profiles were used to verify the bankfull depth and to calculate the bankfull cross sectional area, wetted perimeter, average and maximum depth and width-to-depth ratio. The flood-prone width, which is defined as the valley width at twice the maximum depth at bankfull, and entrenchment ratio, defined as the flood-prone width divided by the bankfull width, were not determined as part of this effort. The flood-prone width will be determined in the future to allow a verification of the channel type (see below). Collected cross section survey data, which included water depths where appropriate, was input into River Morph V. 3.1, along with the longitudinal profile data, which automatically graphed the profiles and also calculated pertinent descriptive criteria such as bankfull elevation, cross sectional area, wetted perimeter and flood prone elevation.

Channel Substrate

Channel bed and bank materials influence the cross-sectional form, plan-view, and longitudinal profile of rivers; they also determine the extent of sediment transport and provide the means of resistance to hydraulic stress (Ritter 1967). Channel substrate was measured using a modified version of Wolman's (1954) pebble count method as described by Rosgen (1993). The modified method adjusts the material sampling locations so that streambed materials are sampled on a proportional basis along a given stream reach. This requires that the six cross sections be located as described above. The pebble count substrate analysis was performed along each of the six cross sections within the monitored reach. Following the original method, particle size was determined as the length of the "intermediate axis" of the particle; that is the middle dimension of its length, width and height. At each of these points a measuring stick or finger was placed on the substrate and the one particle the tip touched was picked up and the size measured. Substrate size classes that were recorded are those used by Wolman (1954). Collected pebble count data was input into River Morph v3.1 which automatically graphed the distribution of particle sizes and calculated pertinent descriptive criteria such as percent by substrate class (size) and a particle size index (D value) for each habitat type for which data is indicated.

Canopy Cover

Vegetative canopy cover (or shade) was determined using a conical spherical densiometer, as described by Platts et al. (1983). The densiometer determines relative canopy "closure" or canopy density, depending on how the readings are taken. This monitoring was only for canopy density, which is the amount of the sky that is blocked within the closure by vegetation, and this is measured in percent. Canopy cover over the stream was determined at each of the six cross sections established following the habitat typing survey. At each cross section, densiometer readings were taken one foot above the water surface at the following locations: once facing the left bank, once facing upstream at the middle of the channel, once facing downstream at the middle of the channel and once facing the right bank. Percent density was calculated collectively over these four readings, and then averaged over the six locations at a site.

Instream Organic Materials

Organic materials play an important role in the character and productivity of stream habitats. This survey of monitored stream reaches was an inventory of the number and size of individual pieces of woody material observed along a longitudinal transect through the reach. All woody debris 4 inches in diameter at the small end and 3 ft in length that lay within the bankfull width were tallied and measured. For the Large Woody Debris (LWD) these data were converted into volumes of material so it was necessary to collect data on the lengths and diameters of the material to allow this calculation. Tree root wads were tallied separately as these typically provide additional habitat benefits because of their size and complexity. For this protocol the definition of a root wad was that it was dead, that it was detached from its original position, that it has a diameter where the tree trunk meets the roots of at least eight inches and that it was less than six feet long from the base of the root ball to the farthest extent of the trunk (Schuett-Hames, 1999**).**

The organic materials survey-transect was walked along the thalweg starting at the downstream end of the reach. All LWD was tallied and measured whether or not it crossed the line of transect. This included material that was suspended above the water surface and extended outside of the wetted stream width; it is not intended to include living trees or shrubs that hung over the water. Measurements taken of all LWD were the diameter at the large end, diameter at the small end and the length between these two ends. The large end diameter shall be measured immediately above the roots, if there are roots attached. The number and total volume of LWD throughout the reach was calculated for each site (River4m, Ltd. 1999).

Pool metrics

Various metrics were used to describe the availability of pool habitat at surveyed sites. The analytical software package River Morph was used to identify pools along each surveyed reach, and to calculate residual depth for each pool identified. Minimum, maximum, and mean residual pool depth were computed for each site, along with the density of pools per 100 m of stream length. Though pool volume was not calculated at this time, data were collected using methodologies outlined in Firehammer et al. (2010) to enable such calculations to be performed at a later date.

Sinuosity and Channel Pattern

The sinuosity of a stream reach was estimated as the ratio of the stream channel length to the direct basin (valley) length. Rosgen (1996) described the procedure for determining sinuosity of the entire stream basin but this also applies to a monitored stream reach. For a large scale determination of sinuosity, a 1:24,000 map or ortho-photo and a ruler, or GIS map in measure option or GPS was used to measure the length of the basin as the straight line distance from the where the stream entered the study reach to where it left the reach. The "total stream length" in the study reach was that measured for the longitudinal thalweg profile (i.e. 500 feet) and the valley length was measured by pulling a hip chain as straight as possible between the upstream and downstream ends of the 500-foot reach. Sinuosity was then calculated by dividing the stream length by the valley length. Meander length, radius of curvature, and belt width were measured using methods outlined in Rosgen (1996).

Stream Typing Level 2

The classification of stream channel types followed guidelines presented by Rosgen (1996) for Level 2 channel typing, and used data collected during the thalweg profile, cross section profile and sinuosity surveying efforts. The objective of classifying streams on the basis of channel morphology was to use discrete categories of stream types to develop consistent, reproducible descriptions of the stream reaches. These descriptions must provide a consistent frame of reference to document changes in the stream channels over time and to allow comparison between different streams. The dominant substrate type (i.e. slit/clay, sand, gravel, cobble) was included as a modifier to the channel type. The numbering for this was 1 for bedrock, 2 for boulder, 3 for cobble, 4 for gravel, 5 for sand, and 6 for silt and clay. Reach data was entered in River Morph Version 3.1 to assess channel types. Rosgen stream channel type classifications are described in more detail in Rosgen (1996).

The delineative criteria to classify channel types for level 2 analysis were entrenchment ratio, width-to-depth (W/D) ratio, sinuosity and slope (Rosgen 1996). Entrenchment ratio was estimated as the typical flood-prone width divided by the bankfull channel width. Bankfull width, or the stream width and depth at bankfull stage, was determined by the elevation of the top of the "highest depositional feature", which could be a change in the size distribution of substrate or bank particles, a stain on rocks in the bank, or, most frequently, a break in the slope of the bank. When the bankfull elevation was not evident in the field, it could usually be determined by looking at the plotted cross section profiles. Though flood-prone width is frequently not evident, especially where floodplain features have been obscured by agriculture or other human activities, it has been defined by Rosgen as the width at the elevation that is twice the bankfull max depth (i.e., twice the distance between the thalweg and the bankfull height). Width-to-depth ratio was defined as the bankfull width divided by the bankfull mean depth in a riffle section. Slope was calculated as the drop in elevation of the water surface divided by the length of the reach, and was measured from the upstream end of one habitat type (preferably a riffle) near the upstream end of the study reach to the upstream end of a similar habitat type near the downstream end of the study reach. Meander length, belt width, radius of curvature, and watershed size were entered into the program as additional descriptors to enable River Morph to be fully functional.

3.3.2 Instream Flow Incremental Methodology (IFIM)

A study was conducted by Hardin-Davis, Inc. in 2003 and 2004 to model the response of physical habitat and stream temperatures to simulated changes in flow and canopy cover in the upper Hangman Creek watershed to evaluate the benefits of prospective restoration actions on suitable habitat for redband trout. Modeling efforts were conducted on reaches in the mainstem of Hangman creek and in Indian and Nechen creeks, with sites chosen to represent a range of conditions from relatively undisturbed to heavily impacted. A full description of the sampling design and methodologies, and of the modeling analyses are provided in Hardin-Davis (2005).

Briefly, physical habitat, quantified in terms of depth, current velocity, substrate, and cover, was measured in the field at representative channel transects at various levels of discharge. Physical Habitat Simulation (PHABSIM) analysis, as a component of Instream Flow Incremental Methodology (IFIM), was then used to integrate the four measured variables into a habitat matrix, and to examine how this matrix changed under a simulated range of discharge (Bovee 1982; Stalnaker et al. 1994). Habitat suitability criteria that have been developed for rainbow trout (a proxy for native redband trout) and speckled dace (a native non-game fish) using the four aforementioned habitat variables were then evaluated with respect to the constructed matrices to generate an index of habitat value (i.e., Weighted Usable Area (WUA)) for the two focal species at various levels of simulated discharge. Modeling analyses followed procedures outlined by the Instream Flow Group (Bovee 1982) and guidelines established by the State of Washington (WDFW and WDOE 2000).

The response of stream temperature in the mainstem of Hangman creek to simulated changes in flow and canopy cover was assessed using the Stream Network Temperature Model (SNTEMP) which uses data on stream geometry, shade, discharge, and meteorology to predict mean water temperatures (Theurer et al. 1984; Bartholow 1989). Field data for existing shade and discharge were used in modeling runs to calibrate against stream temperatures collected in the field. Modeling efforts spanned the baseflow period given that this was the time when temperatures were most limiting. Simulations were then modeled to predict stream temperature under various scenarios that either increased shade or baseflow discharge or both variables to evaluate their relative benefits in providing more optimal summer rearing temperatures. As a final analysis, results from the PHABSIM and SNTMEP modeling efforts were integrated to estimate the potential overall usable habitat area (HA) to redband trout under various restoration scenarios that would increase baseflow discharge and reduce summer rearing temperatures. For a given discharge, the index HA incorporated the WUA per unit length of stream in combination with a temperature suitability weighting factor (ranging from 0 to 1) that was derived from general guidelines for trout (B. Caldwell, pers. comm.).

4.0 RESULTS

4.1 Biological Assessement

4.1.1 Fisheries Abundance and Distribution during Summer Surveys

Redband trout displayed consistent patterns of abundance over 2004-2006 in the upper Hangman Creek watershed where they were found to be sparsely distributed in forested reaches at low to moderate densities (Table 3-Table 5). In Indian Creek, redband trout were primarily found in a cedar dominated reach (i.e., index site 3) with moderate estimated densities of 11.5, 27.3, and 23.4 fish/100 m over the three years. Redband trout were also captured at 40-80% of the other sampled sites in all three years in Indian Creek, but at lower numbers than those recorded at site 3. In the Mission Creek subwatershed, redband trout were only captured in a forested reach in close proximity to the confluence of the West Fork of Mission in addition to the lowermost sampled site in a forested reach in the West Fork. Redband trout abundance was consistently the highest at the lowermost West Fork index site in the Mission Creek subwatershed, with moderate densities of 13.1, 20.1, and 23.4 fish/100 m estimated over the years. Redband trout were only present at one to two sites in forested upper reaches of the Sheep Creek subwatershed, and at low numbers, with estimated densities averaging 7.0 fish/100 m at sites where redband were captured (range, 3.3 – 11.8 fish/100 m). Redband trout were also apparently constrained to upper forested reaches of Hangman mainstem, and, other than the uppermost sampled site in 2006, present only at low numbers, with estimated densities averaging 4.3 fish/100 m at the few sites where they were captured. High densities of redband trout were documented in 2006 in the uppermost Hangman mainstem site and at an index site in Martin Creek (a tributary in the South Fork Hangman sub-watershed) with values of 94.8 and 35.4 fish/100 m respectively estimated.

Redband trout were not captured in any of the index sites located in streams in the northern portion (i.e., Tensed, Moctilemne, Lolo, Rose, North Fork Rock, Little Hangman) of the upper Hangman watershed in 2004, and consequently, these streams were not sampled in 2005 and 2006. In addition, redband trout were virtually absent during sampling events in Nehchen Creek from 2004 to 2006; only one redband trout was captured across all sample sites during all three years (Table 3-Table 5). However, non-native cutthroat trout were found at several of the index sites in Nehchen Creek in 2003 and 2004 and present at moderately high densities (mean, 24.7 fish/100 m) where they were found (Table 6). In 2005 and 2006, cutthroat trout were only captured at one index site in Nehchen Creek, with densities at this site comparatively lower (mean, 14.9 fish/100 m) than in previous years. In all sample years, large numbers of tolerant native minnows, most notably speckled dace and redside shiners, were typically counted in those reaches across sub-watersheds that lacked salmonids and where agriculture dominated (Table 3-Table 5).

4.1.2 Trout Age and Condition

Age class structure of redband trout age 1 and older in the Hangman watershed was consistent over the years 2003-2006 (Table 7). Approximately 50% of the captured fish were classified as age 1 fish (range, 42.3 - 54.1%), with age 2 and age 3 fish constituting 29% (range, 25.6 – 35.4%) and 22% (range, 18.8 – 28.8%) of the sampled population, respectively. Redband trout classified as age 4 were infrequently captured during the sample years. Accordingly, sizes of redband trout were also consistent across years, with approximately 67.4% (range, 60.1 – 79.1%) of the captured fish ranging between 100 and 200 mm in total length. Only eight (2.7%) redband trout captured during summer shocking surveys over the reporting period were greater than 200 mm in length.

Though differences in size and age structure were not detected across years, differences were found among watersheds (Table 8). In the Sheep and South Fork Hangman creek sub-watersheds, approximately 80% of the captured fish were classified as age 1. In comparison, greater percentages of age 2 and 3 fish were found in Indian (56.9), Mission (51.6,), and upper reaches of Hangman (65.7), than in Sheep Creek (20.9) and the South Fork of Hangman (18.9). Furthermore, of all the five analyzed sub-watersheds, upper reaches of Hangman had the highest percentage (35.8) of age 3 redband trout. Differences in the size distribution of redband trout among sub-watersheds exhibited similar patterns. Greater percentages of fish between 100 and 200 mm in total length were found in Indian (76.4), Mission (65.6,), and upper reaches of Hangman (77.6), than in Sheep Creek (41.6) and the South Fork of Hangman (45.9). The majority of redband trout captured in Sheep Creek and the South Fork of Hangman were less than 100 mm in total length.

Mean relative weight scores were all approximately 1.0 for Indian, Mission, and main-stem Hangman, the three sub-watersheds in which enough fish were available for analysis (Table 9). These relative weight scores indicate that captured fish in these habitats during our survey years were comparable in weight to an average sized rainbow trout of a similar length in other representative populations. Mean condition factors for redband trout smaller than 120 mm in length were not appreciably different (i.e., overlap of 95% confidence intervals) among the five analyzed sub-watersheds suggesting that fish in this size range were growing (i.e., acquiring somatic mass) similarly among the tributaries surveyed.

Table 3. Total fish captured and depletion-removal estimates for redband trout (RBT) age 1 and older sampled by multipass electrofishing in the upper Hangman Creek watershed, 2004. Number of tolerant native minnows counted is also displayed. Index sites are identified as being in forested (Y) or non-forested habitat and are ordered relative to their longitudinal position from downstream to upstream within each sub-watershed.

Index site	Forested	Passes	RBT captured	RBT estimate	RBT 95% CI	RBT density (fish/100 m)	Count of tolerant native minnows
			Hangman mainstem				
Hangman 1	.	2	0	0	.	0	308
Hangman 2	.	2	0	0	.	0	296
Hangman 3	.	2	0	0	.	0	469
Hangman 4	.	2	0	0	.	0	475
Hangman 5	.	2	0	0	.	0	357
Hangman 6	.	2	0	0	.	0	170
Hangman 7	.	2	0	0	.	0	204
Hangman 8	.	2	0	0	.	0	384
Hangman 9	.	2	0	0	.	0	257
Hangman 10	.	2	0	0	.	0	469
Hangman 11	.	2	0	0	.	0	107
Hangman 12	.	2	0	0	.	0	309
Hangman 13	.	2	0	0	.	0	34
Hangman 15	Y	2	5	5	5 - 5	8.2	361
Hangman 16	Y	2	4	4	4 - 4	6.6	90
			Indian Creek				
Indian 1	Y	2	5	5	5 - 5	8.2	120
Indian 2	Y	2	9	9	9 - 10	15	0
Indian 3	Y	2	7	7	7 - 7	11.5	0
Indian 4	Y	2	0	0	.	0	0
N.F. Indian 1	Y	2	0	0	.	0	0
E.F. Indian 1	Y	2	0	0	.	0	0
			Mission Creek				
Mission 1	.	2	0	0	.	0	286
Mission 2	.	2	0	0	.	0	168
Mission 3	Y	2	0	0	.	0	16
Mission 4	Y	2	5	5	5 - 5	8.2	0
Mission 5	Y	2	0	0	.	0	0
Mission 6	Y	2	0	0	.	0	0
Mission 7	Y	2	0	0	.	0	0
E.F. Mission 8	.	2	0	0	.	0	0
E.F. Mission 9	.	2	0	0	.	0	0
W.F. Mission 10	Y	2	8	8	8 - 8	13.1	0
W.F. Mission 11	.	2	0	0	.	0	0

Table 3. Continued.

Index site	Forested	Passes	RBT captured	RBT estimate	RBT 95% CI	RBT density (fish/100 m)	Count of tolerant native minnows
				Nehchen Creek			
Nehchen 1	.	2	0	0	.	0	2
Nehchen 2	.	2	0	0	.	0	0
Nehchen 3	Y	2	0	0	.	0	0
Nehchen 4	Y	2	0	0	.	0	0
N.F. Nehchen 1	.	2	0	0	.	0	0
				Sheep Creek			
Sheep 1	.	2	0	0	.	0	98
Sheep 2	.	2	0	0	.	0	183
Sheep 3	Y	2	0	0	.	0	0
Sheep 4	Y	2	2	2	2 - 2	3.3	0
Sheep 5	Y	2	3	3	3 - 3	4.9	0
S.F. Sheep 1	.	2	0	0	.	0	0

4.1.3 Trout Migration

Numbers of redband trout captured by migrant traps located on the Hangman mainstem and on Indian and Nehchen creeks in 2006 and 2007 were typically low and varied across years (Table 10). In Indian Creek, 17 fish were captured in migrant traps in 2007, but no fish were captured the preceding year. In comparison, 13 fish were captured in migrant traps in Nehchen Creek in 2006, but only 4 the following year. Only four fish were captured in the Hangman mainstem resistant-board weir trap over trapping years, two in each of 2006 and 2007.

Though few fish were captured in migrant traps during the reporting period, the majority of captured fish were greater than 200 mm in total length (Table 10). For example, of the 17 fish captured in Indian Creek in 2007, 9 (53%) were greater than 200 mm, with a mean size of 270 mm calculated for these fish. In Nehchen Creek, 11 (85%) and 3 (75%) of the redband trout captured in 2006 and 2007 were greater than 200 mm, with mean sizes of 266 and 242 respectively computed. Three of the four fish captured in the Hangman mainstem trap were also greater than 200 mm (mean, 279 mm). In total, 26 redband trout greater than 200 mm were caught in migrant traps over the two years, whereas only 8 fish of this size class were captured during four years of sampling stream reaches during summer electroshocking surveys.

Table 4. Total fish captured and depletion-removal estimates for redband trout (RBT) age 1 and older sampled by multipass electrofishing in the upper Hangman Creek watershed, 2005. Number of tolerant native minnows counted is also displayed. Index sites were identified as being in forested or non-forested habitat and are ordered relative to their longitudinal position from downstream to upstream within each sub-watershed.

Index site	Forested	Passes	RBT captured	RBT estimate	RBT 95% CI	RBT density (fish/100 m)	Count of tolerant native minnows
			Hangman mainstem				
Hangman 1	.	2	0	0	.	0	590
Hangman 2	.	2	0	0	.	0	670
Hangman 3	.	2	0	0	.	0	398
Hangman 4	.	2	0	0	.	0	622
Hangman 5	Y	2	1	1	1 - 1	1.6	597
Hangman 6	Y	3	1	1	1 - 1	1.6	314
			Indian Creek				
Indian 1	Y	2	2	2	2 - 2	3.3	98
Indian 2	Y	1	4	.	.	.	0
Indian 3	Y	2	14	17	14 - 25	27.3	0
Indian 4	Y	3	2	2	2 - 4	3.6	0
N.F. Indian 5	Y	2	4	5	4 - 7	7.4	0
E.F. Indian 6	Y	2	0	0	.	0	0
			Mission Creek				
Mission 1	.	2	0	0	.	0	185
Mission 2	Y	2	0	0	.	0	10
Mission 3	Y	2	3	3	3 - 3	4.9	0
Mission 4	Y	2	7	7	7 - 8	11.8	0
Mission 5	Y	2	0	0	.	0	0
Mission 6	Y	2	0	0	.	0	0
W.F. Mission 7	Y	2	10	12	10 - 20	20.1	0
W.F. Mission 8	Y	2	0	0	.	0	0
E.F. Mission 9	.	2	0	0	.	0	0
			Nehchen Creek				
Nehchen 1	.	2	0	0	.	0	0
Nehchen 2	.	2	0	0	.	0	0
Nehchen 3	Y	2	1	1	1 - 1	1.6	0
Nehchen 4	Y	2	0	0	.	0	0
N.F. Nehchen 5	.	2	0	0	.	0	0
			Sheep Creek				
Sheep 1	.	2	0	0	.	0	420
Sheep 2	.	2	0	0	.	0	359
Sheep 3	Y	2	0	0	.	0	0
Sheep 4	Y	2	4	4	4 - 4	6.6	0
S.F. Sheep 5	.	2	0	0	.	0	0

Table 5. Total fish captured and depletion-removal estimates for redband trout (RBT) age 1 and older sampled by multipass electrofishing in the upper Hangman Creek watershed, 2006. Number of tolerant native minnows counted is also displayed. Index sites were identified as being in forested or non-forested habitat and are ordered relative to their longitudinal position from downstream to upstream within each sub-watershed.

Index site	Forested	Passes	RBT captured	RBT estimate	RBT 95% CI	RBT density (fish/100 m)	Count of tolerant native minnows
			Hangman mainstem				
Hangman 1	.	2	0	0	.	0	496
Hangman 2	.	2	0	0	.	0	547
Hangman 3	.	2	0	0	.	0	150
Hangman 4	.	2	0	0	.	0	24
Hangman 5	Y	2	2	2	2 - 2	3.3	0
Hangman 6	Y	2	0	0	.	0	172
Hangman 7	Y	2	55	58	55 - 63	94.8	0
			Indian Creek				
Indian 1	Y	2	2	2	2 - 2	3.3	27
Indian 2	Y	2	4	4	4 - 4	6.6	0
Indian 3	Y	2	13	14	13 - 19	23.4	0
Indian 4	Y	2	0	0	.	0	0
E.F. Indian 5	Y	2	0	0	.	0	0
N.F. Indian 6	Y	2	8	8	8 - 9	13.4	0
			Mission Creek				
Mission 1	.	2	0	0	.	0	6
Mission 2	Y	2	0	0	.	0	14
Mission 3	Y	2	0	0	.	0	0
Mission 4	Y	2	3	3	3 - 3	4.9	0
Mission 5	Y	2	0	0	.	0	0
Mission 6	Y	2	0	0	.	0	0
W.F. Mission 7	Y	2	13	14	13 - 19	23.4	0
W.F. Mission 8	Y	2	0	0	.	0	0
E.F. Mission 9	.	2	0	0	.	0	0
			Nehchen Creek				
Nehchen 1	.	2	0	0	.	0	0
Nehchen 2	.	2	0	0	.	0	0
Nehchen 3	Y	2	0	0	.	0	0
Nehchen 4	Y	2	0	0	.	0	0
N.F. Nehchen 5	.	2	0	0	.	0	0
			South Fork Hangman Creek				
Martin 1	Y	2	21	22	21 - 24	35.4	0
S.F. Hangman 1	.	2	0	0	.	0	113
			Sheep Creek				
Sheep 1	.	2	0	0	.	0	333
Sheep 2	.	2	0	0	.	0	297
Sheep 3	Y	2	7	7	7 - 8	11.8	0
Sheep 4	Y	2	5	5	5 - 5	8.2	0
S.F. Sheep 5	.	2	0	0	.	0	0

Table 6. Total fish captured and depletion-removal estimates for cutthroat trout age 1 and older sampled by multipass electrofishing in Nehchen Creek, 2003-2006. Index sites were identified as being in forested or non-forested habitat and are ordered relative to their longitudinal position from downstream to upstream within each sub-watershed.

Index site	**Forested**	**Passes**	**Total captured**	**Index site estimate**	**95% CI**	**Density (fish/100 m)**
			2003			
Nehchen 1	.	2	0	0	.	0
Nehchen 2	.	2	0	0	.	0
Nehchen 3	.	2	0	0	.	0
Nehchen 4	Y	1	8	.	.	.
Nehchen 5	Y	2	20	20	20 - 21	32.9
Nehchen 6	Y	2	9	9	9 - 10	15
Nehchen 7	.	0	.	.	.	.
Nehchen 8	Y	2	21	21	21 - 22	34.8
Nehchen 9	.	2	0	0	.	0
Nehchen 10	.	2	0	0	.	0
Nehchen 11	.	2	0	0	.	0
			2004			
Nehchen 1	.	2	0	0	.	0
Nehchen 2	.	2	20	21	20 - 23	33.8
Nehchen 3	Y	2	12	12	12 - 13	19.8
Nehchen 4	Y	2	7	7	7 - 8	11.8
N.F. Nehchen 1	.	2	0	0	.	0
			2005			
Nehchen 1	.	2	0	0	.	0
Nehchen 2	.	2	0	0	.	0
Nehchen 3	Y	2	0	0	.	0
Nehchen 4	Y	2	3	3	3 - 3	4.9
N.F. Nehchen 5	.	2	0	0	.	0
			2006			
Nehchen 1	.	2	0	0	.	0
Nehchen 2	.	2	0	0	.	0
Nehchen 3	Y	2	0	0	.	0
Nehchen 4	Y	2	14	15	14 - 19	24.8
N.F. Nehchen 5	.	2	0	0	.	0

Table 7. Counts and relative percents of ages and size classes of redband trout (age 1 and older) captured across mainstem and tributary habitats in the upper Hangman Creek watershed, 2003-2006.

	2003		2004		2005		2006		Total	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Ages										
1	30	48.4	22	45.8	22	42.3	72	54.1	146	49.5
2	18	29.0	17	35.4	15	28.8	34	25.6	84	28.5
3	14	22.6	9	18.8	15	28.8	26	19.5	64	21.7
4	0	0	0	0	0	0	1	0.8	1	0.3
Length categories (mm)										
< 100	13	21.0	10	20.8	16	30.8	49	36.8	88	29.8
100 - 150	36	58.1	22	45.8	26	50.0	45	33.8	129	43.7
150 - 200	13	21.0	15	31.3	7	13.5	35	26.3	70	23.7
> 200	0	0	1	2.1	3	5.8	4	3.0	8	2.7

Table 8. Counts and relative percents of ages and size classes of redband trout (age 1 and older) analyzed by select subwatersheds in the upper Hangman Creek watershed, 2003-2006.

	Indian		Mission		Sheep		S.F. Hangman		Hangman	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Ages										
1	44	43.1	31	48.4	19	79.2	30	81.1	22	32.8
2	38	37.3	17	26.6	4	16.7	5	13.5	20	29.9
3	20	19.6	16	25.0	1	4.2	2	5.4	24	35.8
4	0	0	0	0	0	0	0	0	1	1
Length categories (mm)										
< 100	24	23.5	19	29.7	14	58.3	20	54.1	11	16.4
100 - 150	60	58.8	26	40.6	8	33.3	11	29.7	24	35.8
150 - 200	18	17.6	16	25.0	2	8.3	6	16.2	28	41.8
> 200	0	0	3	4.7	0	0	0	0	4	6.0

Table 9. Relative weights and condition factors for redband trout captured in five sub-watersheds in the upper Hangman Creek watershed over the years 2003, 2005, and 2006. Relative weights were only calculated for fish ≥ 120 mm in total length, and were not calculated for Sheep and S.F. Hangman creeks because of the lack of fish this size. Condition factors were only calculated for fish < 120 mm for comparison among sub-watersheds.

Sub-watershed	N	Mean	95% CI
		Relative weights	
Indian	49	0.99	0.95 - 1.03
Hangman	36	0.96	0.92 - 1
Mission	21	1.03	0.98 - 1.07
		Condition factors	
Indian	32	1.16	1.05 - 1.27
Hangman	22	1.05	0.99 - 1.11
Mission	30	1.17	1.13 - 1.21
Sheep	16	1.19	1.09 - 1.28
S.F. Hangman	28	1.06	1 - 1.13

4.1.4 Salmonid Genetics

Genetic structuring analyses (e.g., genetic distance tree) indicated that sampled populations in upper Hangman Creek formed a cohesive group, and were more associated with each other than with fish from lower Hangman and from other reaches in the Spokane River that were sampled by Washington Department of Fish and Wildlife (Small and Von Bargen 2005). However, genetic results indicated that population fragmentation may be occurring at the tributary scale in upper Hangman Creek. Significant genotypic differences (i.e., pairwise F_{st} tests) were detected among sub-populations from Indian Creek, Nehchen Creek, and collectively from Sheep and Mission Creeks. Low allelic richness was also detected in fish sampled from Mission and Sheep Creeks. Furthermore, significant departures from Hardy-Weinberg equilibrium expectations for most of the upper Hangman collections suggest that either substantial inbreeding may be occurring within each sub-population, likely the result of small effective population sizes, or that subpopulations each experienced a recent genetic bottleneck.

Genetic analyses supported the relative purity of redband trout sub-populations in the upper Hangman watershed (Small and Von Bargen 2005). Fish collected from these tributaries shared less than 1% ancestry with the Spokane hatchery collection which was derived from the coastal strain of rainbow trout. In addition, genetic results from redband trout collected from tributaries other than Nehchen Creek indicated a lack of hybridization with cutthroat trout. However, as expected, many of the fish in upper Nehchen Creek were highly associated with cutthroat trout collections, supporting the notion that these fish were more likely cutthroat than rainbow trout. In addition, low allelic and genetic richness in the Nehchen collection supports the likelihood that these cutthroat trout were introduced using a small number of founders from another watershed outside the Spokane basin. The entire report supplied by the Washington Department of Fish and Wildlife is contained in Appendix G. An interview with a landowner revealed that he had transplanted 400 fish from Benewah Creek, where cutthroat trout are the dominant salmonid, to upper Nehchen Creek in 1985.

Table 10. Summary data for redband trout captured in migrant traps in the Hangman mainstem, Indian Creek, and Nehchen Creek in 2006 and 2007.

	Trapping year	
Redband trout metric	**2006**	**2007**
	Hangman mainstem	
Number of captured fish		
All sizes	2	2
Fish ≥ 200 mm (% of total)	2 (100)	1 (50)
Length statistics for captured fish ≥ 200 mm		
Mean (st. dev.)	273.5 (3.5)	291
Range (min - max)	271 - 276	.
	Indian Creek	
Number of captured fish		
All sizes	0	17
Fish ≥ 200 mm (% of total)	0	9 (53)
Length statistics for captured fish ≥ 200 mm		
Mean (st. dev.)	.	269.9 (43.3)
Range (min - max)	.	211 - 323
	Nehchen Creek	
Number of captured fish		
All sizes	13	4
Fish ≥ 200 mm (% of total)	11 (85)	3 (75)
Length statistics for captured fish ≥ 200 mm		
Mean (st. dev.)	266.3 (26.2)	241.7 (23.8)
Range (min - max)	238 - 330	226 - 269

4.1.5 Macro-Invertebrate Communities

Substantial differences were observed in those invertebrate metrics associated with high-quality cold-water trout habitat (e.g., low percent fines in riffle habitats, cold temperatures) between forested reaches and those reaches bounded by agricultural lands in the upper Hangman watershed. In the Hangman, Mission, Sheep, Nehchen, and Indian creek sub-watersheds, EPT richness values generally increased upstream of agriculturally-dominated riparian zones, and were greater than or equal to 15 only in more forested reaches in the upper part of their respective sub-watersheds. Although the percent of EPT exceeded 50% in select sampled reaches in upper Hangman mainstem, the South Fork of Hangman, Mineral, Nehchen, Indian, Tensed, and Moctilemne creeks, the EPT assemblage was often dominated by the ephemeropteran *Serratella spp*. in many of these sampled reaches. Given that this species has been associated with fine sediments and low flow or stagnant waters (Edmunds et al. 1960), and has been rated a tolerance value of 2 on a scale of 10 by Idaho Department of Environmental Quality (Clark and Maret 1993), this metric may not be useful in differentiating the quality of stream habitats for cold-water trout species.

Plecopteran metrics, a more descriptive indictor of high-quality productive trout habitats, better differentiated subwatersheds than the EPT metrics. Plecopteran richness exceeded a value of 5 only in reaches in the upper Hangman and the South Fork of Hangman sub-watersheds, and in numerous reaches in the Nehchen (3 sites) and Indian (4 sites) creek sub-watersheds. Furthermore, percent plecopterans exceeded 15% only in forested reaches in upper Mission and Sheep creeks, and in Nehchen and Indian creeks. In comparison, percentages of plecopterans were extremely low in other reaches, especially those in the northern part of the watershed impacted by agriculture (e.g., Tensed, Rose, NF Rock, Moctilimne, and Lolo creeks). Notably, the dominant taxa in the agriculturally-impacted reaches were mostly dipterans.

Results from the statistical regression analyses corroborated those described above in which invertebrate metrics associated with high-quality trout habitat were significantly related to the percent of fines measured in riffle habitats and to the 7-day running average of maximum daily water temperatures (Table 11). Significant negative linear relationships were detected between percent fines and the Shannon-Weaver H' index, the fine sediment biotic index, the DEQ MBI, long-lived taxa richness, intolerant taxa richness, EPT richness, plecopteran richness, percent EPT, and percent plecopterans, with the latter 8 indices exhibiting the highest significance (i.e., $p < 0.001$). Similar significant negative relationships were found between all the aforementioned invertebrate indices and the maximum daily temperature metric, except for the Shannon-Weaver H' index which was not found to exhibit a significant relationship. In addition, percent EPT was not found to display as strong a negative relationship with the maximum daily temperature metric as with percent fines. Percent chironomids and dipterans, on the other hand, were significantly positively related to both the percent fines in riffle habitats and the maximum daily temperature metric.

Table 11. Summary of statistical linear regressive relationships between selected invertebrate metrics and the percent fines in riffle habitats and the 7-d running average of maximum daily stream temperature at sites sampled for invertebrate assemblage structure in the upper Hangman creek watershed in 2004. Significant relationships at the 0.05, <0.01, and <0.001 level are denoted by a single, double, and triple asterisk, respectively. Also displayed are the direction, positive or negative, of the estimated relationships.

	Percent fines		7-d average of maximum daily stream temperature	
Invertebrate metric	**p-value**	**Regressive relationship**	**p-value**	**Regressive relationship**
Shannon-Weaver H'	0.046 *	Negative	0.785 .	Negative
Fine sediment biotic index	<0.001 ***	Negative	<0.001 ***	Negative
DEQ MBI	<0.001 ***	Negative	<0.001 ***	Negative
Long-lived taxa richness	<0.001 ***	Negative	<0.001 ***	Negative
Intolerant taxa richness	<0.001 ***	Negative	<0.001 ***	Negative
EPT richness	<0.001 ***	Negative	<0.001 ***	Negative
Plecopteran richness	<0.001 ***	Negative	<0.001 ***	Negative
Percent tolerant taxa	0.559 .	Positive	0.642 .	Positive
Percent EPT	<0.001 ***	Negative	0.011 *	Negative
Percent plecopterans	<0.001 ***	Negative	<0.001 ***	Negative
Percent dipterans	0.007 **	Positive	0.002 **	Positive
Percent chironomids	<0.001 ***	Positive	<0.001 ***	Positive
Percent perlids	0.109 .	Negative	0.005 **	Negative

4.2 Chemical Assessment

4.2.1 Water Quality

Measured levels of discharge during baseline flow conditions were dramatically different among tributaries sampled in the upper Hangman Creek watershed over the reporting period (Table 12). In the lowermost reaches in Indian Creek, measured discharge exceeded 0.10 cfs (range, 0.10-0.30 cfs) in each of the four monitoring years; values were relatively lower in assessed reaches in the three upper forks of Indian Creek, but never were there only standing pools or a lack of water. The uppermost forested site in Hangman Creek (i.e., Hangman-Forest) also exhibited baseflow discharge values that exceeded 0.08 cfs in most years. In comparison, at least one of the monitored reaches in each of the other sub-watersheds in which trout were found (i.e., Mission, Sheep, Nehchen, and South Fork Hangman) were found to be dry during several of the monitored years with discharge levels of less than 0.03 cfs measured at many of the other sites. Further, specific reaches in each of East Fork Mission, South Fork Sheep, lower Nehchen, North Fork Nehchen, and upper South Fork Hangman were repeatedly found to be dry during baseflow periods over many of the years throughout the reporting period. Monitored tributary reaches in the northern part of the upper Hangman watershed where trout were not captured (e.g., Andrew Springs, Lolo, Tensed) were always dry when examined at baseline conditions.

Tributary differences in dissolved oxygen measured during baseline conditions over reporting years in the upper Hangman watershed displayed similar patterns as that described for discharge (Table 12). In all monitored reaches in Indian Creek and in the uppermost forested site in Hangman Creek, dissolved oxygen never was found to fall below 6 mg/L. Dissolved oxygen measured in the only wetted reach in Nehchen Creek also exceeded this value in each of the four years. Conversely, dissolved oxygen was found to drop below this level in at least one of the monitored reaches in Mission, Sheep, and South Fork Hangman sub-watersheds, and in the lower main-stem of Hangman Creek. As expected, low dissolved oxygen was often associated with low levels of measured discharge in these reaches. Moreover, many of the lowest baseflow dissolved oxygen readings occurred in 2007 when summer air temperatures were the highest during the reporting period. Lowest overall dissolved oxygen readings across a sub-watershed were found in the Rock Creek drainage where values ranged from 3.26 – 4.78 mg/L in 2004.

Other water quality data, such as pH, conductivity, and alkalinity were collected monthly during 2004, and during June and selected high flow events from 2005 to 2007(Appendix B). From 2004 to 2006, pH values typically ranged from 6 to 7.5, which suggest that pH is not a limiting factor in the upper Hangman Creek watershed. Although some extremely low pH values were measured during 2007, equipment malfunction in part may have explained these abnormally low values. Alkalinity values were generally low (i.e., < 25 mg/L) in forested reaches, but were higher in those reaches that were found within agricultural areas. Nutrient levels were analyzed for sampled reaches but were not tabulated in this report.

Discharge regimes during high flow events, predominantly due to either rain-on-snow events or just heavy rainfall on saturated soils, were flashier in the Hangman main-stem and in Mission and Sheep creeks than in Indian and Nehchen creeks. For example, in May of 2004, a severe rain storm produced a 10 foot rise in stage at the Hangman-stateline gaging station in which discharge attained levels of 2651 cfs (Figure 10; Picture 5). Discharge in both Sheep and Mission creeks reflected the increase recorded in the Hangman main-stem, increasing precipitously to levels approaching 350 and 500 cfs, respectively. In comparison, discharge in Indian and Nehchen creeks during this rain event remained at moderate levels below 100 cfs. As another example, a rain-on-snow event in January of 2006 abruptly increased discharge to approximately 2500 cfs in the Hangman main-stem and to 150 and 450 cfs in Sheep and Mission creeks, respectively. Conversely, discharge in Indian and Nehchen creeks remained relatively unaffected. In addition to Mission and Sheep creeks, other heavily impacted sub-watersheds, such as Smith and Tensed creeks, exhibited severe flooding in moderate rain storms during the reporting period.

Table 12. Summary of discharge and dissolved oxygen at baseline conditions in Hangman Creek during 2004-7.

	2004		2005		2006		2007	
Site	DS (cfs)	D.O. (mg/L)	DS (cfs)	D.O. (mg/L)	DS (cfs)	D.O. (mg/L)	DS (cfs)	D.O. (mg/L)
Hangman								
Hangman-Stateline	<.3	8.62	<.3	7.57	<.3	7.02	0.90	1.85
Hangman-Buckless	0.26	8.73	0.04	8.29	0.14	9.42	0.02	5
Hangman-SF Road	0.07	8.94	0.04	7.95	0.19	8.26	0.07	5.75
Hangman-Forest	0.09	8.78	0.08	9.5	0.13	9.2	0.05	7.26
Moctilimne								
Lower Moctilimne	0.21	6.52			0.19	8.52		
Upper Moctilimne	0.04	8.76	0.04	7.97	0.01	8.10		
Andrew Springs & Lolo								
Andrew Springs	DRY		DRY		DRY		DRY	
Lolo	DRY		DRY		DRY		DRY	
Tensed								
Lower Tensed	DRY		DRY		DRY		DRY	
Upper Tensed	DRY		DRY		DRY		DRY	
Mission								
Mission-Desmet	0.002	6.99	0.01	8.55	0.01	6.48	DRY	
Mission-KVR	0.01	8.24	0.01	9.11	0.01	6.27	0.02	4.56
MF Mission	0.02	8.98	DRY		0.01	8.49	0.01	6.41
EF Mission	0.00	7.53	DRY		DRY		DRY	
WF Mission	0.00	9.45	0.02	5.5	0.01	6.04	0.01	5.54
Sheep								
Sheep-HWY 95	0.0	2.55	0.00		0.0		DRY	
Upper Sheep	0.03	8.42	0.02		0.01		0.03	4.87
SF Sheep	0.0	8.63	DRY		DRY			
Nehchen								
Lower Nehchen	0.031		DRY		DRY		DRY	
Upper Nehchen	0.01	6.59	0.02	8.81	0.07	8.02	0.01	7.54
NF Nehchen	DRY		DRY					
Smith								
Smith	0.00		0.00		DRY		DRY	
Mineral	DRY		DRY		DRY		DRY	
Indian								
Indian-Sanders	0.24	7.8	0.14	8.6	0.16	7.85	0.10	8.66
Indian-Pow Wow	0.28	8.62	0.19	10.13	0.24	8.9	0.30	8.45
MF Indian	0.10	8.66	0.07	10.22	0.04	8.92	0.03	6.3
NF Indian	0.21	8.93	0.09	10.33	0.11	9.31	0.05	9.32
EF Indian	0.04	8.82	0.02	10.01	0.03	7.33	0.02	7.41
SF Hangman								
Lower SF Hangman	0.01	5.46	0.06	7.95	0.03	3.00	0.03	4.1
Upper SF Hangman	0.01	7.61	DRY		DRY		DRY	
Martin	0.09	8.38	0.03	9.29	0.04		0.04	5.56
Upper Hangman Tributaries								
Bunnel	0.01	5.46	0.06	7.95	0.03	9.31	0.03	7.58
Parrot	DRY	7.61	DRY		DRY	8.53	0.01	5.49
Hill	0.01	8.38	0.03	9.29	0.04	8.83		
Rock Creek								
NF Rock-Stateline	0.0	4.16						
Rose	0.03	4.78						
Rock	0.06	3.26						

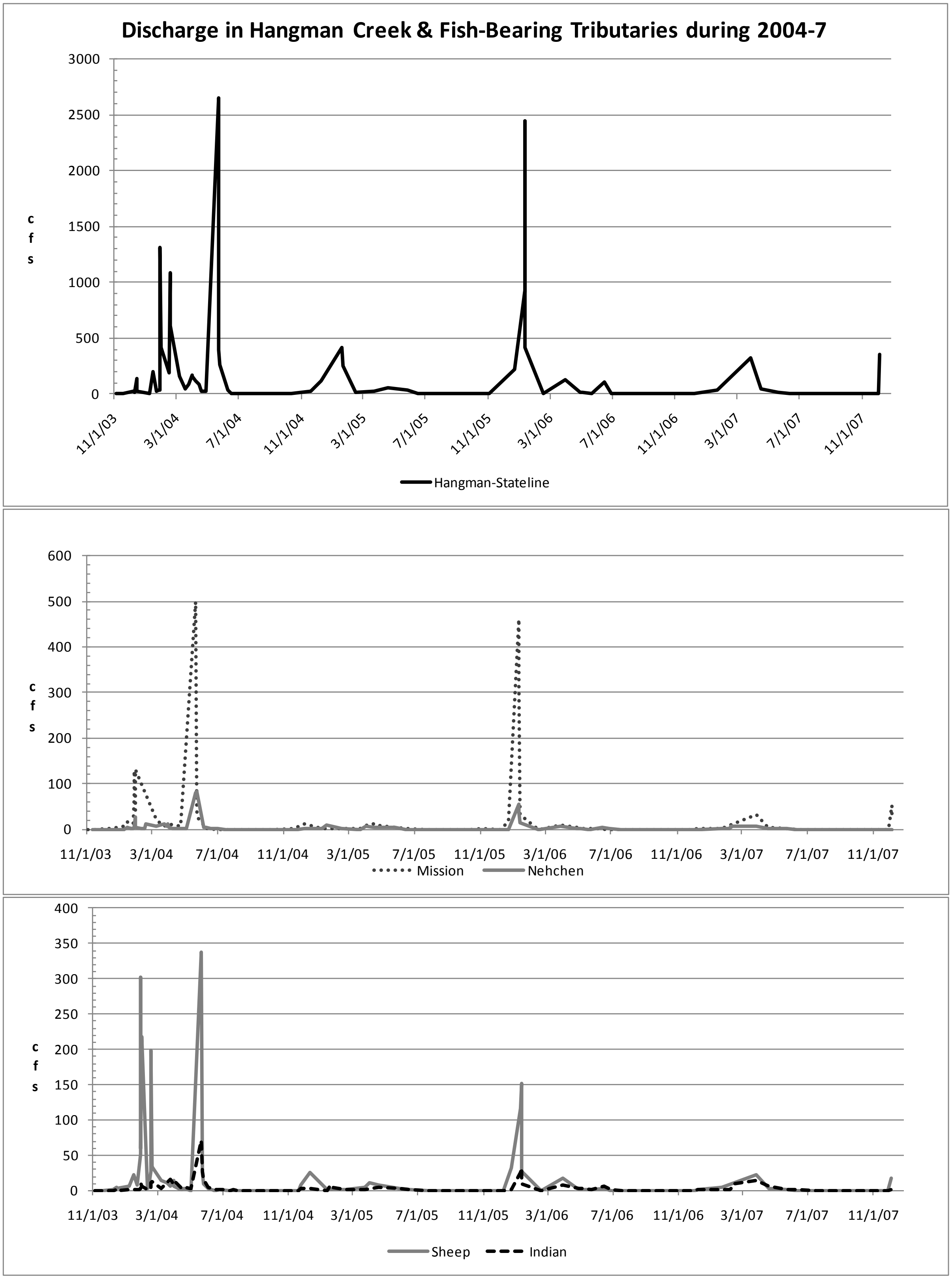


Figure 10. Discharge in Hangman Creek and four tributaries during 2004-7.

Higher levels of total suspended sediment (TSS), concomitant with high flow events, were also recorded in the main-stem of Hangman Creek and in Sheep and Mission creeks than in Indian and Nehchen creeks. For example, during the aforementioned high flow event in May of 2004, TSS concentrations at Hangman RM 0.0 were 153 mg/L (Figure 11). Notably TSS concentrations would have likely been greater if depth integrated sampling had been performed instead of obtaining a grab sample at the water's edge. High TSS levels ranging from 171-214 mg/L were also documented at sites in Mission Creek. In comparison, TSS levels were only 63 mg/L in Indian Creek, approximately a third of that recorded in Hangman main-stem and Mission creeks (Figure 11). A pronounced difference among tributary reaches was also observed during the aforementioned rain-on-snow event in January of 2006 (Figures 12-14). TSS levels were monitored over a 3-d span as tributaries and main-stem reaches responded to the rain event occurring on the 10th. On the initial day of the rain event, TSS levels were much higher in the Hangman main-stem (388 mg/L; stateline site) and in Mission Creek (404 mg/L) than in Nehchen (205 mg/L) and Indian (69 mg/L) creeks. Though TSS levels gradually receded over the next two days, recorded values were still respectively higher in the Hangman main-stem (133 and 35 mg/L), Mission (169 and 36 mg/L), and Sheep (205 and 42 mg/L) creeks than in Nehchen (68 and 26 mg/L) and Indian (31 and 11 mg/L) creeks. TSS levels at the Hangman-Forest, Martin Creek, and lower South Fork Hangman sites exhibited similar levels of TSS over the latter two days of the storm event as those recorded in Indian and Nehchen creeks. Incidentally, when comparing TSS concentrations among sites within each of these highlighted heavy rain events, Tensed Creek (an agriculturally-dominated tributary) displayed some of the highest values.

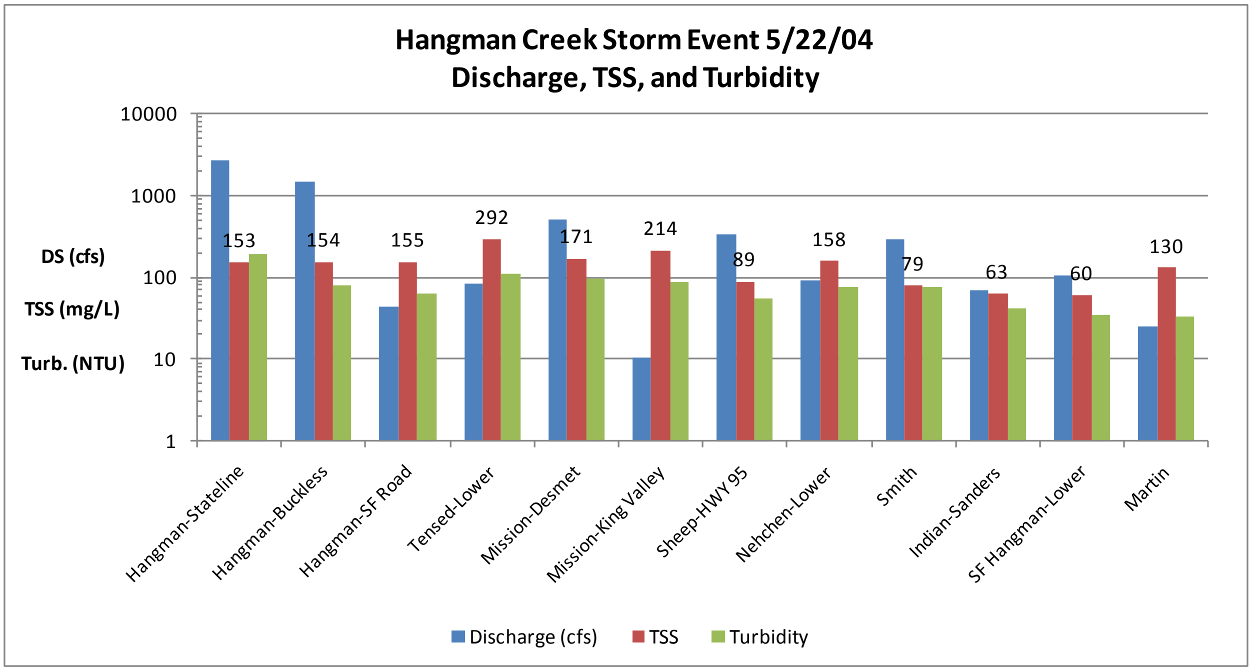


Figure 11. Comparison of discharge, total susptended solids (TSS), and turbidity in the Hangman watershed during a major food event on May 4, 2004 from 0.25" of rain with no snow on the ground.

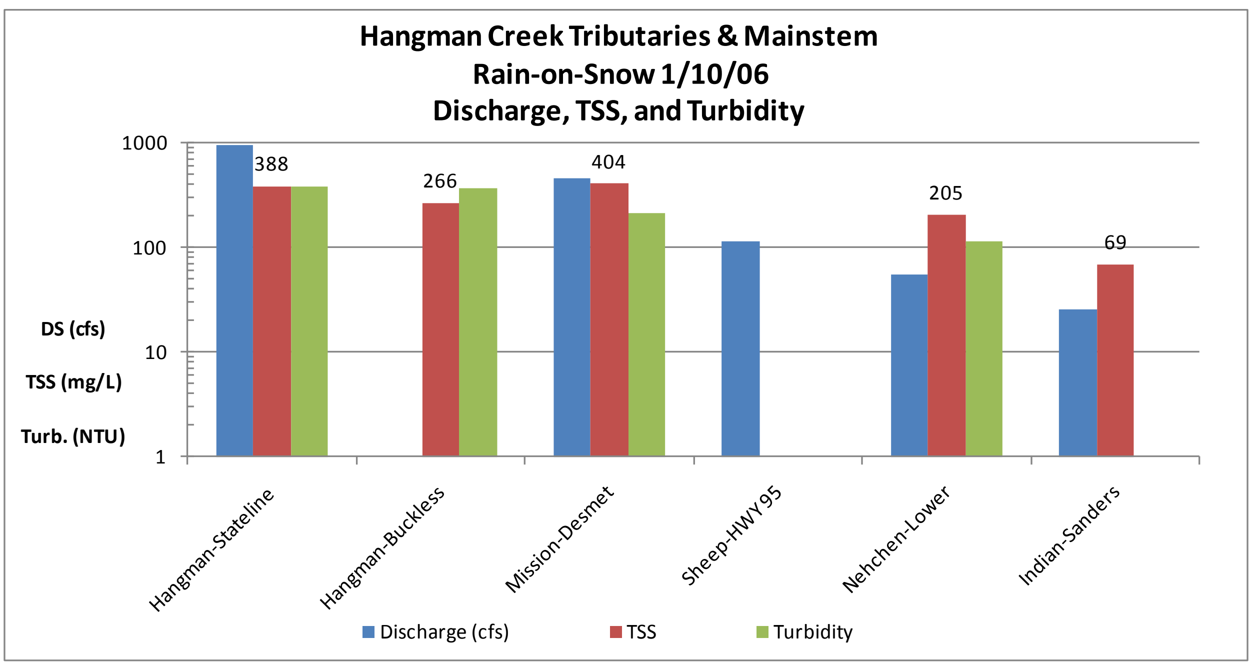


Figure 12. Comparison of discharge, total susptended solids (TSS), and turbidity in the Hangman watershed during a rain-on-snow event on January 10th 2006.

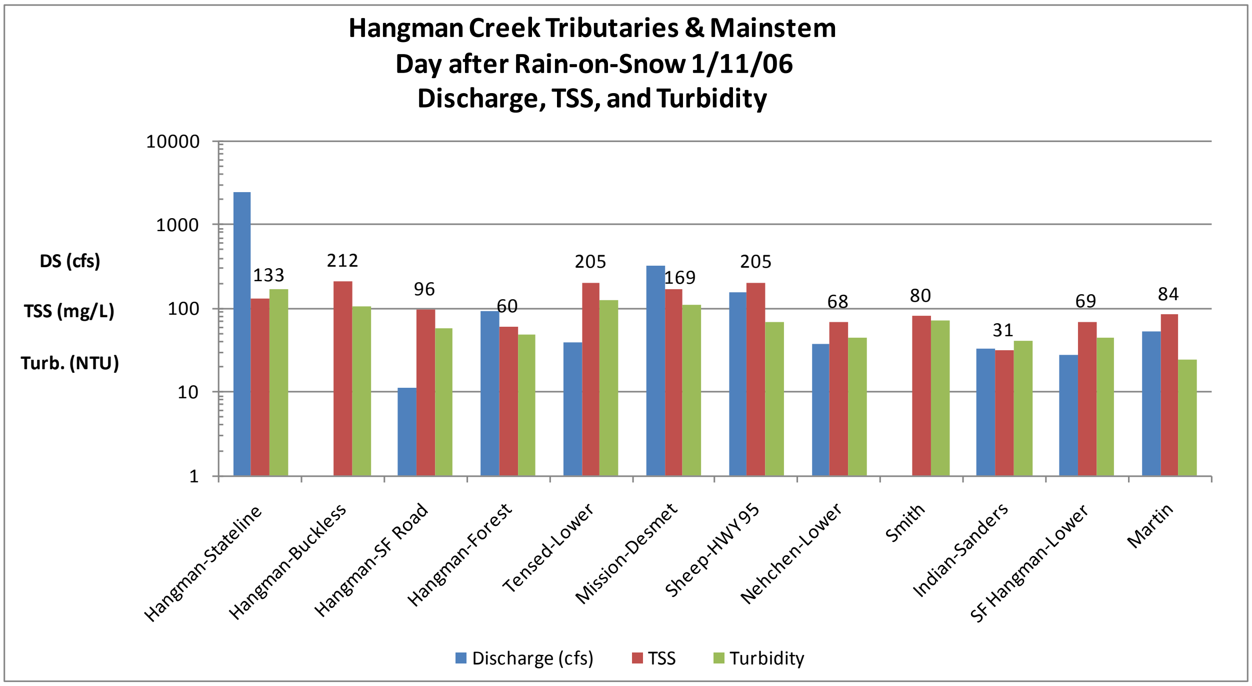


Figure 13. Comparison of discharge, total susptended solids (TSS), and turbidity in the Hangman watershed on January 11th 2006, one day after a rain-on-snow event.

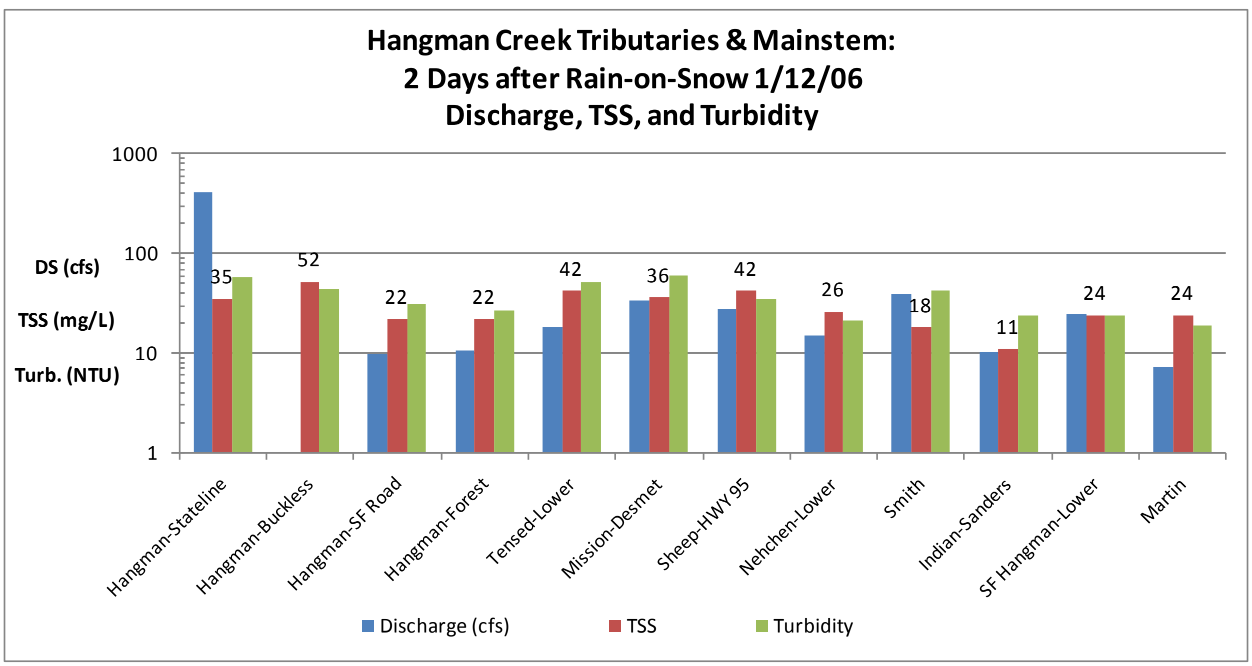


Figure 14. Comparison of discharge, total susptended solids (TSS), and turbidity in the Hangman watershed on January 12th 2006, two days after a rain-on-snow event.

Picture 5. Storm event on May 22nd, 2004 in which the stage at Stateline rose 10.0 feet in 1 day.

4.2.2 Continuous Temperature Monitoring

Temperature profiles in the Hangman watershed exhibited a distinct difference between sampling locations in agriculturally dominant reaches and in forested upper reaches of fish-bearing tributaries (Table 13-Table 16). Generally, the 7-day moving average maximum temperature index exceeded both spawning/incubation and rearing thresholds a much greater percentage of the time in lower non-forested sites than in upriver forested sites within each of the Mission, Sheep, Nehchen, Indian, and South Fork Hangman sub-watersheds. Moreover, in monitored years of 2004-2006, upper forested sites in each of these five sub-watersheds never exceeded the established threshold values. When considering all sites in aggregate within a monitored subwatershed, Indian and Nehchen creeks displayed cooler temperature profiles than Mission and Sheep creeks in the upper Hangman Creek watershed.

Temperatures monitored in the mainstem of Hangman exceeded threshold values collectively over both spawning/incubation and rearing timeframes over 50% of the time in reaches that included and were downstream of RM 12.2 (Table 13-Table 16). In addition, in upriver reaches of Hangman creek, threshold exceedance percentages sharply increased downstream from RM 16.9 to RM 16.5, which, in this case, could be explained by the lack of canopy cover throughout this 0.4 mile reach. However, because of the presence of canopy cover over the next two downstream miles and the influence from Indian Creek, temperatures decreased greatly from RM 16.5 to 14.8. The abrupt increase in stream temperature over relatively short linear downstream distances that has been observed in reaches in the upper Hangman watershed is illustrated for the Hangman mainstem in 2006 (Figure 15). A complete set of temperature profiles are illustrated in Appendix C.

Table 13. Summary of continuous temperature data in the Hangman Creek watershed during 2004. Values represent the percentage of days that a 7-day running average of maximum daily stream temperatures exceeded 14 °C from May 1 to June 31, and 20 °C from July 1 to August 31. Monitored sites were also identified as being in forested or non-forested habitat.

2004 Site	Forested	**Spawning Limit** % Exceeds 14 Deg May 1 - June 30	**Rearing Limit** % Exceeds 20 Deg July 1 - August 31	Overall May 1 - August 31
		Hangman		
Hangman-Stateline RM 0.0	N	80.3	90.3	86.2
Hangman-Liberty RM 3.1	N	44.3	88.7	N/A
Hangman-Farm RM 5.8	N	67.2	N/A	N/A
Hangman-HWY 95 RM 8.1	N	82.0	88.7	84.6
Hangman-Buckless RM 10.5	N	32.8	91.9	N/A
Hangman-Nehchen Hump RM 11.6	N	N/A	N/A	N/A
Hangman-Beasley RM 12.2	N	N/A	N/A	N/A
Hangman-Larson RM14.8	N	16.4	12.9	14.6
Hangman-Crawford RM 15.2	N	21.3	N/A	N/A
Hangman-Bennett RM 16.5	N	27.9	77.4	52.8
Hangman-SF RD- 16.9	Y	14.8	37.1	26.0
Hangman-Forest RM 18.7	Y	4.9	0.0	2.4
		Mission		
Mission-DeSmet RM 0.4	N	50.8	12.9	31.7
Mission-KVR RM 2.3	N	N/A	N/A	N/A
Mission-M.F. RM 4.8	Y	0.0	0.0	0.0
		Sheep		
Sheep-HWY 95 RM 0.6	N	67.2	46.8	56.1
Sheep-Upper RM 2.8	Y	0.0	0.0	0.0
		Nehchen		
Nehchen-Lower RM 0.1	N	11.5	N/A	N/A
Nehchen-Upper RM 2.9	Y	N/A	N/A	N/A
		Indian		
Indian-Sanders RM 0.3	N	13.1	16.1	14.6
Indian-Pow-Wow RM 1.4	Y	6.6	0.0	3.3
Indian-Upper RM 2.9	Y	0.0	0.0	0.0
		SF Hangman & Tributaries		
SF Hangman-Lower RM 0.7	N	N/A	N/A	N/A
S.F. Hangman-Upper RM 1.7	Y	N/A	N/A	N/A
Martin RM 0.2	Y	0.0	0.0	0.0

Table 14. Summary of continuous temperature data in the Hangman Creek watershed during 2005. Values represent the percentage of days that a 7-day running average of maximum daily stream temperatures exceeded 14 ^{o}C from May 1 to June 31, and 20 ^{o}C from July 1 to August 31. Monitored sites were also identified as being in forested or non-forested habitat.

2005 Site	Forested	**Spawning Limit** % Exceeds 14 Deg May 1 - June 30	**Rearing Limit** % Exceeds 20 Deg July 1 - August 31	Overall May 1 - August 31
		Hangman		
Hangman-Stateline RM 0.0	N	100.0	89.7	94.3
Hangman-Liberty RM 3.1	N	77.0	94.8	85.4
Hangman-HWY 95 RM 8.1	N	54.1	74.2	64.2
Hangman-Buckless RM 10.5	N	50.8	NA	N/A
Hangman-Nehchen Hump RM 11.6	N	55.7	59.7	57.7
Hangman-Beasley RM 12.2	N	59.0	56.5	57.7
Hangman-Larson RM14.8	N	NA	0.0	N/A
Hangman-Crawford RM 15.2	N	NA	0.0	N/A
Hangman-Bennett RM 16.5	N	18.0	45.2	31.7
Hangman-SF RD- 16.9	Y	16.4	0.0	8.1
Hangman-Forest RM 18.7	Y	0.0	0.0	0.0
Bunnel RM 0.2	Y	NA	0.0	N/A
		Mission		
Mission-KVR RM 2.3	N	29.5	0.0	14.6
Mission-M.F. RM 4.8	Y	0.0	0.0	0.0
		Sheep		
Sheep-HWY 95 RM 0.6	N	54.1	0.0	27.6
Sheep-Upper RM 2.8	Y	0.0	0.0	0.0
		Nehchen		
Nehchen-Lower RM 0.1	N	4.9	1.6	3.3
Nehchen-Upper RM 2.9	Y	NA	0.0	N/A
		Indian		
Indian-Sanders RM 0.3	N	14.8	0.0	7.3
Indian-Pow-Wow RM 1.4	Y	0.0	0.0	0.0
Indian-Upper RM 2.9	Y	NA	0.0	N/A
Indian-EF. RM 0.3	Y	0.0	0.0	0.0
Indian-NF RM 0.1	Y	0.0	0.0	0.0
		SF Hangman & Tributaries		
SF Hangman-Lower RM 0.7	N	11.5	NA	N/A
S.F. Hangman-Upper RM 1.7	Y	0.0	NA	N/A
Martin RM 0.2	Y	0.0	0.0	0.0

Table 15. Summary of continuous temperature data in the Hangman Creek watershed during 2006. Values represent the percentage of days that a 7-day running average of maximum daily stream temperatures exceeded 14 ^{o}C from May 1 to June 31, and 20 ^{o}C from July 1 to August 31. Monitored sites were also identified as being in forested or non-forested habitat.

2006		**Spawning Limit** % Exceeds 14 Deg	**Rearing Limit** % Exceeds 20 Deg	Overall
Site	Forested	May 1 - June 30	July 1 - August 31	May 1 - August 31
		Hangman		
Hangman-Stateline RM 0.0	N	78.3	54.8	81.0
Hangman-Liberty RM 3.1	N	80.0	66.1	89.0
Hangman-Farm RM 5.8	N	78.3	71.0	91.0
Hangman-HWY 95 RM 8.1	N	78.3	54.8	81.0
Hangman-Buckless RM 10.5	N	78.3	NA	NA
Hangman-Nehchen Hump RM 11.6	N	78.3	58.1	83.0
Hangman-Beasley RM 12.2	N	80.0	54.8	82.0
Hangman-Larson RM14.8	N	41.7	12.0	32.5
Hangman-Crawford RM 15.2	N	45.0	0.0	27.0
Hangman-Bennett RM 16.5	Y	48.3	51.6	61.0
Hangman-SF RD- 16.9	Y	25.0	17.2	25.7
Hangman-Forest RM 18.7	Y	0.0	0.0	0.0
Bunnel RM 0.2	Y	0.0	0.0	0.0
		Mission		
Mission-DeSmet RM 0.4	N	NA	NA	N/A
Mission-KVR RM 2.3	N	66.6	4.8	43.0
Mission-M.F. RM 4.8	Y	0.0	0.0	0.0
		Sheep		
Sheep-Confluence 0.0	N	80.0	15.4	57.5
Sheep-HWY 95 RM 0.6	N	NA	NA	NA
Sheep-Upper RM 2.8	Y	0.0	0.0	0.0
		Nehchen		
Nehchen-Lower RM 0.1	N	16.7	0.0	10.0
Nehchen-Upper RM 2.9	Y	0.0	0.0	0.0
		Indian		
Indian-Sanders RM 0.3	N	20.0	6.9	16.3
Indian-Pow-Wow RM 1.4	Y	0.0	0.0	0.0
Indian-Upper RM 2.9	Y	0.0	0.0	0.0
Indian-EF. RM 0.3	Y	0.0	0.0	0.0
Indian-NF RM 0.1	Y	0.0	0.0	0.0
		SF Hangman & Tributaries		
SF Hangman-Lower RM 0.7	N	20.0	0.0	12.0
S.F. Hangman-Upper RM 1.7	Y	0.0	0.0	0.0
Martin RM 0.2	Y	0.0	0.0	0.0

Table 16. Summary of continuous temperature data in the Hangman Creek watershed during 2007. Values represent the percentage of days that a 7-day running average of maximum daily stream temperatures exceeded 14 °C from May 1 to June 31, and 20 °C from July 1 to August 31. Monitored sites were also identified as being in forested or non-forested habitat.

2007 Site	Forested	**Spawning Limit** % Exceeds 14 Deg May 1 - June 30	**Rearing Limit** % Exceeds 20 Deg July 1 - August 31	Overall May 1 - August 31
		Hangman		
Hangman-Stateline RM 0.0	N	49.2	NA	N/A
Hangman-Liberty RM 3.1	N	85.2	NA	N/A
Hangman-Farm RM 5.8	N	85.2	NA	N/A
Hangman-HWY 95 RM 8.1	N	85.2	NA	N/A
Hangman-Nehchen Hump RM 11.6	N	85.2	NA	N/A
Hangman-Beasley RM 12.2	N	86.9	NA	N/A
Hangman-Larson RM14.8	N	44.3	NA	N/A
Hangman-Crawford RM 15.2	N	44.3	NA	N/A
Hangman-Bennett RM 16.5	N	32.8	NA	N/A
Hangman-SF RD- 16.9 *	Y	32.8	NA	N/A
Hangman-Forest RM 18.7	Y	0.0	NA	N/A
Bunnel RM 0.2	Y	0.0	NA	N/A
		Mission		
Mission-DeSmet RM 0.4	N	49.2	NA	N/A
Mission-KVR RM 2.3	N	55.7	NA	N/A
Mission-M.F. RM 4.8	Y	0.0	NA	N/A
		Sheep		
Sheep-Confluence 0.0	N	45.9	NA	N/A
Sheep-HWY 95 RM 0.6	N	57.4	NA	N/A
Sheep-Upper RM 2.8	Y	0.0	NA	N/A
		Nehchen		
Nehchen-Lower RM 0.1	N	18.0	NA	N/A
Nehchen-Upper RM 2.9	Y	13.1	NA	N/A
		Indian		
Indian-Sanders RM 0.3	N	27.9	NA	N/A
Indian-Upper RM 2.9	Y	14.8	NA	N/A
Indian-EF. RM 0.3	Y	0.0	NA	N/A
Indian-NF RM 0.1	Y	0.0	NA	N/A
		SF Hangman & Tributaries		
SF Hangman-Lower RM 0.7	N	21.3	NA	N/A
S.F. Hangman-Upper RM 1.7	Y	0.0	NA	N/A
Martin RM 0.2	Y	0.0	NA	N/A

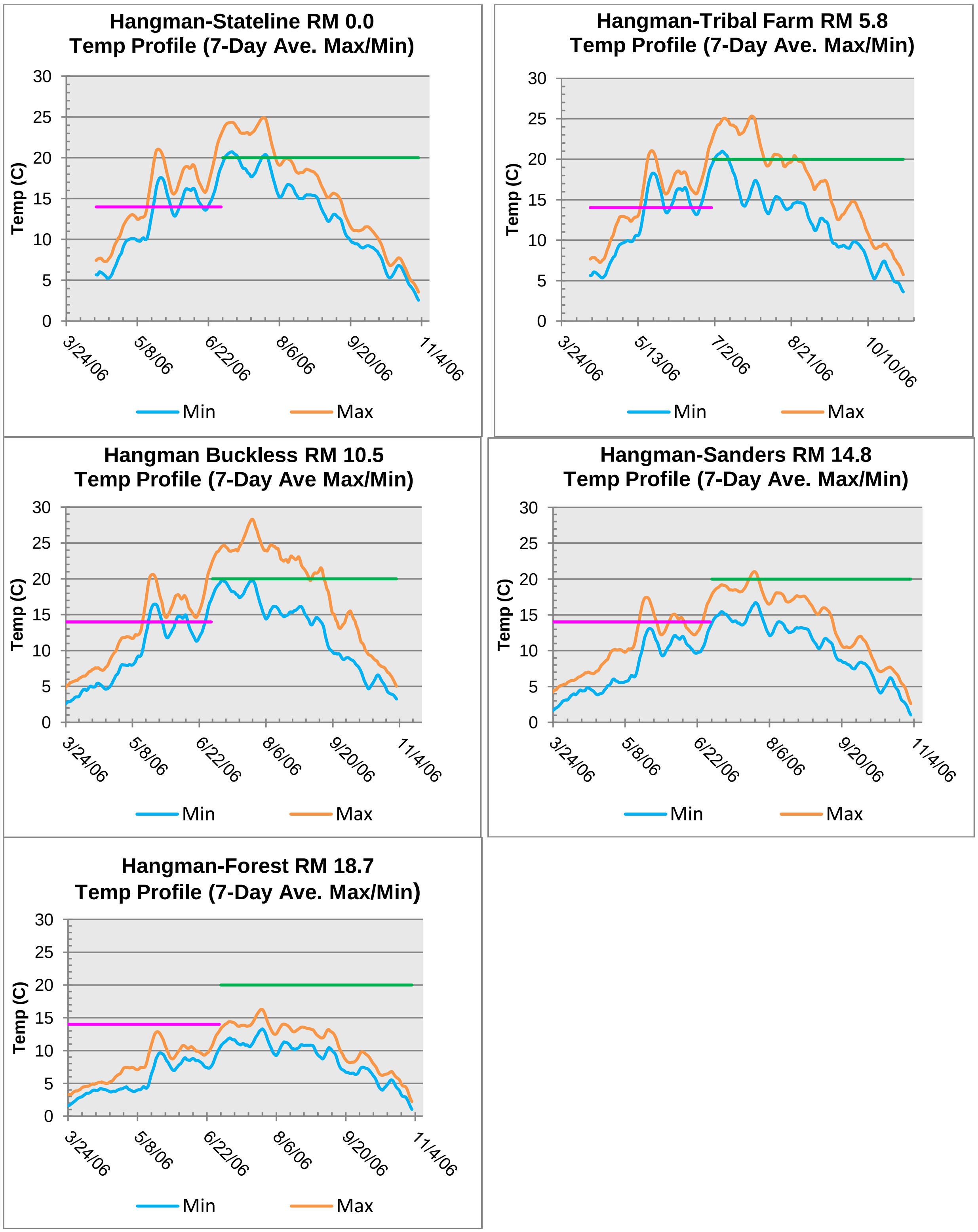
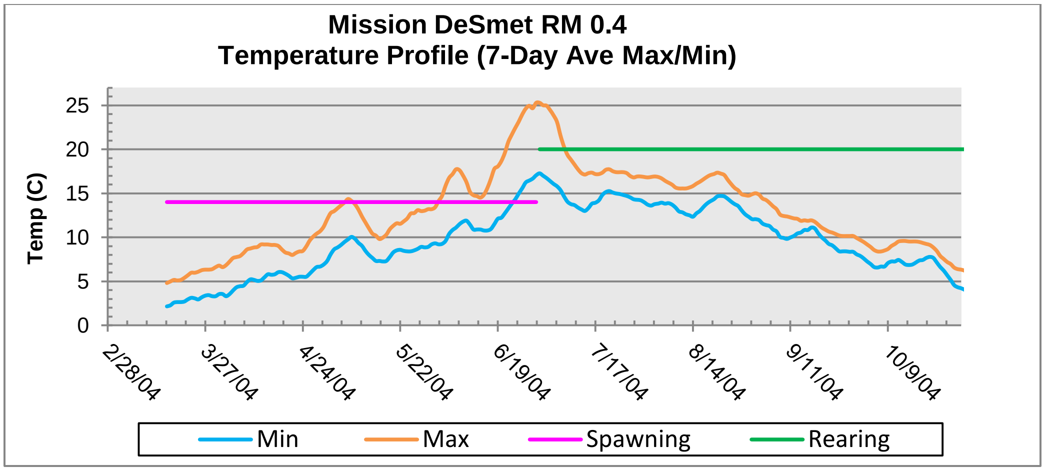


Figure 15. Average weekly maximum/minimum temperature profiles of Hangman Cr. at several locations in 2006 on Hangman Creek starting at stateline RM 0.0 and proceeding upstream, marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.



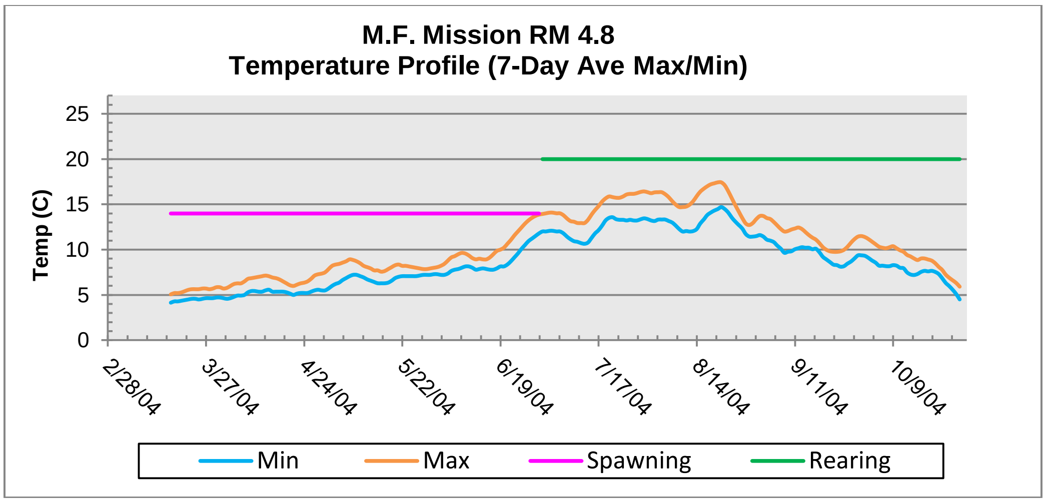


Figure 16. Average weekly maximum/minimum temperature profiles of Mission Cr. at DeSmet-RM 0.4 and MF Mission-RM 4.8 in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

4.3 Physical Habitat Asssessment

4.3.1 Rosgen Channel Typing

Fifteen sites were surveyed during 2004-2007 to conduct Rosgen channel typing surveys and to measure habitat attributes that have been linked to the quality of trout habitat. Five of the 15 sites were entrenched and classified as Rosgen F and G channel types, with 3 of the 5 sites located in downriver reaches in each of Mission, Nehchen, and Sheep creeks, and the other two sites located in the Hangman mainstem (Table 17). In addition, sinuosity values in the three sampled reaches of the Hangman mainstem ranged from 1.16 - 1.23. Historically, as supported by aerial photography, E and C channels were likely more prevalent in the Hangman mainstem than at the present with sinuosity values ranging from 1.4 to 1.8.

Measured physical attributes at surveyed sites indicated substantial habitat differences among tributaries and among reaches within tributaries. Generally, sites sampled in Indian and Nehchen creeks had larger substrate, greater canopy cover, and more LWD than those sites sampled in the mainstem of Hangman and in lower reaches of Sheep and Mission creeks, though attributes measured at sites sampled in upper reaches of Sheep and Mission creeks were comparable to those measured in the two former creeks (Table 17). For example, D50 values at all sites, except site 3 in Indian Creek, ranged from 6 – 14.6 in Indian and Nehchen creeks. In comparison, D50 values never exceeded 6 at any of the sites in the Hangman mainstem and Sheep and Mission creeks, though values were observed to increase upstream in the latter two tributaries. Canopy cover percentages ranged from 73 to 85% in Nehchen Creek and from 88 to 96% in Indian Creek, which was comparable to those measured in upper reaches in Mission (98%) and Sheep (94%) creeks, but substantially higher than those measured in the lower reaches of Mission (1.8%) and Sheep (32%) creeks and in the Hangman mainstem (range, 4.3 – 32%). In addition, number of pieces of LWD per site ranged from 16 to 67 in Indian Creek and from 12 to 16 in Nehchen Creek. LWD counts were also high in upper Mission and Sheep creeks, with 59 and 23 pieces enumerated, respectively. However, LWD counts were low at downstream sites in Mission (2 pieces) and Sheep (11 pieces) creeks and at all mainstem Hangman sites (range, 0 – 7 pieces). Though LWD counts were relatively high in some tributary reaches in the upper Hangman watershed, much of the wood was relatively small (e.g., lack of pieces > 1.0 m^3). For example, even though a volumetric LWD loading of 9.68 m^3/100 m, the highest of all the surveyed sites, was calculated for site 2 in Indian Creek, most of the volume was comprised of alder that had fallen into the stream during the spring from the weight of wet snow.

Generally, pools were deeper in the entrenched sites in the mainstem of Hangman Creek and in lower reaches of Sheep and Mission creeks, than in upper reaches of these two tributaries and in Indian and Nehchen creeks (Table 17). Mean residual pool depths ranged from 2.1 -3.0 ft at sites 12 and 13a in the mainstem, and were 1.5 and 1.9 ft at lower sites in Mission and Sheep creeks, respectively. In comparison, mean residual pool depth was 1.1 and 1.0 ft at sites in upper reaches of Mission and Sheep creeks, respectively, and ranged from 0.6 to 1.1 ft (mean, 0.7 ft) in Indian Creek and from 0.4 to 1.2 ft (mean, 0.8 ft) in Nehchen Creek. Moreover, sampled reaches in Nehchen creek generally had low pool density, with approximately one pool per 100 m of stream length calculated for two of the three sampled sites (Table 17).

Table 17. Summary of Rosgen Channel Typing Surveys completed in the Hangman watershed during 2004 -2007.

	Site Identification	Hangman_11	Hangman_12	Hangman_13a	Mission_2	Nehchen_2	Nehchen_4a	Indian_2	EF Indian	Indian_3	Sheep_2	Sheep_3	Nehchen_4b	Indian_1	Martin_1	Mission_5
Morphology	Initial Level 1 Survey Stream Type	C	C	C	C	B	A	B	A	A	C	B	A	B	C	C
	Basin Area mi2	39.9	36.98	33.992	9.19	3.74	1.16	3.32	0.64	1.06	7.17	1.4	1.15	4.55	1.63	4.9
	Percent Forest (Stream Stats)	66.4	67.1	68.9	61	62	66.4	94	90.6	98.5	63.6	98.7	66.4	82.4	97.7	67.5
	Level 2 Survey Year	2004	2004	2004	2004	2004	2004	2004	2004	2005	2006	2006	2006	2006	2006	2007
	Valley Type	8	8	8	8	8	2	2	2	2	8	2	2	8	2	8
	Valley Slope	0.005	0.004	0.006	0.007	0.028	0.063	0.020	0.089	0.059	0.010	0.037	0.054	0.010	0.019	0.018
	Bankfull Width (ft)	28.12	28.91	28.21		13.06	9.09	28.45	4.7	20.31	17.22	11.42	7.8	8.69	12.1	13
	Bankfull Mean Depth (ft)	1.97	1.67	1.76	2.06	0.69	0.68	1.09	0.9	0.77	0.86	0.69	0.83	1.4	0.74	1.15
	Flood-Prone Width	64.97	41.44	35	23.15	15.66	16.99	50.5	24.94	37.56	27.32	63	7.8	37.14	30.63	26.35
	Water Surface Slope	0.218	0.467	0.552	0.006	2.586	0.058	0.015	0.071	0.050	0.008	0.022	0.051	0.008	0.014	0.011
	Sinuosity	1.16	1.23	1.17	1.13	1.15	1.09	1.3000	1.2	1.2	1.23	1.7	1.07	1.18	1.42	1.69
	BKF Q (cfs)	422.9	417.6	395.9	251.8	45.15	32.64	140.5	43.63	62.32	80.61	65.71	31.57	76.70	55.95	89.49
	Velocity (fps)	8.2	7.88	7.95	7.62	5	5.29	4.49	8.22	4.01	5.45	8.35	4.85	5.1	6.21	4.81
	Cross Sectional Area	51.57	36.14	49.8	33.04	9.03	6.17	31.3	5.31	15.54	14.79	7.87	6.51	12.2	9.01	15.04
	Entrenchment Ratio	2.48	1.39	1.26	1.34	1.2	1.87	1.78	4.87	1.85	1.39	5.52	1.23	4.27	2.53	2.01
	Width to Depth Ratio	13.31	23.13	17.73	7.79	18.93	13.37	25.86	10.83	26.38	20.02	16.55	9.4	6.21	16.35	11.42
	Rosgen Stream Classification	C5	F5	F4	G5c	F4b	B4a	B4c	**B4a ***	B4a	F5	C4b	A4	E4	C4	B4c
Substrate	Channel Materials D50	3.7	1	3.5	0.01	14.6	7.5	6	6.27	3.8	0.08	3.7	10.5	12.48	2	5.3
Cover	Canopy Density (%)	32.3	4.3	6.3	1.75	73	85.3	89.3	87.8	91.75	31.83	94	85.3	96.25	92.75	98
LWD	Total Count	7	0	1	2	16	14	67	27	27	11	23	12	16	38	59
	Total Pieces >1.0m³ (*)	0	0	0	0	0	0	4	1	0	1	0	2	0	6	1
	Total Pieces >2.0m³ (*)	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
	Total Pieces >4.0m³ (*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Volume (m³)	0.179	0.000	0.034	0.221	0.732	0.649	14.752	5.296	4.161	3.515	4.672	4.537	0.939	11.585	11.205
	Density m³/100m	0.117	0.000	0.022	0.145	0.480	0.426	9.680	3.475	2.730	2.307	3.066	2.977	0.616	7.602	7.353
Residual Pools	Mean Residual Depth (ft)	1.57	2.98	2.11	1.54	1.18	0.79	0.65	0.63	0.58	1.92	1	0.4	1.05	0.87	1.09
	Min (ft)	1.14	2.72	1.5	0.97	1.18	0.51	0.45	0.4	0.54	1.23	0.67	0.4	0.68	0.55	0.74
	Max (ft)	1.89	3.24	2.62	2.49	1.18	1.01	0.71	0.88	0.62	3.23	1.58	0.4	1.67	1.13	1.65
	Number of Pools (#/100m)	3.29	1.32	2.63	1.97	1.1	4.39	3.29	13.16	2.19	4.61	3.16	1.1	5.92	12.06	3.95

4.3.2 Instream Flow Incremental Methodology (IFIM) and stream temperature modeling scenarios

Results from the PHABSIM analysis indicated that, under simulation scenarios, WUA for redband trout was a low percentage of the total available area in all reaches modeled (i.e., Hangman main-stem, Indian, and Nehchen creeks) in the upper Hangman creek watershed, though the greatest WUA was estimated for the reach sampled in Indian Creek (Hardin-Davis 2005). For example, at simulated discharge levels of 5 cfs, adult redband trout WUA was only 6% of the total surface area in Hangman and Nehchen creek reaches, whereas it was 10% of the available area in Indian creek. The low percentage of WUA across modeled reaches was related to the lack of cover (e.g., undercut banks, LWD, and overhanging vegetation) and water depth in surveyed habitats. In addition, under modeled discharge scenarios, WUA in Nehchen and Indian creeks increased steeply with increasing levels of simulated discharge up to 5 cfs, and increased slightly thereafter with additional flow. In the two Hangman main-stem reaches, WUA for both juvenile and adult redband trout increased steadily with increasing levels of simulated discharge; however, the percent increase in WUA per additional increase in flow was not as great in the Hangman main-stem as in the reaches modeled in Indian and Nehchen creeks. Most of the increase in usable habitat per increase in flow was explained by the increase in water depth given that deep pool habitat is lacking in modeled reaches, especially those in tributaries.

The SNTEMP model was used to simulate three restoration scenarios, increased base flow, increased shade, and a combination of increased flow and shade, along 18 miles of the Hangman Creek main-stem. Increased base flow (1 cfs added) reduced summer temperatures by an average of only about 0.2 ^{o}C. In comparison, increased shade caused a reduction of approximately 2.0 ^{o}C, a value ten times greater than that generated under the increased base flow scenario. When the two factors were combined in the simulation analyses, main-stem temperatures were reduced only slightly more than when shade was the sole variable incorporated into the model. The SNTEMP model was integrated with the PHABSIM model to evaluate the increase in usable habitat area (HA) in the main-stem of Hangman Creek under restoration scenarios that would increase baseflow discharge or reduce summer rearing temperatures. Increasing baseflow discharge revealed minimal gains in HA in main-stem habitat, whereas increasing shade, and thus reducing stream temperatures, caused a large increase in HA. A more detailed description of the results of the modeling analyses can be found in 9.10 Appendix I. Instream Flow Incremental Methodology Report by Hardin-Davis

5.0 RESTORATION EFFORTS

Riparian restoration efforts began in 2005 at four locations within the upper Hangman Creek watershed (Figure 17). Restoration efforts entailed planting a variety of native species that were tailored to the specific objectives established for each location. Following is the list of the four restoration locations along with a brief description of their current condition and the restoration objectives. A list of the number of each species planted at each location is further provided in Table 18.

Hangman Reach 11.
Common name is Hangman-Sweatlodge

T44, R 4W, Sect 28 NW ¼ - NE ¼

Current condition: Reed Canary grass dominates the riparian, with mixed forest and meadow outside riparian.

Objective: Stabilize banks with native riparian plants capable of supporting beaver activity and shading the channel.

Nehchen Reach 2.

Common name:Nehchen-Beasely CRP

T44, R 4W, Sect 21 NE ¼

Current condition: One fourth of the property was planted with conifers as part of a CRP program, leaving the rest with open meadow mixed with noxious weeds. The riparian is a mix of open areas with sloughing banks, and alder/cottonwood overstory

Objective: Stabilize banks with native riparian plants capable of providing additional canopy.

Nehchen Reach 4.

Common name:Upper Nehchen

T44, R 4W, Sect 25

Current condition: Removal of one culvert and installation of a larger culvert has left a lot of bare ground with a lack of conifers due to timber harvest.

Objective: Stabilize banks with native riparian plants capable of supporting beaver activity and shading the channel.

Indian Reach 2.

Common name: Indian Pow Pow

T44N, R4W, Sec 36

Current condition: Red alder and fern dominate the riparian, and grand fir dominates the upland. Cedar was the dominate tree prior to timber operations. Mature alder are contributing to unstable side channels, but no pools are formed from the unstable woody debris jams created from dying alder

Objective: Reestablish Red Cedar as the dominate tree to improve bank stabilization.

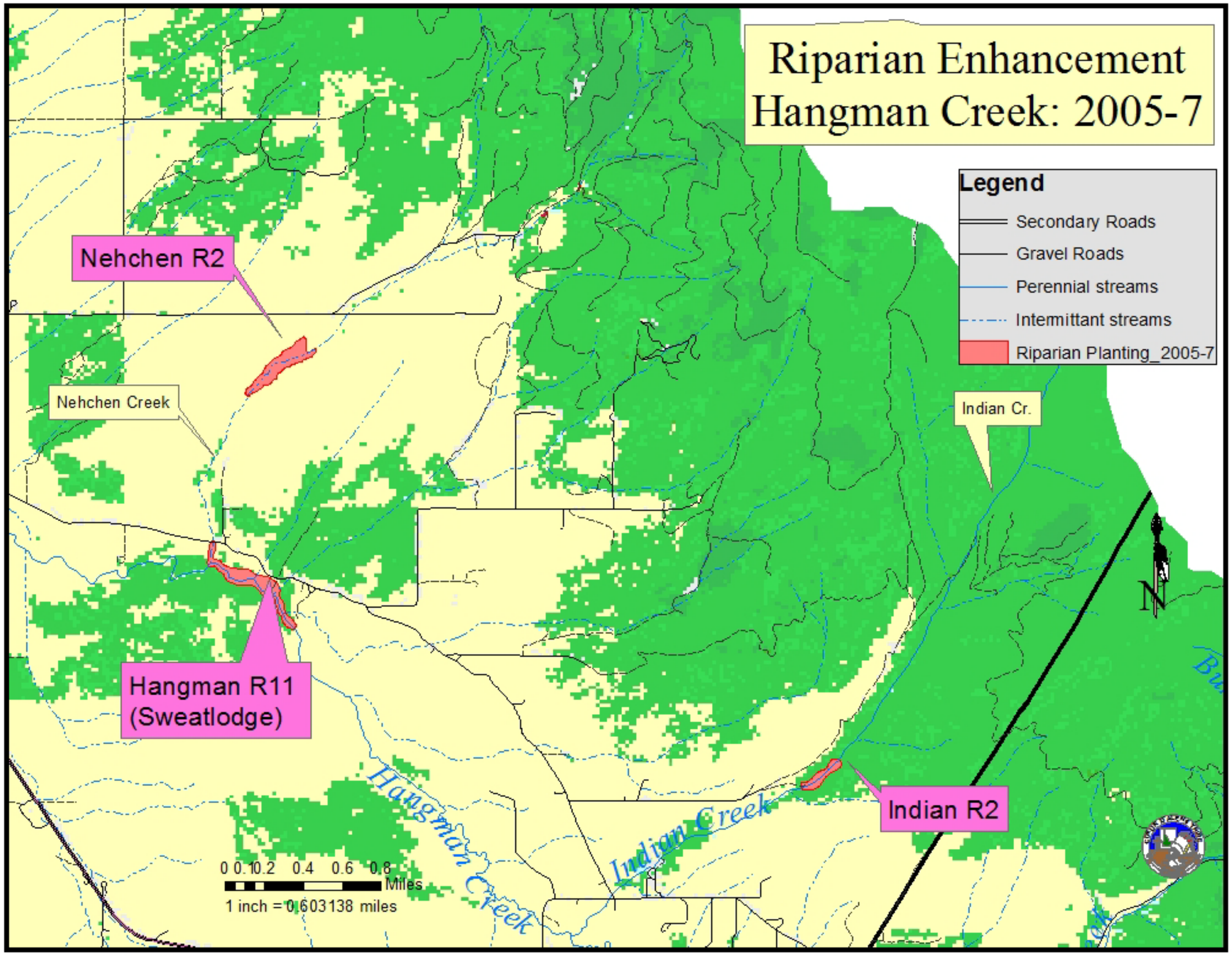


Figure 17. Locations of riparian enhancement during 2005- 2007.

Survival rates from fall planting to the following spring were vastly different among the species planted at the restoration sites in the upper Hangman watershed (Table 18). Conifers have exhibited much higher initial year survival rates than deciduous trees. For example, 71% of the Western Red Cedar that have been planted at the Indian Creek site have survived. The Douglas fir and Ponderosa pine that have been planted at the Hangman site have also exhibited relatively high survival rates of 89.1 and 73.1%, respectively during the first two years of planting, though survival rates for both species were lower during 2007 planting activities. On the other hand, the Lodgepole pine that have been planted at the Hangman site have performed poorly compared to other coniferous species with estimated survival rates of approximately 2% for trees planted in 2005 and 2006.

Of the deciduous species planted, containerized aspen, cottonwood and alder were the main component of plantings from 2005 to 2007. Survival rates were relatively modest one year after planting (e.g., 30-50%), but these estimates did not reflect survival rates 6 months later. Site visits to the areas more than one year after planting indicated that most of the trees had been pulled by beaver, washed out by flood, or died from lack of water. There were only a few cottonwoods that had survived 2 years. Success of willow plantings were also difficult to reliably assess because they were often cut low to the ground where minimal sunlight was available in the face of a competitor, reed canary grass; many of the willow shoots were alive but barely growing.

Various attempts were made during consecutive years of riparian restoration efforts to improve the survival rates of planted trees. Breathable trees cones were used during initial planting efforts in 2005 to improve survival rates, but proved ineffective against beaver depredation, and consequently were not used thereafter. In 2006, chicken wire and stakes were used to protect small plants, but also proved ineffective. High flow events compromised the integrity of the chicken wire corrals, and trees that were planted at higher elevations using stakes still incurred severe beaver damage. Though solid tree cones were used as an alternative on both conifers and small potted plants because they did not bend as easily as the chicken wire (Picture 6 and 7), they too proved ineffective against beavers and high flows. Highest success rates were found when taller 3 foot cones were used (apparently able to deter beavers) and when larger 5 gallon trees were planted. Lastly, large deciduous trees that were planted along the entire length of Hangman Creek were wrapped in chicken wire in 2007 to prevent damage from beavers. Apparently, this deterrent technique was somewhat successful in that increased beaver cuttings on hawthorn, and not planted species, was observed soon after implementation.

Picture 6. Use of chicken wire to protect small plants in 2005-2007.

Picture 7. The use of short cones to protect small plants in 2005-2007.

Table 18. Summary of vegetation planted, and initial survival rates, in Hangman Creek during 2005 -2007.

2005	Location Code	# Planted	% Survival 1st Year	% Survival 3rd Year
Cedar	IN2	300	67.0	58.0
Douglas Fir	HA11	1000	89.1	40.2
Alder (1 gallon)	HA11	250	41.0	0.0
Aspen (2 Gallon)	HA11	150	30.0	10.0
Cottonwood (5 gallon)	HA11	50	55.0	40.0
Cup Size dogwood	IN2	50	60.0	55.0
Lodge Pole Pine	HA11	850	2.4	0.0

2006	Location Code	# Planted	% Survival 1st Year
Cedar	IN2	300	75.0
Lodepole Pine	HA11	1500	2.4
Ponderosa	HA11	1500	65.0
Alder (1 gallon)	HA11	140	40.0
Aspen (1 gallon)	HA11	140	50.0
Aspen (2 Gallon)	HA11	140	30.0
Cottonwood (2 gallon)	HA11	140	20.0
Cottonwood (5 gallon)	HA11	80	55.0

2007	Location Code	# Planted	% Survival 1st Year
Ponderosa Pine	HA11	2000	51.0
Ponderosa Pine	NE2	2000	80.0
Douglas Fir	NE2	250	75.0
Douglas Fir	HA11	750	28.0
White Pine	NE2	750	50.0
White Pine	HA11	250	39.0
Lodgepole Pine	HA11	500	43.0
Aspen (1 gallon)	HA11	100	10.0
Aspen (2 Gallon)	HA11	100	15.0
Willow (5 gallon)	HA11	100	5.0
Willow shoots (Dummond)	HA11	250	0.0
MacKenzie Willow (1 gal)	HA11	16	0.0
Cottonwood (5 gal)	NE2	20	0.0
Cottonwood (1 gallon)	HA11	100	0.0
Bebbs Willow (1 gallon)	HA11	184	0.0

6.0 DISCUSSION

Redband trout distribution and abundance

Though redband trout were present in annual sampling events in the upper Hangman Creek watershed throughout the reporting period, they were limited in their distribution to a few distinct tributary reaches. Redband trout were found in upstream forested reaches of Mission, Sheep, Indian, Hangman, and South Fork Hangman creeks, whereas downstream reaches in most of these tributaries, including the mainstem of Hangman creek, that were impacted by agriculture were practically devoid of trout. Moreover, redband trout were found to be most widely distributed, albeit at low numbers in many of the sampled reaches, in Indian Creek, a primarily forested subwatershed. Furthermore, redband trout were not captured in surveys conducted in the northern subsection of the upper Hangman watershed which was dominated by agricultural land use, and virtually absent from summer sampling events in Nehchen Creek. Results from this four-year survey were not only consistent with findings from the 2002 survey (Peters et al 2003), but were also similar across reporting years, which lends credence to the verity of actual redband trout distribution in the upper Hangman watershed. It is noteworthy that trout were found in only one Indian Creek sample during the 3 years in locations above two culverts suspected of being fish barriers (Site 4, 2005). A full survey of these two culverts in the coming year would be useful to assess fish passage.

Given that one of the primary objectives of the project is to increase the distribution of redband trout, it is imperative that conditions conducive to establishment are restored in those reaches that currently are seemingly restricting the spatial extent of existing remnant subpopulations. Apparently, the overall geomorphological template in the upper watershed could provide the habitat that would support a spatially-continuous redband population. Muhlfeld et al. (2001a) found that redband trout in the Kootenai River drainage in Montana were most abundant during summer surveys in low-gradient mid-elevation reaches that were located in alluvial valleys with prominent floodplain habitats, conditions that prevail in much of the upper Hangman Creek watershed. Further, overwintering habitat for redband trout in the Kootenai basin was associated with deep, slow-moving pool habitats (Muhlfeld et al. 2001b). Though pool habitat was scarce in tributary reaches in the upper Hangman watershed, pools greater than 1 m were documented in lower reaches of Sheep and Mission tributaries and in proximate main-stem Hangman reaches.

Improving the suitability of rearing habitats to expand the spatial distribution of redband trout would also likely increase connectivity and promote the exchange of reproductive individuals among tributary sub-populations. Results from the genetic analysis indicated that sampled subpopulations in tributary reaches in the upper Hangman Creek watershed exhibited evidence of reproductive isolation. The degraded habitat in downstream tributary reaches may be inhibiting the movement of adults among sub-drainages which could give rise to the observed results. Alternatively, differences in the genetic signature among subpopulations may have been due to genetic drift associated with small effective population sizes. The significant departures from Hardy-Weinberg equilibrium that were detected in fish sampled from upper Hangman tributaries attest to this supposition. Whatever the reason, increasing the connectivity of tributary subpopulations would promote a more robust and resilient population structure and would minimize the adverse consequences (e.g., demographic stochasticity, inbreeding depression) that arise from isolated, small populations (Gilpin and Soule 1986). Further, given that the genetic signature from redband trout in California Creek, a tributary in the lower reach of Hangman

Creek, aligned more with fish from upper Hangman than with those downstream in the Spokane subbasin, there is evidence that movement and sub-population connectivity throughout the drainage likely existed in the past and may have been an important mechanism that promoted metapopulation persistence.

Results from the genetic analyses also indicated that redband trout in the upper Hangman watershed were relatively pure with a lack of detectable introgression with coastal strains of rainbow trout. Thus, even though the non-native coastal subspecies of rainbow trout have been repeatedly introduced into the Spokane River by WDFW from 1933 to 2002, apparently conditions in upper Hangman have prevented successful colonization by these fish and a resulting lack of genetic introgression. Another finding from the genetic analyses that confirmed our visual observations was that fish sampled from upper Nehchen Creek were genetically more similar to cutthroat trout, a salmonid not native to the Hangman watershed, than to redband trout. However, given the low allelic richness detected in these fish and the lack of detectable cutthroat genes in other sampled tributary subpopulations, it is likely that the fish from Nehchen creek were the result of a localized introduction of a small number of fish and, as a result, are relatively isolated and not widespread throughout the upper Hangman watershed. This in fact was confirmed by a landowner who claims to have transplanted cutthroat trout from Benewah Creek, a tributary of Coeur d'Alene Lake in 1985. In addition, the more recent surveys during this reporting period suggested that cutthroat trout densities in upper Nehchen Creek may be declining. Notwithstanding these findings, it is imperative to periodically conduct additional genetic analyses to track possible changes to the salmonid assemblage in the upper Hangman Creek watershed.

Not only was the distribution of redband trout limited in the upper Hangman watershed, but estimated densities of age 1 and older fish were typically less than 12 fish/100 m in many of the reaches in which they were found over all years during the reporting period. Upon converting these linear stream densities to areal densities (fish/100 m^2 of stream area given a mean wetted width of 2 m), this equates to values less than 6 fish/100 m^2. These values are relatively low in comparison to densities that have been documented in other regions that support redband trout. For example, Zoellick et al. (2005) reported linear mean densities of 28 and 47 fish/100 m for redband trout age 1 and older in four desert drainages of southwestern Idaho that were repeatedly sampled in the 1970's and 1990's, respectively. In a more comprehensive analysis conducted across southwestern Idaho streams, Meyer et al. (2010) reported mean areal densities of 21 fish/100 m^2 in desert streams and 11 fish/100 m^2 in montane streams. Dambacher and Jones (2007) summarized areal densities of redband trout age 1 and older in both montane and high desert streams in eastern Oregon. Based on their summary, the authors established threshold values of $\leq$6, 6-19, and >20 fish/100 m^2 to describe reaches with low, moderate, and high densities, respectively. According to this delineation, many of the reaches in the upper Hangman watershed support only low densities of redband trout. However, in some reaches in the upper Hangman watershed, estimated redband trout densities approached those that have been documented in these other regions. For example, linear densities in reaches of Indian and Mission creeks exceeded 20 fish/100 m (converted areal densities of 10 fish/100 m^2) in some years. In addition, linear densities of 35 and 95 fish/100 m (18 and 47 fish/100 m^2) were respectively documented in a forested reach of a tributary to the South Fork of Hangman and in the uppermost forested sampled reach of Hangman creek in 2006. These values suggest that given the appropriate conditions, redband trout can approach rather high densities in the upper Hangman watershed.

Though redband trout densities were low overall across the upper Hangman watershed, the age class structure was apparently stable with one to three year olds consistently well represented in fish collections over reporting years. Despite the inability to obtain robust estimates of survival rates because of inadequate numbers of fish, these results suggest that high levels of mortality for these age groups would not fully explain the low densities found in surveyed reaches. Rather, the lack of redband trout captured across much of the sampled habitat may be in part the result of insufficient spawning habitat, high mortality rates of age-0 fish, or a paucity of spawners to seed the available habitat. Any or all of these putative explanations should be addressed more fully in future monitoring efforts. However, there was some evidence that suitable habitat may not be sufficiently available to support larger, older age classes in some of the surveyed subwatersheds. Redband trout in the South Fork of Hangman and Sheep Creek were predominantly one year olds with an overall smaller size structure than that found in Indian, Mission, and upper Hangman creeks. The lack of older age groups in these two tributaries may suggest either high mortality rates or high rates of emigration out of these tributaries into Hangman main-stem reaches downstream.

Summer monitoring efforts did reveal the lack of older, larger redband trout (i.e., > age 3) in reaches sampled across the upper Hangman watershed. However, whereas fish greater than 200 mm were rarely captured during summer electrofishing surveys, the majority of redband trout captured in migrant traps in Indian, Nehchen, and the main-stem of Hangman during the spring were of this size range. Apparently, large adults may be present in such low numbers in the upper Hangman watershed that they are not well represented in summer fish collections. Trapping results indicated that, though a high percentage of the captured fish were greater than 200mm, few fish of this size range were captured in any given year. However, these results could be attributed to an inability to effectively capture fish in traps during the spring because of high spring discharge compromising trap performance. On numerous occasions over the reporting period, migrant traps were inoperable during spring freshets. Alternatively, the lack of large redband trout in summer surveys but their presence in migrant traps could be attributed to seasonal differences in habitat use in the upper Hangman watershed. Large adults may be overwintering in deep main-stem habitat and then intercepted in traps during spring spawning migrations as they ascend tributaries. Further, post-spawn fish may then move back down into main-stem habitat as conditions in tributaries become sub-optimal during summer rearing periods. More information regarding the behavior of adult redband trout is needed to better understand seasonal movements in the upper Hangman watershed. Consequently, though trapping has proven to be difficult at times, migrant traps will continue to be deployed in future monitoring efforts to capture large mobile fish. Moreover, additional data that describe seasonal use of Hangman main-stem habitats by both adult and juvenile redband trout would aid in evaluating its importance in providing summer and overwintering habitat and in providing a potential corridor to permit exchange of individuals among tributaries in the upper watershed. As such, we intend to modify our tagging techniques and use visible implant elastomer (VIE) tags which will enable us to mark a wider range of size classes than in previous years. Fish will be marked with a color and body placement unique to their tributary of capture so that recapture events in subsequent years will permit an examination of potential movements throughout the upper watershed.

Limiting Factors – Physical and chemical attributes of surveyed reaches
Much of the disparity in the distribution and density of redband trout among tributaries and among reaches within tributaries could be explained by the dramatic differences in the physical and chemical attributes that constituted habitat suitability in the upper Hangman watershed. Forested reaches in Indian Creek and in upper Sheep and Mission creeks, where redband trout were commonly found, typically had a lower percentage of fines in surveyed riffle substrates, greater canopy cover, and more LWD than in other reaches, such as downriver reaches of Sheep and Mission creeks and main-stem reaches in Hangman creek, where agriculture predominated. In addition, summer temperature profiles, most likely related to the presence of canopy cover, were cooler and more suitable for incubation and rearing in upper forested reaches of monitored sub-watersheds than in downriver agricultural reaches.

These four factors – substrate size, canopy cover, LWD, and temperature – have been frequently associated with the quality of trout habitat in small streams, and have been linked to redband trout presence and density in various desert and montane systems. Meyer et al. (2010) found the occurrence of redband trout in southwest Idaho streams to increase as the percent of silt substrate decreased and as the amount of stream shading increased. The authors also noted that redband trout were always present in the desert streams that were examined in their study when mean summer temperatures were between 10 and 16^{o}C, but were less likely to occur as temperatures increased from 16 to 22^{o}C. Densities of redband trout in southwest Idaho desert streams have also been found to be positively correlated with the percent of canopy cover and stream shading (Zoellick and Cade 2006), and to be negatively correlated with maximum summer stream temperatures (Zoelllick 2004). In high desert streams in eastern Oregon, redband trout abundance was also positively related to the percent of silt-free substrates and percent canopy cover and negatively related to temperature, with high temperatures (e.g., daily maximums of 26-31^{o}C) considered to be a greater detriment than silt in the degraded reaches that were examined (Li et al. 1994).

As supported by the findings of the aforementioned studies, lack of canopy cover and concomitant high summer temperatures may be a major factor limiting the distribution and abundance of redband trout in many of the stream reaches in the upper Hangman Creek watershed. The link between stream shading and temperature was especially evident for main-stem reaches in Hangman creek where summer temperatures were documented to sharply increase over relatively short distances downstream as the riparian canopy markedly decreased. Throughout the reporting period, stream temperature metrics in downriver reaches of Mission and Sheep creeks and in the main-stem of Hangman Creek, where canopy cover was lacking, exceeded established temperature thresholds a high percentage of the time. The metric that was chosen to evaluate thermal suitability was the percent time a 7-d moving average of maximum daily temperature exceeded 14^{o}C during a spawning/incubation timeframe (i.e., May 1 – June 30) and 20^{o}C during summer rearing periods (i.e., July 1 – August 31). Other metrics have been used to assess the suitability of stream temperatures for salmonids. Currently the State of Idaho uses 22° C as the maximum limit for temperature, and the daily average shall not exceed 19° C for more than 10% of the days within the critical period (Idaho Dept. of Environmental Quality

2002). The State of Washington, Dept of Ecology (2002), has recently proposed to alter their temperature requirements for salmonids that would include species and life stage specific limits for a seven-day average of daily maximum. This would include a limit for spawning and rearing of salmonids at 16° C, and redband trout rearing at 18°. Despite the variety of metrics that have been proposed, our metric seemed to differentiate stream reaches reasonably well where redband trout were found to be present and lacking, and consequently, will continue to be used in future assessments.

We improved our understanding of the spatial resolution of longitudinal changes in ambient stream temperatures across tributary and main-stem reaches with the deployment of additional temperature loggers in the upper Hangman Creek watershed during this survey period. However, ambient longitudinal temperatures do not always fully explain thermal heterogeneity across stream reaches. Patches of cold water may be found in lower strata of low-velocity deep pool habitats during summer periods as has been documented in other systems (Ebsersole et al. 2001, 2003; Firehammer et al. 2010). Such thermal refugia may be especially important for large redband trout given that they have been reported to be more sensitive to thermal stresses associated with elevated temperatures than smaller conspecifics (Rodnick et al. 2004). We intend to examine the availability and distribution of these potential refugia in main-stem habitats of Hangman Creek in future monitoring years following established protocol (Firehammer et al. 2010).

In addition to stream temperature monitoring, the accumulation of several more years of baseflow dissolved oxygen and discharge data throughout this reporting period was instrumental in identifying those reaches in the upper Hangman Creek watershed that consistently displayed suboptimal rearing conditions for redband trout. For example, tributaries in the northern part of the Hangman Creek watershed that were heavily impacted by agriculture (e.g., Andrew Springs, Lolo, Tensed, and Rock creeks) either lacked water during baseflow periods or displayed dissolved oxygen profiles that would be insufficient to support salmonids. Low flow (e.g., standing pools) and attendant low levels of dissolved oxygen was also documented repeatedly in monitored reaches of Mission, Sheep, and South Fork of Hangman sub-watersheds. Furthermore, lower reaches of Nehchen Creek were repeatedly found to be intermittent during summer periods over the reporting period. Given that large redband trout have been found to ascend this tributary during spring migratory periods and that they may be using lower reaches as spawning habitat, more information is needed on the fate of fry that would be emerging coincident with the observed dewatering periods. Notwithstanding the high temperatures and low dissolved oxygen levels that are often associated with low flow, lack of discharge can also impact salmonids by decreasing the volume of macro invertebrate drift. Harvey et al. (2006) demonstrated that, under experimentally reduced streamflow conditions, the rate of invertebrate drift into pools and the rate of growth of rainbow trout was also reduced.

Additional data collection throughout the reporting period also illustrated the potential for certain reaches in some years to present sub-optimal conditions for redband trout during peak flow events. Discharge during brief, infrequent severe storms or rain-on-snow events was substantially more flashy in lower reaches of Sheep and Mission creeks and in the main-stem of Hangman Creek than in Nehchen and Indian creeks. Furthermore, given that this was only prominently evident during the 2004 and 2006 monitoring years, these suboptimal periods may not have been detected if monitoring was only conducted in any given year. The absence of LWD and overall lack of complexity documented during habitat surveys in reaches of the Hangman main-stem and in lower Sheep and Mission creeks likely increased the vulnerability of fish to these peak flow events. Elevated levels of total suspended solids (TSS) were also recorded concurrent with peak discharge events in the main-stem of Hangman creek and in lower reaches of Mission and Sheep creeks. Though the duration of these elevated levels would unlikely ever be of such a prolonged extent to cause lethal effects on salmonids, the TSS levels measured in these reaches could produce sub-lethal effects such as increased coughing, increased respiration rates, long term reduction in feeding success, and overall poor condition. Moreover, suspended sediment concentrations of 30 mg/L over the course of a few days, conditions that were observed during our survey, can have the same sub-lethal effect as storm events producing much higher TSS concentrations over more brief periods (Newcombe and Jensen 1996).

Channel forming processes were also found to be highly impaired in the lower reaches of Mission and Sheep creeks and in main-stem reaches of Hangman creek. As revealed in the Rosgen channel typing surveys conducted during the reporting period, these reaches were in a transitional phase from a Rosgen C to an F classification, and were characterized by deeply incised channels, and a sinuosity that was not consistent with their low gradient of less than 0.5%. Channel incision further reduces the frequency of overbank flows and, as a result, impairs normal functions of a stream-riparian ecosystem. Most of these stream channel changes were likely the result of a combination of factors including historical channel straightening and the installation of tiles on dry land agriculture fields, the removal of riparian vegetation, high road density, and excessive levels of timber harvest. Rosgen channel typing surveys were instrumental in providing baseline data from which comparisons will be able to be drawn to evaluate changes after restoration efforts are implemented in degraded reaches.

Though water quality and physical features (e.g., low canopy cover and LWD volume, excessive fine sediments) were typically inadequate to support suitable rearing habitat for redband trout in the main-stem of Hangman creek and in lower reaches of Mission and Sheep creeks, these same reaches were primarily the sole reaches that provided deep pools in surveyed sub-watersheds in upper Hangman. Even in the Indian Creek sub-watershed, where redband trout were the most abundant and widespread, surveyed pools often did not exceed one foot in residual depth. Deep, slow pools have been shown to be preferred habitats during summer rearing periods by redband trout of all ages (Muhlfeld et al. 2001a). Moreover, deep pools also provide vital overwintering habitats (Muhlfeld et al. 2001b), especially in those systems, like the upper Hangman watershed, where shallow summer habitats would become suboptimal under freezing and rain-on-snow conditions during late fall and winter periods. Lack of pool habitat may explain the absence of older, larger redband trout in summer surveys conducted in Sheep and South Fork of Hangman creeks; these fish may have been forced to emigrate out of their natal habitats to find suitable habitat downriver. The absence of pool habitats in surveyed reaches in tributaries of the upper Hangman watershed may in part be the result of an overall lack of large pieces of woody debris that are essential in both channel and pool-forming processes.

Analysis of macro-invertebrate samples collected across sub-watersheds in 2004 reflected the differences in water quality and habitat features, specifically substrate size and stream temperature, observed among reaches. Generally, macro-invertebrate metrics described a trend of decreasing habitat quality (i.e., greater stream temperatures and higher percentages of fine sediments) for salmonid species from upstream to downstream for all tributaries, with the exception of Indian Creek. Riffle beetles and sensitive stoneflies were the most dominant taxa at many of the sample sites in Indian Creek, a primarily forested sub-watershed that exhibited cooler temperatures and a larger substrate size composition relative to many of the other sub-watersheds surveyed. In comparison, sample sites in the northern part of the study area that were dominated by agriculture did not have a single Plecopteran in their invertebrate samples. Plecopterans were also virtually absent in many of the lower agriculturally-influenced sites in the main-stem of Hangman Creek. Richards et al. (1993) also reported plecopteran composition to respond negatively to the intensity of agricultural use in their surveyed streams.

As evidenced in our study, percent plecopterans and plecopteran richness were not only the most useful metrics in differentiating the quality of physical and chemical conditions of stream reaches, but also may be instrumental in assessing the quality of feeding habitats for redband trout. For example, large food items for trout are often the more sensitive invertebrate species, such as the large stoneflies of the genera Perlidae (22mm) and Pteronarcyidae (40mm). Hayes et al. (2000) developed a model to predict growth of brown trout based on temperature and size structure of drift. While growth was limited in their modeling analysis mostly by costs of reproduction, growth was also related to the increased foraging costs associated with feeding on small invertebrate prey. In their analysis, the size structure of invertebrate assemblages significantly predicted growth across ontogenetic stages of stream-dwelling trout.

The relative low cost of sampling and lab analysis of macro-invertebrate provided data closely related to much more costly water quality and temperature sampling in Hangman Creek over the course of the project. Overall macro-invertebrates were an excellent indicator of base-flow temperature and percent fine sediments which affect spawning and rearing of salmonids. Only 14 of the metrics calculated by EcoAnalysts, Inc were statistically analyzed, but further analysis can be done with existing data to look at other relationships.

In summary, of all the surveyed sub-watersheds in the upper Hangman watershed, Indian Creek, a primarily forested tributary, though lacking in quantity of deep pool habitat, had the most suitable perennial flows and annual discharge regimes, the lowest temperatures, the highest level of dissolved oxygen, high levels of canopy cover, and suitable substrate size. Not unexpectedly, Indian Creek was also the one sub-watershed that supported the most robust distribution and density of redband trout, even though it was one of the relatively smaller sub-watersheds in upper Hangman. Similar comparative results were reported by Dambacher and Jones (2007) for several streams in the Crooked River basin in Oregon. The authors found that the stream that supported the highest densities of redband trout also provided the best available habitat with respect to the greatest volume of LWD, lowest temperatures, perennial flows, and lowest level of imposed disturbances (e.g., cattle grazing, logging), even though it had the smallest basin area of the streams surveyed. As such, it is imperative to protect and preserve the quality and quantity of suitable rearing habitats that were evident in Indian Creek.

Restoration priorities

Restoration efforts during the reporting period focused on enhancing the quality of degraded rearing habitats in main-stem reaches of Hangman Creek to address documented deficiencies and to improve the suitability of migratory corridors that would increase the connectivity of sub-populations in tributaries in the upper Hangman watershed and promote both genetic interchange and colonization potential. Based on the modeling analysis conducted by Hardin-Davis, Inc. (2005), the most effective method to expedite the increase in usable habitats in the main-stem of Hangman would be to improve the suitability of rearing temperatures by increasing the amount of stream shading. Consequently, much of our restoration activities were devoted to riparian plantings that would eventually promote the augmentation of canopy cover in main-stem reaches. Based on experimentation with various techniques throughout the reporting period and the lessons learned therein, we intend to continue with restoration efforts to re-establish the native riparian vegetative community but to focus on planting primarily large native species (e.g., five gallon potted plants) using protection methods (e.g., large tree cones) that were apparently effective in preventing substantial beaver depredation and physical damage from freshets. Larger plantings were found to be more able than the smaller conspecifics to compete for sunlight with the reed canary grass that is prevalent in these reaches. In the future, we also plan to use hog panels as a means of protecting plantings against high flows and beaver foraging. In addition, supplemental watering during elevated summer air temperatures (e.g., 2007 summer) should increase the survival rates of planted species. Furthermore, based on the estimated short-term survival rates of coniferous species throughout the reporting period, we intend to primarily use Ponderosa pine in future riparian restoration efforts to restore coniferous communities.

In addition, future restoration priorities should be focused on protecting and enhancing the availability of suitable habitat in Indian Creek, where the most robust remnant sub-population of redband trout is currently found. Preservation of such refugia for redband trout in the upper Hangman watershed and bolstering that sub-population would ensure that, under the goal of re-establishing connectivity among tributaries, individuals would be sufficiently available to colonize and re-establish robust populations in other sub-watersheds. Results from the Hardin-Davis, Inc. (2005) analysis indicated that increasing the quantity of usable physical habitat for redband trout in Indian Creek would be best accomplished by increasing baseflow discharge. The increase in usable habitat in their modeling analyses under additional increments in flow was predominantly due to increases in pool depth given the lack of available deep pool habitat in Indian Creek. Consequently, because of the paucity of large pieces of LWD in Indian Creek, we intend to install pool-forming large woody debris structures in its reaches to increase residual pool depths. In addition, these structures should also augment the availability of cover for redband trout, a feature which was also shown to be lacking in modeled tributary reaches (Hardin-Davis, Inc. 2005).

7.0 ACKNOWLEDGEMENTS

We wish to thank the Coeur d'Alene for the support given to this project, and to the Power Planning Council, United Columbia Tribes (UCUT), and Bonneville Power Administration for funding and technical guidance. The following were instrumental as partners and sources of data: Idaho Department of Environmental Quality, Washington Department of Fish & Wildlife, Spokane Conservation District, Idaho Department of Lands, EcoAnalysts, Hardin-Davis Inc, and to internal staff that provided technical assistance and data gathering; Glen Lambert, Dr Dale Chess, Scott Fields, Gerald Green, Dan Jolibois, Stephanie Hallock, Carla Marratt, Angelo Vitale, Berne Jackson, and finally to tribal elder, Feliz Aripa, who provided historical information and inspiration to all of us.

8.0 BIBLIOGRAPHY

American Public Health Association. 1992. Standard methods for the examination of water and wastewater, 18th Ed. Washington D.C. American Public Health Association.

Anderson, R.O., and R.M. Neumann. 1996. Length, Weight, and Associated Indices. Pages 447-482 in B.R. Murphy and D.W. Willis, editors.Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Aripa, F. 2003. Personal communication with tribal elder.

Armour, C.L., K.P. Burnham, and W.S. Platts. 1983. Field methods and statistical analyses for monitoring small salmonid streams. USDI, Fish and Wildlife Service. FWS/OBS-83/33.

Bailey, R.G. 1995. Description of the bioregions of the United States. US Department of Agriculture, Forest Service Miscellaneous Publication No. 1391.

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

Bauer, S. B. and T. Wilson. 1983. Water Quality Status Report: Assessment of Nonirrigated Cropland Runoff, Hangman Creek, Benewah County, 1981-1982. Idaho Department of Health and Welfare Report No. WQ-51. 124pp.

Black, A. E., E. Strand, R. G. Wright, J. M. Scott, P. Morgan, and C. Watson. 1998. Land use history at multiple scales: implications for conservation planning. Landscape and Planning 43:49-63.

Bovee, K.D. 1982. A guide to stream habitat analysis using the Instream Flow Incremental Methodology. Instream Flow Information Paper No. 12. U.S. Fish Wildlife. Service. FWS/OBS-82/26.

Clark, W. H., and T. R. Maret. 1993. Water Quality Monitoring Protocols Report No. 5; Protocols for assessment of biotic integrity (macroinvertebrates) for wadeable streams. Idaho Department of Environmental Quality, Boise ID.

Coeur d'Alene Tribe Water Resources Program. 2002. Water quality summary for Hangman Creek watershed. Plummer, ID.

Conlin, K. and B.D. Tuty. 1979. Juvenile salmon field trapping manual. Dept. of Fisheries and Oceans. Fisheries and Marine Service Resource Services Branch, Habitat Protection Division, Vancouver, B.C.

Cooper, S. V., K. E. Neiman, R. Steele, and D. W. Roberts. 1991. Forest habitat types of northern Idaho: a second approximation. USDA Forest Service General Technical Report INT-236. Intermountain Forest and Range Experiment Station, Ogden, UT.

Dambacher, J.M. and K.K. Jones. 2007. Benchmarks and patterns of abundance of redband trout in Oregon streams: a compilation of studies. Pages 47-55 *in* R.K. Schroeder and J.D. Hall, editors. Redband trout: resilience and challenge in a changing landscape. Oregon Chapter, American Fisheries Society, Corvallis, Oregon.

Daubenmire, R. F. 1988. Steppe vegetation of Washington. Wash. State Univ., Pullman. 131pp.

Ebersole, J.L., W.J. Liss, and C.A. Frissell. 2001. Relationship between stream temperature, thermal refugia and rainbow trout *Oncorhynchus mykiss* abundance in arid-land streams in the northwestern United States. Ecology of Freshwater Fish 10: 1-10.

Ebersole, J.L., W.J. Liss, and C.A. Frissell. 2003. Thermal heterogeneity, stream channel morphology, and salmonid abundance in northeastern Oregon stream. Canadian Journal of Fisheries and Aquatic Sciences 60: 1266-1280.

Edelen, W., and D. Allen. 1998. A chronicle of Latah (Hangman) Creek: Fisheries and land use. 1995-1997 Report to Washington State Conservation Commision. Water Quality Implementation Grant #95-40-IM. Project Sponsor: Spokane County Conservation District.

Edmunds, G. F., S.L. Jensen, and L. Berner. 1960. The Mayflies of North and Central America. University of Minnesota Press, Minneapolis. 330 pp.

Fields, S. 2002. Personal communication. Water Resources Program Manager, Coeur d’ Alene Tribe, Plummer ID.

Firehammer, J.A., A.J. Vitale, and S.A. Hallock. 2010. Implementation of fisheries enhancement opportunities on the Coeur d’Alene Reservation. 2008 Annual Report. Project No. 1990-044-00. 146 pp. U.S. Department of Energy, Bonneville Power Administration, Portland, OR.

Gilpin, M. E. and M. E. Soule. 1986. Minimum viable populations: Processes of species extinction. In M. E. Soule (ed.), *Conservation Biology: The Science of Scarcity and Diversity*, pp. 19-34. Sinauer Associates, Sunderland, MA.

Gruell, G. E., 1983. Fire and Vegetative Trends in the Northern Rockies: Interpretations from 1871-1982. General Technical Report INT-158. Intermountain Forest and Range Experiment Station, Ogden, UT.

Hagle, S. K., G. I. McDonald, E. A. Norby. 1989. White pine blister rust in Northern Idaho and Western Montana: Alternatives for Integrated Management. General Technical Report INT-261. USDA Forest Service Intermountain Research Station.

Hardin, T.S. 1988. The use of habitat models to evaluate stream improvement structures, In-Stream Rehabilitation Manual, Oregon Chapter American Fisheries Society.

Hardin-Davis, Inc. 2005. Physical habitat and temperature in Hangman Creek, Idaho: Final Report to the Coeur d'Alene Tribe. Corvallis OR. 57pp.

Harrelson, Cheryl C., C.L. Rawlins and J.P. Potyondy. 1994. Stream Channel Reference Sites: An Illustrated Guide to Field Technique. General Technical Report RM-245. Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, Fort Collins, CO.

Harvey, B. C., R. J. Nakamoto, and J. L. White. (2006). Reduced streamflow lowers dry-season growth of rainblow trout in a small stream. *Transactions of the American Fisheries Society* 135:998-1005.

Hayes, J. W., J.D. Stark, and K. A. Shearer. (2000). Development and test of a whole-lifetime foraging and bioenergetics growth model for drift-feeding brown trout. . *Transactions of the American Fisheries Society* , 129:315-332.

Hydrolab Corporation. 1997. DataSonde® 4 and MiniSonde® Water Quality Multiprobes Users Manual. Austin, TX.

Idaho Dept. of Environmental Quality. 2002 Water Body Assessment Guidance (WBAG) 2nd Ed-Final. Boise, ID.

Idaho Department of Environmental Quality. 2007. Upper Hangman Creek Subbasin Assessment and Total Maximum Daily Load. Boise, ID.

Intermountain Province Subbasin Plan. 2004. Northwest Power and Conservation Council. Portland, OR.

Isaacson, J. A. 1998. Riparian Study of the Headwaters of Latah Creek. SnowH20 Aquatic Consultants.

Jankovsky-Jones, M. 1999. Conservation strategy for Spokane River Basin wetlands. Unpublished report prepared with funding from the United States Environmental

Protection Agency through Section 104(b) (3) of the Clean Water Act. 26 pp. plus appendices.

Jearld, T. 1983. Age determination. Pages 301-324 *in* L.A. Nielson and D.L. Johnson, editors, Fisheries Techniques. American Fisheries Society, Bethesda, MD.

Leopold, L.B. 1994. A View of the River. Harvard University Press, Cambridge, MA. 298 pp.

Li, H.W., G.A. Lamberti, T.N. Pearsons, C.K. Tait, J.L. Li, and J.C. Buckhouse. 1994. Cumulative effects of riparian disturbances along high desert trout streams of the John Day Basin, Oregon. Transactions of the American Fisheries Society 123: 627-640.

Lichthardt, J. and R. K. Mosely. 1997. Status and conservation of the Palouse Grassland in Idaho. US Fish and Wildlife Service, Publication No. 14420-5-0395.

Lux, F.E. 1971. Age determination of fishes (revised). NMFS, Fishery leaflet 637.

Kinkead, B.A.. 2011. Personal communication; GIS exercise. Coeur d'Alene Tribe, Plummer ID.

Maloy, O. C. 1997. White pine blister rust control in North America: A case history. Annu. Rev. Phytopath. 35:87-109.

Meyer, K.A., J.A. Lamansky Jr., and D.J. Schill. 2010. Biotic and abiotic factors related to redband trout occurrence and abundance in desert and montane streams. Western North American Naturalist 70: 77-91.

Muhlfeld, C.C., D. H. Bennett, and B. Marotz. 2001a. Summer habitat use by Columbia River Redband trout in the Kootenai River Drainage, Montana. North American Journal of Fisheries Management 21:223-235.

Muhlfeld, C.C., D. H. Bennett, and B. Marotz. 2001b. Fall and winter habitat use and movement by Columbia River Redband trout in a small stream in Montana. North American Journal of Fisheries Management 21:170-177.

Newcombe, C.P., J.O. Jensen. 1996. Channel suspended sediment and fisheries: A synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16: 693-727.

Northwest Power and Conservation Council. 2000. Draft Spokane Subbasin Plan Summary. In *Columbia River Basin Fish and Wildlife Program.* Portland, Oregon.

Northwest Power and Conservation Council. 2004. Spokane Subbasin Plan.." In *Columbia River Basin Fish and Wildlife Program.* Portland, Oregon.

Peck, D.V., J.M. Lazorchak, and D.J. Klemm, editors. 2001. Western Pilot Study Draft Field Operations Manual for Wadeable Streams. Environmental Monitoring and Assessment Program-Surface Waters. U.S. Environmental Protection Agency. Corvallis, OR.

Peters R., B.A. Kinkead, and M. Stanger. 2003. Year-End Report: 2001-2002 Implement Fisheries Enhancement on the Coeur d'Alene Indian Reservation: Hangman Creek. BPA Project # 2001-032-00. 189 pp. U.S. Department of Energy, Bonneville Power Administration, Portland, OR.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. USDA Forest Service General Technical Report INT-138.

Redmond, R. L. and M. L. Prather. 1996. Mapping Existing Vegetation and Land Cover Across Western Montana and Northern Idaho. Wildlife Spatial Analysis Lab. University of Montana. Missoula, Montana.

Reynolds, J.B. 1983. Electrofishing. Pages 147-163 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, MD.

Richards, C., G.E. Host, J.W. Arthur. (1993). Identification of predominant communities within a large agricultural catchment. In *Freshwater Biology*, 29:285-294. Wiley Online, doi:10.111/j.1365-2427.1993.tb00764.x

Ritter, J.R. 1967. Bed-material Movement. Middle Fork Eel River, CA. US Geological Survey Prof. Paper 575-C: pp. C219-C221.

River4m, Ltd. 1999. Reference Reach Spreadsheet, A Stream Channel Assessment Tool, Version 2.2L (Microsoft Excel). Distributed by Ohio Department of Natural Resources, Columbus, OH.

Rodnick, K.J., A.K. Gamperl, K.R. Lizars, M.T. Bennett, R.N. Rausch, and E.R. Keely. 2004. Thermal tolerance and metabolic physiology among redband trout populations in south-eastern Oregon. Journal of Fish Biology. 64:310-335.

Rosgen, D.L. 1993. A classification of natural rivers. Catena 22:169-199.

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

Roy, A. H., A.D. Rosemnd, D.S. Leigh, Michael J. Paul, J. B. Wallace. (2003). Habitat-specific responses of stream insects to land cover disturbance:biological consequences and monitoring implications. . *Journal of the North American Benthological Society* , Vol 22. No 2:292-307.

Scholz, A., K. O'Laughlin, D. Geist, D. Peone, J. Uehara, L. Fields, T. Kleist, I. Zozaya, T. Peone, and K. Teesatuski. 1985. Compilation of information on salmon and steelhead trout run size, catch, and hydropower related losses in the Upper Columbia River Basin, above Grand Coulee Dam. Upper Columbia United Tribes, Fisheries Center. Eastern Washington University, Cheney, WA. Fisheries Technical Report No. 2.

Schuett-Hames, D., A.E. Pleus, and D. Smith. 1999. TFW Monitoring Program manual for the salmonid spawning habitat availability survey. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-007. DNR #109.November.

Seber, G.A.F., and E.D. LeCren. 1967. Estimating population parameters from catches large relative to the population. Journal Animal Ecology 36:631-643.

Small, M. P., and J. Von Bargen. 2005. Final Draft Report: Microsatellite DNA analysis of rainbow trout population structure in the Hangman Creek drainage with comparison to populations in the greater Spokane River drainage and hatchery rainbow trout collections. Washington State Department of Fish and Wildlife, Science Division, Conservation, Genetic Lab. 19pp.

Spokane County Water Conservation District. 1994. Hangman Creek Watershed Management Plan. Spokane, Washington.

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.

Stewart, R. 2002. Resistance board weir panel construction manual. Regional Information Report No. 3A02-21. Alaska Department of Fish and Game, Division of Commercial Fisheries Arctic-Yukon-Kuskokwim Region.

U.S. Environmental Protection Agency (USEPA). 1993. Methods for the Determination of Inorganic Substances in Environmental Samples. Publication # EPA 600/R-93-100 (includes methods 160.2, 180.1, 351, 300. Washington, D.C.

Washington State Dept. of Ecology. 2002. Revised temperature criteria for fresh water. Publication #. 00-10-066. Olympia, WA.

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

Wolman, M.G. 1954. A method of sampling coarse carrier-bed material. *Transactions of American Geophysical Union*. Volume 35:951-956.

WRCC. 2008. Western Regional Climate Center. DeSmet 1 S, Idaho Station # 102513. (www.wrcc.dri.edu).

Zippen, C. 1958. The removal method of population estimation. Journal of Wildlife Management 22:82-90.

Zoellick, B.W. 2004. Density and biomass of redband trout relative to stream shading and temperature in southwestern Idaho. Western North American Naturalist 64: 18-26.

Zoellick, B.W. and B.S. Cade. 2006. Evaluating redband trout habitat in sagebrush desert basins in southwestern Idaho. North American Journal of Fisheries Management 26: 268-281.

Zoellick, B.W., D.B. Allen, and B.J. Flatter. 2005. A long-term comparison of redband trout distribution, density, and size structure in southwestern Idaho. North American Journal of Fisheries Management 25: 1179-1190.

9.0 APPENDICES

9.1 Appendix A: Water Quality and Continuous Temperature Monitoring Sites

Appendix A-1. Water Quality Sites and Laboratory Methods

Main-stem Hangman

01-SH000000, Hangman, Stateline.   T45N, R6W, Sec 36, NW 1/4 . River mile (RM) 0.0 on Hangman Creek Road. Located in Agriculture land.

02-SH000000, Hangman-HWY 95. T44N, R5W, Sec 24, NW 1/4. Hangman Creek RM 8.1 at Hwy 95. Located in Agriculture land.

03-SH000000, Hangman Creek at Nehchen Hump. T44N, R4W, Sec 28, NW 1/4. RM 11.6 on Old Sanders Road. Mixed land use area.

05-SH000000, Hangman at confluence with SF Hangman. T43 N, R4W, Sec 1, SE 1/4. RM 16.5 on Emida/Sanders Road. Mixed land use area.

06-SH000000, Hangman in Forest. T43N, R3W, Sec 5, NE 1/4. RM 18.7 on Emida/Sanders Road. Forested area.

07-SH000000, Upper Hangman. T44N, R3W, Sec 33, SW 1/4. RM 19.2 off Emida/Sanders Road. Forested area.

Tributaries

01-SH050000, Lolo Creek. T44N, R5W, Sec 26, SW 1/4. Lolo Creek is at RM 4.0 on Hangman Creek. Sample site is at Benewah Creek Road crossing at RM 2.9. Located in Agriculture land.

01-SH070000, Lower Tensed Creek.   T44N, R5W, Sec 11, SE 1/4. Confluence with Hangman Creek is RM 6.8. Sample site is at Old Tensed Road crossing at RM 0.7. Located in Agriculture land.

02-SH070000, Upper Tensed Creek. T44N, R4W, Sec 6, NE ¼. Sample site is 100 yards SE of Little Butte Road at RM 3.0. Forested area.

01-SH060000, Lower Mission Cr. T44N, R5W, Sec 35, NW . Confluence with Hangman Creek is RM 7.5, and sample site is at the second King Valley Road crossing at RM 2.3 of Mission Creek. Located in Agriculture land.

02-SH060000, M.F. Mission Cr. T43N, R5W, Sec 10, NE 1/4. At Pole Camp Road crossing at RM 4.8. Forested area.

01-SH060010, E.F. Mission Cr. T43N, R5W, Sec 3, SE $^1/_4$. $^1/_4$ mile west of Pole Camp Road on haul road at RM 0.2. Lightly forested area.

01-SH060020, W.F. Mission Creek. T43N, R5W, Sec 3, NW $^1/_4$. At old bridge crossing that is tank-trapped, 1/3 mile west of Pole Camp Road at RM 0.5. Mixed land uses in area

01-SH080000, Sheep Creek at HWY 95. Confluence with Hangman Creek is RM 9.1. Sample site under bridge at Hwy 95 at RM 0.6. Mixed land use area.

02-SH080000, Upper Sheep Creek. T43N, R5W, Sec 1 SE ¼. 1 mile south of end of Sheep Creek Road, at forestry gate at RM 2.8. Forested area.

01-SH090000, Lower Nehchen Creek. T44N, R4W, Sec 28, NW ¼. RM 11.5 on Hangman Creek. Below culvert on Old Sanders Road at RM 0.1. Located in Agriculture land.

02-SH090000, Upper Nehchen. T44N, R4W, Sec 14, NW ¼. 1 mile behind Potlatch gate above Apple Horse Farm above culvert on logging road at RM 2.9. Forested area.

01-SH100000, Unnamed creek upstream of Nehchen. T44N, R4W, Sec 28, NE ¼. RM 12.2 on Hangman Creek. Sample site is below culvert on Old Sanders Road. Mixed land uses area.

01-SH110000, Lower Smith Creek. T43N, R4W, Sec 3, SE ¼. RM 13.5 on Hangman Creek. Above culvert on Sanders Road at RM 1.0. Located in Agriculture land.

01-SH110010, Mineral Creek. T43N, R4W, Sec 3, SE ¼. At confluence with Smith Creek on Sanders Road at RM 0.0. Located in Agriculture land.

02-SH120000, Upper S.F. Hangman Creek. T43N, R4W, Sec 13, SW ¼. SF Hangman Confluence with Hangman Creek is RM 16.6. At end of Papoose Road at RM 1.7. Forested area.

01-SH120010, Conrad Creek. T43N, R4W, Sec 12, SE ¼. Above culvert on Papoose Road at RM 0.1. Mixed land use area.

01-SH120020, Martin Creek. T43N, R3W, Sec 18, NW ¼. 50 yards east of Pappoose Road at RM 0.2. Mixed land use area.

01-SH130000, Benak Cr. T44N, R3W, Sec 33, SW ¼. Across from Hill Cr on Elmida/Sanders Road on north side of Hangman Creek at RM 0.0. Forested area.

01-SH140000, Hill Creek. T44N, R3W, Sec 33, SW ¼. RM on Hangman Cr. Above culvert on Elmida/Sanders Road at RM 0.0. Forested area.

01-SH160000, Parrot Creek. T44N, R3W, Sec 33, SW ¼. Above culvert on Elmida/Sanders Road at RM 0.0. Forested area.

01-SH170000, Bunnel Creek. T44N, R3W, Sec 33, SW ¼. Joins Parrot Cr to become Bunnel Creek at hairpin turn on Elmida/Sanders Road at RM 0.5. Forested area.

01SH0200000 Indian Creek-Sanders. T44N, R4W, Sec 30, NW ¼. Confluence with Hangman Creek is RM 15.0. Sample site is at RM 0.3 on Indian Creek. Rural area.

02-SH020000, Indian Creek-Pow Wow. T44N, R4W, Sec 30, NW ¼. Confluence with Hangman Creek is RM 15.0. Sample site is at RM 1.4 on Indian Creek. Forested area.

03-SH020000, Upper Indian. T44N, R3W, Sec 30, NE ¼. RM 2.9 on Indian Creek. Behind gate on logging road above confluence with N.F. Indian. Forested area.

01-SH020010, E.F. Indian Creek T44N, R3W, Sec 30, SE ¼. RM 2.6 on Indian Cr. Opposite side of Indian Creek from road at RM 0.3. Forested area.

01-SH020020, N.F. Indian Cr. T44N, R3W, Sec 30, SW ¼. RM 2.7 on Indian Cr. Above culvert on logging road at RM 0.1. Forested area.

01-SH010000, Little Hangman Creek. T45N, R6W, Sec 12. At stateline with Washington. Agriculture area.

01-SH010010, Lower Moctileme Creek. T45N, R6W, Sec 12. On Hwy 60, 100 feet above confluence with Little Hangman at RM 0.0. Agriculture area.

01-SH030000, NF Rock Creek. T47N, R6W, Sec 12. At Hwy 58 crossing near Washington border. Agriculture area.

No code. Rock Creek. T46N, R6W, Sec 1. At stateline with Washington. Agriculture area.

No code. Rose Creek. T47N, R6W, Sec 13. At stateline with Washington. Agriculture area.

All bacteria samples will be handled according to Standard methods for the examination of water and wastewater 18th Ed. (APHA) 1992 procedure 9060A collection and preservation of samples. Samples will be stored immediately in an ice bath for preservation and delivered to the contract laboratory within 6 hours of collection. All samples will follow strict chain of custody procedures as outlined in section 1060.B.1: Chain of custody procedures (APHA). Bacteria analysis will be completed by a qualified analytical laboratory in accordance with (APHA) standard method SM9213D for E.coli.
All samples were handled according to Standard Methods for the Examination of Water and Wastewater, 18th Ed. (APHA 1992), Procedure 1060: Collection and preservation of samples. Strict chains of custody procedures were followed, as outlined in section 1060.B.1: Chain of custody procedures (APHA). All containers used were specially cleaned and prepared by the contract laboratory.

Total Suspended Solids was analyzed using EPA method 160.2: Gravimetric determination of Total Suspended Solids (USEPA 1993). TSS is defined as the residue left on a filter paper of 2µm or smaller pore size after a portion of sample has been filtered and dried. A qualified analytical laboratory completed turbidity analysis in accordance with standard method 2130B: Nephelmetric determination of turbidity (APHA, 1992) and/or EPA method 180.1 (USEPA 1993). Alkalinity was analyzed using EPA method 310.1 (APHA, 1992)

9.2 Appendix A-2. Continuous Temperature Sampling Site Descriptions

01-SH000000, Hangman, Stateline. T44N, R5W, Sec 36, NW $^1/_4$. River mile (RM) 0.0 on Hangman Creek Road. Located in Agriculture land.

Hangman, Liberty. T44N, R5W, Sec. 5, NE ¼. River Mile (RM) 3.1 on Hangman Creek Road. Located in Agriculture land.

Hangman, Farm. T44N, R5W, Sec. 10, NE ¼. River Mile (RM) 5.8 on Hangman Creek Road. Located in Agriculture land.

06-SH000000, Hangman-HWY 95. T44N, R5W, Sec. 24, NW $^1/_4$. Hangman Creek RM 8.1 at Hwy 95. Located in Agriculture land.

07-SH000000, Hangman, Buckless. T44N, R4W, Sec. 29, NE ¼. River Mile (RM) 10.5 on Sanders Road. Located in mixed land use area.

03-SH000000, Hangman Creek at Nehchen Hump. T44N, R4W, Sec 28, NW $^1/_4$. RM 11.6 on Old Sanders Road. Mixed land use area.

00-SH000000, Hangman, Beasley. T44N, R4W, Sec. 28, SE ¼. River Mile (RM) 12.2 on Sanders Road. Mixed land use area.

00-SH000000, Hangman, Larson. T43N, R4W, Sec. 2, NW ¼. River Mile (RM) 14.8 on the Old Sanders Road. Mixed land use area.

00-SH000000, Hangman, Crawford. T43N, R4W, Sec. 2, NE ¼. River Mile (RM) 15.2 on the Old Sanders Road. Mixed land use area.

00-SH000000, Hangman, Bennett. T43N, R4W, Sec. 1, NW ¼. River Mile (RM) 16.5 on the Old Sanders Road. Forested area.

00-SH000000, Hangman, S.F.Road. T43N, R4W, Sec. 1, SE ¼. River Mile (RM) 16.9 on the Old Sanders Road. Mixed land use area.

06-SH000000, Hangman in Forest. T43N, R3W, Sec 5, NE $^1/_4$. RM 18.7 on Emida/Sanders Road. Forested area.

01-SH170000, Bunnel Creek. T44N, R3W, Sec 33, SW ¼. Joins Parrot Cr to become Bunnel Creek at hairpin turn on Elmida/Sanders Road at RM 0.5. Forested area.

00-SH000000, Mission, DeSmet. T44N, R5W, Sec. 26, NE ¼. River Mile (RM) 0.4. Located on agriculture land.

00-SH000000, Mission, King Valley Road. T44N, R5W, Sec. 26, SW ¼. River Mile (RM) 2.3. Located on King Valley Road. On agriculture land.

02-SH060000, M.F. Mission Cr. T43N, R5W, Sec. 10, NE $^{1}/_{4}$. At Pole Camp Road crossing at RM 4.8. Forested area.

Sheep Creek Confluence. T44N, R4W, Sec. 29, NW ¼. River Mile (RM) 0.0. Located on agriculture land.

01-SH080000, Sheep Creek at HWY 95. Confluence with Hangman Creek is RM 9.1. Sample site under bridge at Hwy 95 at RM 0.6. Mixed land use area.

02-SH080000, Upper Sheep Creek. T43N, R5W, Sec 1 SE ¼. 1 mile south of end of Sheep Creek Road, at forestry gate at RM 2.8. Forested area.

01-SH090000, Lower Nehchen Creek. T44N, R4W, Sec 28, NW ¼. RM 11.5 on Hangman Creek. Below culvert on Old Sanders Road at RM 0.1. Located in Agriculture land.

02-SH090000, Upper Nehchen. T44N, R4W, Sec 14, NW ¼. 1 mile behind Potlatch gate above Apple Horse Farm above culvert on logging road at RM 2.9. Forested area.

01SH0200000 Indian Creek-Sanders. T44N, R4W, Sec 30, NW ¼. Confluence with Hangman Creek is RM 15.0. Sample site is at RM 0.3 on Indian Creek. Rural area.

02-SH020000, Indian Creek-Pow Wow. T44N, R4W, Sec 30, NW ¼. Confluence with Hangman Creek is RM 15.0. Sample site is at RM 1.4 on Indian Creek. Forested area.

03-SH020000, Upper Indian. T44N, R3W, Sec 30, NE ¼. RM 2.9 on Indian Creek. Behind gate on logging road above confluence with N.F. Indian. Forested area.

01-SH020010, E.F. Indian Creek T44N, R3W, Sec 30, SE ¼. RM 2.6 on Indian Cr. Opposite side of Indian Creek from road at RM 0.3. Forested area.

01-SH020020, N.F. Indian Cr. T44N, R3W, Sec 30, SW ¼. RM 2.7 on Indian Cr. Above culvert on logging road at RM 0.1. Forested area.

00-SH000000, S.F. Hangman, Lower. T43N, R4W, Sec. 12, NE ¼. River Mile (RM) 0.7. Located on forested area.

02-SH120000, Upper S.F. Hangman Creek. T43N, R4W, Sec 13, SW ¼. SF Hangman Confluence with Hangman Creek is RM 16.6. At end of Papoose Road at RM 1.7. Forested area.

01-SH120020, Martin Creek. T43N, R3W, Sec 18, NW ¼. 50 yards east of Pappoose Road at RM 0.2. Mixed land use area.

9.3 Appendix B: Supplemental Water Quality Data; Nutrients 2004-2005

Table B-1. Complete set of water quality data for Hangman-Stateline RM 0.0 during the water years 2004-5.

			STL ID	7629	7795	7895	8285	8455	9581	
			Site Code	05SH000000	05SH000000	05SH000000	05SH000000	05SH000000	05SH000000	05SH000000
			Sample Date	11/12/03	12/16/03	1/22/04	3/25/04	4/19/04	8/11/04	8/10/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS							
PHYSICAL PROPERTIES										
Total Suspended Solids	2	EPA 160.2	mg/L	4	6	5	3	5	3	2
Turbidity	0.02	EPA 180.1	NTU	1.65	53.6	21	11.1	6.74	3.88	1.12
INORGANIC, NON-METALLICS										
Chloride, Cl	0.02	EPA 300.0	mg/L	2.64	5.31	5	1.25	1.79	2.14	2.16
Fluoride, F	0.02	EPA 300.0	mg/L	0.29	0.12	0	0.05	0.07	0.25	0.23
Ammonia as N	0.005	EPA 350.1	mg/L							nd
Nitrate as N	0.005	EPA 300.0	mg/L	0.06	3.11	7	0.69	0.86	0.04	nd
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.023	0.137	0	0.037	0.058	0.051	0.033
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.005	0.045	0	0.005	0.016	<0.01	0.02
ortho-Phosphate as P	0.01	EPA 365.1								0.033
Sulfate	0.03	EPA 300.0	mg/L	7.00	7.30	10	3.47	4.43	4.79	3.69
TKN	0.02	EPA 351.2	mg/L	0.32	0.81	1	0.24	0.44	0.37	0.3
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.11	0	<0.01	<0.01	<0.01	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	107.6		26	18.3	36.5	91.4	80
E-Coli, MF		SM9213D	#/100m					8		
			Discharge (cfs)	2.39	21.20	22.45	91.05	25.59	<.3	<0.3
			Hydrolab Readings							
			pH	7.46		6.81	6.46	7.65	7.47	8.18
			Conductivity	257		128.5	54.6	96.8	201	171
			D.O. (mg/L)	8.61		12.87	12.12	12.34	8.62	7.57
			Temp C	1.49		0.73	6.17	9.28	19.21	22.37

Table B-2. Complete set of water quality data for Hangman-Buckless RM 10.5 during the water years 2004-5.

			STL ID	7639	7897	8292	8508	9600	
			Site Code	07-SH000000	07 SH000000	07SH000000	07SH000000	07SH000000	07SH000000
			Sample Date	11/12/03	1/22/04	3/25/04	4/20/04	8/11/04	8/10/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS						
PHYSICAL PROPERTIES									
Total Suspended Solids	2	EPA 160.2	mg/L	5	2	4	4	2	2
Turbidity	0.02	EPA 180.1	NTU	4.85	14.7	9.06	6.49	1.71	0.05
INORGANIC, NON-METALLICS									
Chloride, Cl	0.02	EPA 300.0	mg/L	2.73	4.67	0.99	1.36	1.27	2.26
Fluoride, F	0.02	EPA 300.0	mg/L	0.1	<0.05	<0.05	<0.05	0.11	0.11
Ammonia as N	0.005	EPA 350.1	mg/L						0.02
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01	2.86	0.02	0.02	0.01	0.01
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.064	0.064	0.033	0.036	0.031	0.057
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.026	0.017	0.005	0.017	<0.01	nd
ortho-Phosphate as P	0.01	EPA 365.1	mg/L						0.038
Sulfate	0.03	EPA 300.0	mg/L	1.39	5.89	2.29	2	0.8	0.71
TKN	0.02	EPA 351.2	mg/L	0.33	0.58	0.16	0.2	0.37	0.09
Ammonia as N	0.01	EPA350.3	mg/L	0.01	0.03	<0.01	<0.01	0.02	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	36.5	24.4	12.2	24.4	38.6	47.2
E-Coli, MF		SM9213D	#/100m				180		
			Discharge (cfs)	0.92	17.64	68.27	13.17	0.26	0.04
			Hydrolab Readings						
			pH	7.11	7.02	7.09	7.16	8.05	7.18
			Conductivity	74.6	81.7	32.6	49.3	86.2	96
			D.O. (mg/L)	11.12	13.94	13.23	8.63	8.73	8.29
			Temp C	1.63	0.96	6.86	8.09	25.31	20.64

Table B-3. Complete set of water quality data for Hangman-Sanders RM 14.8 during the water years 2004-5.

			STL ID	9550	
			Site Code	08SH000000	08SH000000
			Sample Date	8/9/04	8/11/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS		
PHYSICAL PROPERTIES					
Total Suspended Solids	2	EPA 160.2	mg/L	5	5
Turbidity	0.02	EPA 180.1	NTU	3.83	5.02
INORGANIC, NON-METALLICS					
Chloride, Cl	0.02	EPA 300.0	mg/L	1.05	0.89
Fluoride, F	0.02	EPA 300.0	mg/L	0.07	0.06
Ammonia as N	0.005	EPA 350.1	mg/L		0.02
Ammonia as N	0.005	EPA 350.1	mg/L		nd
Nitrate as N	0.005	EPA 300.0	mg/L	0.01	0.057
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.046	0.042
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	<0.01	nd
ortho-Phosphate as P	0.01	EPA 365.1	mg/L		1.15
Sulfate	0.03	EPA 300.0	mg/L	1.26	nd
TKN	0.02	EPA 351.2	mg/L	0.22	0.02
Ammonia as N	0.01	EPA350.3	mg/L	0.01	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	30.5	24.6
E-Coli, MF		SM9213D	#/100m		
			Discharge (cfs)	0.512	0.14
			Hydrolab Readings		
			pH	8.26	6.95
			Conductivity	59.6	49
			D.O. (mg/L)	8.25	8.15
			Temp C	19.48	17.08

Table B-4. Complete set of water quality data for Hangman-SF Road RM 16.9 during the water years 2004-5.

			STL ID	7636	7802	7900	8293	8516	9556	
			Site Code	09SH000000	09SH000000	09SH000000	09H000000	09SH000000	09SH000000	09SH000000
			Sample Date	11/12/03	12/16/03	1/22/04	3/25/04	4/20/04	8/10/04	8/11/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS							
PHYSICAL PROPERTIES										
Total Suspended Solids	2	EPA 160.2	mg/L	<2	4	8	13	2	3	2
Turbidity	0.02	EPA 180.1	NTU	2.73	7.86	14.6	12.6	8.79	3.68	
INORGANIC, NON-METALLICS										
Chloride, Cl	0.02	EPA 300.0	mg/L	4.06	4.64	4.76	1.12	1.8	3.63	4.85
Fluoride, F	0.02	EPA 300.0	mg/L	0.07	0.05	<0.05	<0.05	0.08	0.07	0.06
Ammonia as N	0.005	EPA 350.1	mg/L							0.02
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01	0.36	0.48	0.05	0.03	0.03	0.09
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.042	0.037	0.052	0.046	0.039	0.051	0.082
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.021	0.007	0.013	0.007	0.012	<0.01	
ortho-Phosphate as P	0.01	EPA 365.1	mg/L							0.089
Sulfate	0.03	EPA 300.0	mg/L	2.87	4.49	4.37	2.26	2.15	1.63	1.22
TKN	0.02	EPA 351.2	mg/L	0.22	0.2	0.28	0.17	0.17	0.39	0.3
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.02	0.01	<0.01	<0.01	0.02	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	20.3		22.3	12.2	14.2	24.4	30.8
Bacteriological										
E-Coli, MF		SM9213D	#/100m					81		
			Discharge (cfs)	0.15	1.80	1.85	7.92	1.96	0.07	NA
			Hydrolab Readings							
			pH	6.78		6.78	6.47	7.25	7.23	7.09
			Conductivity	54.5		54.5	31	38.3	61.7	83
			D.O. (mg/L)	13.98		13.98	11.82	8.56	8.94	7.95
			Temp C	0.49		0.49	6.46	7.6	16.51	16.19

Table B-5. Complete set of water quality data for Hangman-Forest RM 18.7 during the water years 2004-5.

			STL ID	7635	7799	8515	9590	
			Site Code	10SH000000	10SH000000	10SH000000	10SH000000	10-SH000000
			Sample Date	11/12/03	12/16/03	4/20/04	8/11/04	8/10/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS					
PHYSICAL PROPERTIES								
Total Suspended Solids	2	EPA 160.2	mg/L	<2	5	<2	2	3
Turbidity	0.02	EPA 180.1	NTU	4.53	5.97	6.24	2.61	3.13
INORGANIC, NON-METALLICS								
Chloride, Cl	0.02	EPA 300.0	mg/L	3.22	5.21	1.26	1.63	3.13
Fluoride, F	0.02	EPA 300.0	mg/L	<0.05	0.05	0.06	0.06	0.06
Ammonia as N	0.005	EPA 350.1	mg/L					nd
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01	0.21	0.01	0.1	0.79
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.021	0.022	0.033	0.029	0.41
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.009	<0.002	0.009	0.01	nd
ortho-Phosphate as P	0.01	EPA 365.1	mg/L					0.028
Sulfate	0.03	EPA 300.0	mg/L	3.26	5.2	2.26	1.94	1.9
TKN	0.02	EPA 351.2	mg/L	0.12	0.13	0.1	0.05	nd
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.01	<0.01	0.01	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	22.3		16.2	28.4	26.6
Bacteriological								
E-Coli, MF		SM9213D	#/100m					
			Discharge (cfs)	0.13	0.42	1.51	0.09	0.08
		Hydrolab Readings						
			pH	7.07		7.16	7.35	7.53
			Conductivity	52.6		34.7	56.4	62
			D.O. (mg/L)	12.22		8.49	8.78	9.5
			Temp C	1.43		6.07	14.38	14.15

Table B-6. Complete set of water quality data for Hangman-Kostillo RM 19.6 during the water years 2004-5.

			STL ID	8512	9594
			Site Code	11SH000000	11SH000000
			Date	4/20/04	8/11/04
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS		
PHYSICAL PROPERTIES					
Total Suspended Solids	2	EPA 160.2	mg/L	<2	2
Turbidity	0.02	EPA 180.1	NTU	7.8	9.53
INORGANIC, NON-METALLICS					
Chloride, Cl	0.02	EPA 300.0	mg/L	0.68	1.15
Fluoride, F	0.02	EPA 300.0	mg/L	0.07	0.06
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01	<0.01
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.028	0.049
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.015	<0.01
Sulfate	0.03	EPA 300.0	mg/L	1.92	1.14
TKN	0.02	EPA 351.2	mg/L	0.1	0.28
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	<0.01
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	18.3	28.4
Bacteriological					
E-Coli, MF		SM9213D	#/100m		
			Discharge (cfs)	0.03	standing pools
			Hydrolab Readings		
			pH	7.43	6.23
			Conductivity	37.1	59.5
			D.O. (mg/L)	8.59	4.77
			Temp C	4.96	13.55

Table B-7. Complete set of water quality data for Andrew Springs RM 0.1 during the water years 2004.

			STL ID	8456
			Site ID	01SH009000
			Sample Date	4/19/2004
ANALYSIS PARAMETERS PHYSICAL PROPERTIES	**Detection limit**	METHOD	UNITS	
Total Suspended Solids	2	EPA 160.2	mg/L	16
Turbidity	0.02	EPA 180.1	NTU	17.3
INORGANIC, NON-METALLICS				
Chloride, Cl	0.02	EPA 300.0	mg/L	1.85
Fluoride, F	0.02	EPA 300.0	mg/L	0.11
Nitrate as N	0.005	EPA 300.0	mg/L	2.56
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.098
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.046
Sulfate	0.03	EPA 300.0	mg/L	9.28
TKN	0.02	EPA 351.2	mg/L	0.7
Ammonia as N	0.01	EPA350.3	mg/L	0.02
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	65
Bacteriological				
E-Coli, MF		SM9213D	#/100m	
			Discharge (cfs)	1.04
			Hydrolab Readings	
			pH	7.53
			Conductivity	175
			D.O. (mg/L)	11.27
			Temp C	8.79

Table B-8. Complete set of water quality data for Lolo Creek RM 2.9 during the water years 2004.

			STL ID	8454
			Site ID	01SH008000
			Sample Date	4/19/04
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS	
PHYSICAL PROPERTIES				
Total Suspended Solids	2	EPA 160.2	mg/L	13
Turbidity	0.02	EPA 180.1	NTU	12.5
INORGANIC, NON-METALLICS				
Chloride, Cl	0.02	EPA 300.0	mg/L	2.32
Fluoride, F	0.02	EPA 300.0	mg/L	0.06
Nitrate as N	0.005	EPA 300.0	mg/L	2.97
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.06
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.032
Sulfate	0.03	EPA 300.0	mg/L	6.93
TKN	0.02	EPA 351.2	mg/L	0.43
Ammonia as N	0.01	EPA350.3	mg/L	<0.01
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	32.5
Bacteriological				
E-Coli, MF		SM9213D	#/100m	
			Discharge (cfs)	1.30
			Hydrolab Readings	
			pH	7.26
			Conductivity	108.5
			D.O. (mg/L)	12.03
			Temp C	8.09

Table B-9. Complete set of water quality data for Tensed Creek RM 0.7 during the water years 2004.

			STL ID	7896	8286	8458
			Site ID	01 SH010000	01-SH010000	01SH010000
			Sample Date	1/22/04	3/25/04	4/19/04
ANALYSIS PARAMETERS	**Detection**	METHOD	UNITS			
PHYSICAL PROPERTIES	**limit**					
Total Dissolved Solids	7	EPA 160.1	mg/L			
Total Suspended Solids	2	EPA 160.2	mg/L	3	2	4
Turbidity	0.02	EPA 180.1	NTU	31.9	14.4	14.1
Hardness as CaCO3	0.33	EPA 200.7	mg/L			
INORGANIC, NON-METALLICS						
Chloride, Cl	0.02	EPA 300.0	mg/L	1.77	1.12	1.13
Fluoride, F	0.02	EPA 300.0	mg/L	<0.05	<0.05	0.06
Nitrate as N	0.005	EPA 300.0	mg/L	0.44	0.69	0.65
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.113	0.057	0.062
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.029	0.009	0.018
Sulfate	0.03	EPA 300.0	mg/L	5.14	3.26	3.4
TKN	0.02	EPA 351.2	mg/L	0.48	0.33	0.37
Ammonia as N	0.01	EPA350.3	mg/L	0.02	<0.01	0.01
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	20.3	16.2	22.3
Bacteriological						
E-Coli, MF		SM9213D	#/100m			62
			Discharge (cfs)	1.11	3.37	1.57
		Hydrolab Readings				
			pH	7.07	6.61	7.72
			Conductivity	52.1	45	59.1
			D.O. (mg/L)	13.43	12.99	11.64
			Temp C		6.78	10.92

Table B-10. Complete set of water quality data for Tensed-Upper-RM 3.0 during the water years 2004-5.

			STL ID	8457
			Site ID	02SH010000
			Date	4/19/04
ANALYSIS PARAMETERS	**Detection**	METHOD	UNITS	
PHYSICAL PROPERTIES	**limit**			
Total Dissolved Solids	7	EPA 160.1	mg/L	
Total Suspended Solids	2	EPA 160.2	mg/L	32
Turbidity	0.02	EPA 180.1	NTU	17.8
Hardness as CaCO3	0.33	EPA 200.7	mg/L	
INORGANIC, NON-METALLICS				
Chloride, Cl	0.02	EPA 300.0	mg/L	1.1
Fluoride, F	0.02	EPA 300.0	mg/L	0.06
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.073
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.009
Sulfate	0.03	EPA 300.0	mg/L	2.82
TKN	0.02	EPA 351.2	mg/L	0.2
Ammonia as N	0.01	EPA350.3	mg/L	<0.01
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	16.2
Bicarbonate as CaCO3	1	EPA 310.1	mg/L	
Carbonate as CaCO3	1	EPA 310.1	mg/L	
Bacteriological				
Fecal Coliform, MF		SM9222D	#/100m	
E-Coli, MF		SM9213D	#/100m	
			Discharge (cfs)	
			Hydrolab Readings	
			pH	6.75
			Conductivity	39.1
			D.O. (mg/L)	10.43
			Temp C	5.69

Table B-11. Complete set of water quality data for Mission-Desmet RM 0.4 during the water years 2004-5.

			STL ID	7631	7796	7904	8287	8530	9582	
			Site ID	01-SH011000	01 SH011000	01 SH011000	01SH011000	01SH011000	01SH011000	01SH011000
			Sample Date	11/12/03	12/16/03	1/22/04	3/25/04	4/22/04	8/11/04	8/11/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS							
PHYSICAL PROPERTIES										
Total Suspended Solids	2	EPA 160.2	mg/L	8	3	3	12	6	8	13
Turbidity	0.02	EPA 180.1	NTU	17.3	26.1	22.5	16.7	19.3	3.89	7.84
NORGANIC, NON-METALLICS										
Chloride, Cl	0.02	EPA 300.0	mg/L	19.3	3.24	3.22	1.42	1.31	12.6	10.1
Fluoride, F	0.02	EPA 300.0	mg/L	0.13	0.07	0.06	0.06	0.06	0.12	0.22
Ammonia as N	0.005	EPA 350.1	mg/L							nd
Nitrate as N	0.005	EPA 300.0	mg/L	0.56	0.85	4.32	0.17	0.17	<0.01	nd
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.081	0.124	0.124	0.077	0.108	0.071	0.146
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.009	0.042	0.007	0.025	0.036	<0.01	
ortho-Phosphate as P	0.01	EPA 365.1	mg/L							0.127
Sulfate	0.03	EPA 300.0	mg/L	11.5	7.44	9.89	3.01	2.67	4.26	5.71
TKN	0.02	EPA 351.2	mg/L	0.63	0.5	0.76	0.34	0.44	0.49	0.68
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.02	0.08	0.02	0.02	0.02	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	141.1		26.4	18.3	30.5	136	135
Bacteriological										
E-Coli, MF		SM9213D	#/100m					8		
			Discharge (cfs)	0.001	0.85	2.2	7.59	6.96	0.00	0.01
			Hydrolab Readings							
			pH	6.8		6.63	7.3	7.35	7.49	7.94
			Conductivity	405		110.3	53.1	26.3	312	301
			D.O. (mg/L)	6.86		12.05	14.04	8.35	6.99	8.55
			Temp C	1.14		0.23	7.7	11.16	18.98	21.22

Table B-12. Complete set of water quality data for Mission-KVR RM 2.3 during the water years 2004-5.

			STL ID	7630	8529	9554	
			Site ID	02SH011000	02SH011000	02SH011000	02SH011000
			Sample Date	11/12/03	4/22/04	8/10/04	8/11/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS				
PHYSICAL PROPERTIES							
Total Suspended Solids	2	EPA 160.2	mg/L	32	6	4	3
Turbidity	0.02	EPA 180.1	NTU	3.02	18.8	4.08	3.36
INORGANIC, NON-METALLICS							
Chloride, Cl	0.02	EPA 300.0	mg/L	1.35	1.19	1.77	1.23
Fluoride, F	0.02	EPA 300.0	mg/L	0.27	<0.05	0.27	0.26
Ammonia as N	0.005	EPA 350.1	mg/L				0.01
Nitrate as N	0.005	EPA 300.0	mg/L	0.01	0.08	0.03	0.03
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.077	0.093	0.06	0.065
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.03	0.028	<0.01	
ortho-Phosphate as P	0.01	EPA 365.1	mg/L				0.052
Sulfate	0.03	EPA 300.0	mg/L	3.77	2.36	3.63	3.38
TKN	0.02	EPA 351.2	mg/L	0.19	0.43	0.28	nd
Ammonia as N	0.005	EPA350.3	mg/L	<0.01	<0.01	<0.01	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	70	24.4	75.1	67.6
Bacteriological							
E-Coli, MF		SM9213D	#/100m				
			Discharge (cfs)	0.00	4.36	0.01	0.01
			Hydrolab Readings				
			pH	6.69	7.21	6.96	7.24
			Conductivity	157.7	19.7	147.9	145
			D.O. (mg/L)	5.32	10.72	8.24	9.11
			Temp C	5.14	7.9	13.52	14.15

Table B-13. Complete set of water quality data for MF Mission RM 4.8 during the water years 2004-5.

			STL ID		9551
			Site ID	03SH01100	03SH01100
			Sample Date	4/22/04	8/9/04
ANALYSIS PARAMETERS	**Detect**	METHOD	UNITS		
PHYSICAL PROPERTIES	**limit**				
Total Suspended Solids	2	EPA 160.2	mg/L	<2	<2
Turbidity	0.02	EPA 180.1	NTU	11.9	5.8
NORGANIC, NON-METALLICS					
Chloride, Cl	0.02	EPA 300.0	mg/L	1.66	1.33
Fluoride, F	0.02	EPA 300.0	mg/L	0.2	0.06
Nitrate as N	0.005	EPA 300.0	mg/L	0.02	0.04
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.032	0.034
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.012	<0.01
Sulfate	0.03	EPA 300.0	mg/L	2.13	1.15
TKN	0.02	EPA 351.2	mg/L	0.33	0.16
Ammonia as N	0.005	EPA350.3	mg/L	0.04	0.01
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	12.2	
Bacteriological					
E-Coli, MF		SM9213D	#/100m		
			Discharge (cfs)	0.83	0.02
			Hydrolab Readings		
			pH	7.27	7.16
			Conductivity	10.6	39.7
			D.O. (mg/L)	10.64	8.98
			Temp C	5.39	13.42

Table B-14. Complete set of water quality data for WF Mission RM 0.3 during the water years 2004-5.

			STL ID		9553	
			Site Code	01SH01120	01SH01120	01SH011200
			Sample Date	4/22/04	8/10/04	8/12/05
ANALYSIS PARAMETERS	**Detect limit**	METHOD	UNITS			
PHYSICAL PROPERTIES						
Total Suspended Solids	2	EPA 160.2	mg/L	7	3	14
Turbidity	0.02	EPA 180.1	NTU	24.5	3.73	1.98
INORGANIC, NON-METALLICS						
Chloride, Cl	0.02	EPA 300.0	mg/L	1.02	1.68	0.74
Fluoride, F	0.02	EPA 300.0	mg/L	<0.05	0.09	0.11
Ammonia as N	0.005	EPA 350.1	mg/L			0.01
Nitrate as N	0.005	EPA 300.0	mg/L	0.12	0.01	nd
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.104	0.049	0.084
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.035	<0.01	
ortho-Phosphate as P	0.01	EPA 365.1	mg/L			0.043
Sulfate	0.03	EPA 300.0	mg/L	2.75	1.35	0.84
TKN	0.02	EPA 351.2	mg/L	0.28	0.23	0.29
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.01	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	20.3	28.4	43
Bacteriological						
E-Coli, MF		SM9213D	#/100m			
			Discharge (cfs)	1.98	0.00	0.02
		Hydrolab Readings				
			pH	7.25	6.8	6.7
			Conductivity	16.9	59.4	79
			D.O. (mg/L)	10.69	9.45	5.5
			Temp C	7.15	13.72	11.28

Table B-15. Complete set of water quality data for EF Mission RM 0.1 during the water years 2004-5.

			STL ID		9552
			Site ID	01SH01110	01SH01110
			Sample Date	4/22/04	8/10/04
ANALYSIS PARAMETERS	**Detect**	METHOD	UNITS		
PHYSICAL PROPERTIES	**limit**				
Total Suspended Solids	2	EPA 160.2	mg/L	<2	2
Turbidity	0.02	EPA 180.1	NTU	13.4	6.76
INORGANIC, NON-METALLICS					
Chloride, Cl	0.02	EPA 300.0	mg/L	1.14	1.36
Fluoride, F	0.02	EPA 300.0	mg/L	<0.05	0.06
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01	<0.01
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.06	0.043
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.029	0.02
Sulfate	0.03	EPA 300.0	mg/L	1.88	0.77
TKN	0.02	EPA 351.2	mg/L	0.2	0.11
Ammonia as N	0.01	EPA350.3	mg/L	0.01	<0.01
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	14.2	26.4
Bacteriological					
E-Coli, MF		SM9213D	#/100m		
			Discharge (cfs)	0.84	standing pools
			Hydrolab Readings		
			pH	6.74	6.73
			Conductivity	12.9	58.2
			D.O. (mg/L)	10.29	7.53
			Temp C	6.4	12.12

Table B-16. Complete set of water quality data for Sheep-HWY 95 RM 0.6 during the water years 2004-5.

			STL ID	7632	7804	7903	8288	8460	9584
			Site ID	01-SH013000	01 SH013000	01 SH013000	01SH013000	01SH013000	01SH013000
			Sample Date	11/12/03	12/16/03	1/22/04	3/25/04	4/19/04	8/11/04
ANALYSIS PARAMETERS PHYSICAL PROPERTIES	**Detection limit**	METHOD	UNITS						
Total Suspended Solids	2	EPA 160.2	mg/L	101	5	<2	3	3	10
Turbidity	0.02	EPA 180.1	NTU	13.6	31.4	13.8	8.72	8.29	2.67
INORGANIC, NON-METALLICS									
Chloride, Cl	0.02	EPA 300.0	mg/L	17.6	2.89	3.38	1.1	1.41	2.35
Fluoride, F	0.02	EPA 300.0	mg/L	4.56	0.05	0.07	<0.05	<0.05	0.13
Nitrate as N	0.005	EPA 300.0	mg/L	0.03	3.94	5.85	0.08	<0.01	<0.01
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.762	0.114	0.079	0.032	0.046	0.085
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.194	0.047	0.043	0.008	0.023	<0.01
Sulfate	0.03	EPA 300.0	mg/L	2.93	6.75	6.81	2.22	1.87	0.27
TKN	0.02	EPA 351.2	mg/L	3.23	0.99	0.86	0.15	0.23	0.27
Ammonia as N	0.01	EPA350.3	mg/L	0.03	0.28	0.11	<0.01	<0.01	<0.01
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	150.2			11.2	24.4	79.2
Bacteriological									
E-Coli, MF		SM9213D	#/100m					3	
			Discharge (cfs)	0	2.5	7.29	6.59	2.4	0
			Hydrolab Readings						
			pH	6.49		6.77	6.51	7.12	7.1
			Conductivity	353		113.5	30.2	56.4	160
			D.O. (mg/L)	2.95		13.23	12.79	11.74	2.55
			Temp C	0.62		0.46	5.79	7.92	14.94

Table B-17. Complete set of water quality data for Sheep-Upper RM 2.8 during the water years 2004-5.

			STL ID	8459	9549	
			Site ID	02SH01300	02SH01300	02SH013000
			Sample Date	4/19/04	8/9/04	8/11/05
ANALYSIS PARAMETERS	**Detect**	METHOD	UNITS			
PHYSICAL PROPERTIES	**limit**					
Total Dissolved Solids	7	EPA 160.1	mg/L			
Total Suspended Solids	2	EPA 160.2	mg/L	2	8	2
Turbidity	0.02	EPA 180.1	NTU	7	4.93	2.89
Hardness as CaCO3	0.33	EPA 200.7	mg/L			
NORGANIC, NON-METALLICS						
Chloride, Cl	0.02	EPA 300.0	mg/L	0.87	0.9	0.65
Fluoride, F	0.02	EPA 300.0	mg/L	0.12	0.06	0.06
Ammonia as N	0.005	EPA 350.1	mg/L			nd
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01	0.02	0.08
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.023	0.039	0.035
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.011	0.01	
ortho-Phosphate as P	0.01	EPA 365.1	mg/L			0.031
Sulfate	0.03	EPA 300.0	mg/L	1.65	0.97	0.91
TKN	0.02	EPA 351.2	mg/L	0.2	0.13	nd
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.01	nd
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	12.2	16.2	20.5
Bicarbonate as CaCO3	1	EPA 310.1	mg/L			
Carbonate as CaCO3	1	EPA 310.1	mg/L			
Bacteriological						
Fecal Coliform, MF		SM9222D	#/100m			
E-Coli, MF		SM9213D	#/100m			
			Discharge (cfs)	0.35	0.03	0.02
			Hydrolab Readings			
			pH	7.38	7.11	7.22
			Conductivity	24.1	347	40
			D.O. (mg/L)	11.54	8.42	8.82
			Temp C	6.22	14.74	13.9

Table B-18. Complete set of water quality data for SF Sheep RM 0.3 during the water years 2004-5.

			STL ID	9583
			Site ID	01SH013100
			Sample Date	8/11/04
ANALYSIS PARAMETERS	**Detection**	METHOD	UNITS	
PHYSICAL PROPERTIES	**limit**			
Total Suspended Solids	2	EPA 160.2	mg/L	7
Turbidity	0.02	EPA 180.1	NTU	8.34
INORGANIC, NON-METALLICS				
Chloride, Cl	0.02	EPA 300.0	mg/L	2.77
Fluoride, F	0.02	EPA 300.0	mg/L	<0.05
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.061
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	<0.01
Sulfate	0.03	EPA 300.0	mg/L	0.65
TKN	0.02	EPA 351.2	mg/L	0.21
Ammonia as N	0.01	EPA350.3	mg/L	<0.01
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	26.4
Bacteriological				
E-Coli, MF		SM9213D	#/100m	
			Discharge (cfs)	0.003
			Hydrolab Readings	
			pH	6.89
			Conductivity	52.5
			D.O. (mg/L)	8.63
			Temp C	18.73

Table B-19. Complete set of water quality data for Nehchen-Lower RM 0.3 during the water years 2004-5.

			STL ID	7898	8291	8509
			Site ID	01SH015000	01SH015000	01SH015000
			Sample Date	1/22/04	3/25/04	4/20/04
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS			
PHYSICAL PROPERTIES						
Total Suspended Solids	2	EPA 160.2	mg/L	6	8	2
Turbidity	0.02	EPA 180.1	NTU	5.87	5.73	4.83
INORGANIC, NON-METALLICS						
Chloride, Cl	0.02	EPA 300.0	mg/L	1.93	0.74	0.76
Fluoride, F	0.02	EPA 300.0	mg/L	<0.05	<0.05	<0.05
Nitrate as N	0.005	EPA 300.0	mg/L	2	0.06	0.04
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.034	0.025	0.026
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.009	0.004	0.012
Sulfate	0.03	EPA 300.0	mg/L	5.36	2.22	2.14
TKN	0.02	EPA 351.2	mg/L	0.3	0.14	0.13
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	<0.01	<0.01
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	16.2	11.2	12.2
Bacteriological						
E-Coli, MF		SM9213D	#/100m			7
			Discharge (cfs)	1.93	10.86	2.47
			Hydrolab Readings			
			pH	6.87	6.26	7.12
			Conductivity	57.1	26.4	33.8
			D.O. (mg/L)	13.04	11.33	8.55
			Temp C	2.96	7.24	7.02

Table B-20. Complete set of water quality data for Nehchen-Upper RM 2.9 during the water years 2004-5.

			STL ID	8507	9601	
			Site ID	02SH015000	02SH015000	02SH015000
			Sample Date	4/20/04	8/11/04	8/10/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS			
PHYSICAL PROPERTIES						
Total Suspended Solids	2	EPA 160.2	mg/L	2	3	nd
Turbidity	0.02	EPA 180.1	NTU	2.12	3.42	1.63
INORGANIC, NON-METALLICS						
Chloride, Cl	0.02	EPA 300.0	mg/L	0.61	1.21	0.78
Fluoride, F	0.02	EPA 300.0	mg/L	<0.05	0.05	nd
Nitrate as N	0.005	EPA 300.0	mg/L	0.01	0.02	0.15
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.011	0.035	0.017
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.005	0.01	nd
ortho-Phosphate as P	0.01	EPA 365.1	mg/L			0.008
Sulfate	0.03	EPA 300.0	mg/L	1.94	0.88	1.66
TKN	0.02	EPA 351.2	mg/L	0.07	0.32	nd
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.03	nd
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	8.12	24.4	16.4
Bacteriological						
E-Coli, MF		SM9213D	#/100m			
			Discharge (cfs)	1.20	0.03	0.02
			Hydrolab Readings			
			pH	6.68	6.56	7.13
			Conductivity	20.8	45.4	37
			D.O. (mg/L)	8.69	6.59	8.43
			Temp C	5.65	17.22	14.27

Table B-21. Complete set of water quality data for Smith RM 1.0 during the water years 2004-5.

			STL ID	7633	7803	7902	8289		9547	9586	
			Site ID	01SH017000	01SH017000	01SH017000	01SH017000	01SH017000	01SH001700	01SH017000	01SH017000
			Sample Date	11/12/03	12/16/03	1/22/04	3/25/04	4/22/04	8/9/04	8/11/04	8/10/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS								
PHYSICAL PROPERTIES											
Total Suspended Solids	2	EPA 160.2	mg/L	3	4	2	6	27	6	8	17
Turbidity	0.02	EPA 180.1	NTU	3.93	25.1	17	14.2	58.5		7.01	14.1
INORGANIC, NON-METALLICS											
Chloride, Cl	0.02	EPA 300.0	mg/L	7.44	7.99	9.84	1.78	4.13	3.92	4.83	4.98
Fluoride, F	0.02	EPA 300.0	mg/L	0.17	0.06	0.1	0.05	<0.05	0.28	0.15	0.17
Ammonia as N	0.005	EPA 350.1	mg/L								nd
Nitrate as N	0.005	EPA 300.0	mg/L	0.05	2.90	4.95	0.05	0.14	0.28	<0.01	nd
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.076	0.081	0.077	0.057	0.111	0.076	0.079	0.17
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.075	0.022	0.026	0.016	0.018	0.03	<0.01	nd
ortho-Phosphate as P	0.01	EPA 365.1	mg/L								0.027
Sulfate	0.03	EPA 300.0	mg/L	5.90	6.01	7.67	2.13	1.9	11	1.29	0.79
TKN	0.02	EPA 351.2	mg/L	0.41	0.57	0.99	0.21	0.43	0.42	1.04	0.7
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.05	0.04	<0.01	0.01	0.01	0.02	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	50.7		22.3	16.2	28.4	123.8	69	77.9
Bacteriological											
Fecal Coliform, MF		SM9222D	#/100m								
E-Coli, MF		SM9213D	#/100m					121			
			Discharge (cfs)	0.16	1.00	3.60	5.54	2.53		0.00	0.00
			Hydrolab Readings								
			pH	7.04			7	7.4		7.55	8.05
			Conductivity	126.6			38	27.2		158	165
			D.O. (mg/L)	10.33			14.31	10		9.16	9.3
			Temp C	1.84			6.84	9.67		17.97	17.81

Table B-22. Complete set of water quality data for Upper Mineral RM 1.5 during the water years 2004-5.

			STL ID	9585
			Site Code	02SH017100
			Sample Data	8/11/04
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS	
PHYSICAL PROPERTIES				
Total Dissolved Solids	7	EPA 160.1	mg/L	
Total Suspended Solids	2	EPA 160.2	mg/L	10
Turbidity	0.02	EPA 180.1	NTU	8.67
Hardness as CaCO3	0.33	EPA 200.7	mg/L	
INORGANIC, NON-METALLICS				
Chloride, Cl	0.02	EPA 300.0	mg/L	1.57
Fluoride, F	0.02	EPA 300.0	mg/L	<0.05
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.051
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	<0.01
Sulfate	0.03	EPA 300.0	mg/L	0.52
TKN	0.02	EPA 351.2	mg/L	0.68
Ammonia as N	0.01	EPA350.3	mg/L	0.02
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	20.3
Bicarbonate as CaCO3	1	EPA 310.1	mg/L	
Carbonate as CaCO3	1	EPA 310.1	mg/L	
Bacteriological				
Fecal Coliform, MF		SM9222D	#/100m	
E-Coli, MF		SM9213D	#/100m	
			Discharge (cfs)	0.004
			Hydrolab Readings	
			pH	6.99
			Conductivity	35.1
			D.O. (mg/L)	8
			Temp C	16.58

Table B-23. Complete set of water quality data for Indian-Sanders RM 0.3 during the water years 2004-5.

			STL ID	7637	7798	7899	8290	8522	9587	
			Site ID	01-SH018000	01 SH018000	01 SH018000	01SH018000	01SH018000	01SH018000	01SH018000
			Sample Date	11/12/03	12/16/03	1/22/04	3/25/04	4/21/04	8/11/04	8/10/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS							
PHYSICAL PROPERTIES										
Total Suspended Solids	2	EPA 160.2	mg/L	<2	<2	6	6	3	3	nd
Turbidity	0.02	EPA 180.1	NTU	1.87	5.17	7.18	8.59	3.19	2.17	2.54
INORGANIC, NON-METALLICS										
Chloride, Cl	0.02	EPA 300.0	mg/L	1.34	1.46	1.73	0.8	0.67	0.64	0.69
Fluoride, F	0.02	EPA 300.0	mg/L	<0.05	<0.05	0.06	<0.05	<0.05	0.06	0.06
Ammonia as N	0.005	EPA 350.1	mg/L							0.01
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01	0.1	1.9	0.03	<0.01	0.02	0.05
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.024	0.033	0.046	0.031	0.017	0.034	0.038
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.012	0.006	0.011	0.005	0.009	<0.01	nd
ortho-Phosphate as P	0.01	EPA 365.1	mg/L							0.033
Sulfate	0.03	EPA 300.0	mg/L	1.74	2.77	4.26	2.42	1.88	1.38	1.23
TKN	0.02	EPA 351.2	mg/L	0.14	0.16	0.39	0.15	0.12	0.09	0.09
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.02	0.01	<0.01	<0.01	0.01	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	16.2		22.3	10.2	12.2	22.3	22.6
Bacteriological										
E-Coli, MF		SM9213D	#/100m					5		
			Discharge (cfs)	0.22	0.58	2.10	15.38	4.25	0.24	0.14
			Hydrolab Readings							
			pH	6.83			6.39	7.66	7.1	7.19
			Conductivity	35.9			26.7	11.1	46.2	0.047
			D.O. (mg/L)	12.14			12.18	11.09	7.8	8.6
			Temp C	1.06			5.36	5.77	17.07	16.88

Table B-24. Complete set of water quality data for Indian Pow Wow RM 1.4 during the water years 2004-5.

			STL ID	7638	8518	9596	
			CLIENT ID	02SH018000	02SH018000	02SH018000	02SH018000
			SAMPLE DATE	11/12/03	4/21/04	8/11/04	8/10/05
ANALYSIS PARAMETERS	**Detection**	METHOD	UNITS				
PHYSICAL PROPERTIES	**limit**						
Total Suspended Solids	2	EPA 160.2	mg/L	<2	2	<2	nd
Turbidity	0.02	EPA 180.1	NTU	1	2.65	1.22	1.5
INORGANIC, NON-METALLICS							
Chloride, Cl	0.02	EPA 300.0	mg/L	0.99	0.64	0.64	0.71
Fluoride, F	0.02	EPA 300.0	mg/L	0.06	<0.05	0.05	nd
Ammonia as N	0.005	EPA 350.1	mg/L				nd
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01	<0.01	0.06	0.1
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.018	0.012	0.019	0.025
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.009	0.007	<0.01	nd
ortho-Phosphate as P	0.01	EPA 365.1	mg/L				0.019
Sulfate	0.03	EPA 300.0	mg/L	2.04	1.87	1.41	1.32
TKN	0.02	EPA 351.2	mg/L	0.09	0.07	<0.05	nd
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	<0.01	0.01	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	20.3	14.2	20.3	20.5
Bacteriological							
E-Coli, MF		SM9213D	#/100m				
			Discharge (cfs)	0.17	3.34	0.28	0.19
			Hydrolab Readings				
			pH		7.22	7.42	7.23
			Conductivity		10	41.2	41
			D.O. (mg/L)		11.17	8.62	10.13
			Temp C		4.4	16.43	14.38

Table B-25. Complete set of water quality data for Indian-Upper RM 2.9 during the water years 2004-5.

			STL ID	8520	9598	
			Site Code	03SH018000	03SH018000	03SH018000
			Sample Date	4/21/04	8/11/04	8/10/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS			
PHYSICAL PROPERTIES						
Total Suspended Solids	2	EPA 160.2	mg/L	<2	3	nd
Turbidity	0.02	EPA 180.1	NTU	2.13	1.23	0.95
INORGANIC, NON-METALLICS						
Chloride, Cl	0.02	EPA 300.0	mg/L	0.58	0.73	0.79
Fluoride, F	0.02	EPA 300.0	mg/L	<0.05	0.06	0.05
Ammonia as N	0.005	EPA 350.1	mg/L			nd
Nitrate as N	0.005	EPA 300.0	mg/L	0.03	0.06	0.08
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.011	0.019	0.028
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.011	0.01	nd
ortho-Phosphate as P	0.01	EPA 365.1	mg/L			0.016
Sulfate	0.03	EPA 300.0	mg/L	2.17	2.26	2.06
TKN	0.02	EPA 351.2	mg/L	0.06	0.07	nd
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.01	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	18.3	30.5	34.8
Bacteriological						
E-Coli, MF		SM9213D	#/100m			
			Discharge (cfs)	1.35	0.10	0.07
			Hydrolab Readings			
			pH	7.35	7.46	7.68
			Conductivity	13.3	69.4	70.0
			D.O. (mg/L)	11.19	8.66	10.22
			Temp C	3.91	14.05	12.67

Table B-26. Complete set of water quality data for NF Indian RM 0.1 during the water years 2004-5.

			STL ID	8519	9597	
			Site Code	01SH018300	01SH018300	01SH018300
			Sample Date	4/21/04	8/11/04	8/10/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS			
PHYSICAL PROPERTIES						
Total Suspended Solids	2	EPA 160.2	mg/L	5	<2	4
Turbidity	0.02	EPA 180.1	NTU	1.76	0.84	2.79
INORGANIC, NON-METALLICS						
Chloride, Cl	0.02	EPA 300.0	mg/L	1.09	0.63	0.62
Fluoride, F	0.02	EPA 300.0	mg/L	0.18	<0.05	nd
Ammonia as N	0.005	EPA 350.1	mg/L			nd
Nitrate as N	0.005	EPA 300.0	mg/L	0.01	0.05	0.06
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.008	0.013	0.022
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.006	<0.01	nd
ortho-Phosphate as P	0.01	EPA 365.1	mg/L			0.008
Sulfate	0.03	EPA 300.0	mg/L	1.31	0.9	0.89
TKN	0.02	EPA 351.2	mg/L	0.22	<0.05	nd
Ammonia as N	0.01	EPA350.3	mg/L	0.04	0.01	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	10.2	16.2	14.4
Bacteriological						
E-Coli, MF		SM9213D	#/100m			
			Discharge (cfs)	1.06	0.21	0.92
			Hydrolab Readings			
			pH	7.54	7.11	6.75
			Conductivity	7	24.8	26
			D.O. (mg/L)	11.02	8.93	10.33
			Temp C	4.84	14.31	12.65

Table B-27. Complete set of water quality data for EF Indian RM 0.3 during the water years 2004-5.

			STL ID	8521	9599	
			Site Code	01SH018200	01SH018200	01SH018200
			Sample Date	4/21/04	8/11/04	8/10/05
ANALYSIS PARAMETERS	**Detection**	METHOD	UNITS			
PHYSICAL PROPERTIES	**limit**					
Total Suspended Solids	2	EPA 160.2	mg/L	<2	2	2
Turbidity	0.02	EPA 180.1	NTU	2.31	1.31	1.23
INORGANIC, NON-METALLICS						
Chloride, Cl	0.02	EPA 300.0	mg/L	1.09	1.59	0.84
Fluoride, F	0.02	EPA 300.0	mg/L	0.16	0.05	0.05
Ammonia as N	0.005	EPA 350.1	mg/L			nd
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01	0.01	0.01
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.067	0.012	0.023
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.014	0.01	nd
ortho-Phosphate as P	0.01	EPA 365.1	mg/L			0.014
Sulfate	0.03	EPA 300.0	mg/L	2.47	2.36	2.16
TKN	0.02	EPA 351.2	mg/L	0.74	0.32	nd
Ammonia as N	0.01	EPA350.3	mg/L	0.05	0.02	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	18.3	22.3	22.6
Bacteriological						
E-Coli, MF		SM9213D	#/100m			
			Discharge (cfs)	0.41	0.04	0.02
		Hydrolab Readings				
			pH	7.67	7.33	7.24
			Conductivity	12.7	49.4	49
			D.O. (mg/L)	10.84	8.82	10.01
			Temp C	4.87	14.26	12.46

Table B-28. Complete set of water quality data for SF Hangman-Lower RM 0.7 during the water years 2004-5.

			STL ID	7640	7800	7901	8294	8523	9588	
			Site ID	01SH020000	01SH020000	01SH020000	01SH020000	01SH020000	01SH020000	01SH020000
			Sample Date	11/12/03	12/16/03	1/22/04	3/25/04	4/21/04	8/11/04	8/11/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS							
PHYSICAL PROPERTIES										
Total Suspended Solids	2	EPA 160.2	mg/L	2	4	3	5	<2	3	3
Turbidity	0.02	EPA 180.1	NTU	3.7	11.5	17.4	8.2	7.62	4.96	4.69
INORGANIC, NON-METALLICS										
Chloride, Cl	0.02	EPA 300.0	mg/L	2.02	1.2	1.25	0.71	0.72	1.3	1.02
Fluoride, F	0.02	EPA 300.0	mg/L	0.09	0.06	0.05	0.06	0.05	0.11	0.11
Ammonia as N	0.005	EPA 350.1	mg/L							0.04
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01	0.04	0.08	<0.01	<0.01	0.01	0.08
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.061	0.049	0.051	0.039	0.042	0.08	0.106
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.033	0.012	0.01	0.017	0.022	<0.01	
ortho-Phosphate as P	0.01	EPA 365.1	mg/L							0.111
Sulfate	0.03	EPA 300.0	mg/L	3.7	4.03	3	2.23	2.16	2.55	2.01
TKN	0.02	EPA 351.2	mg/L	0.24	0.18	0.23	0.1	0.19	0.17	0.12
Ammonia as N	0.01	EPA350.3	mg/L	0.01	<0.01	0.01	<0.01	<0.01	0.01	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	42.6		26.4	18.3	26.4	56.8	59.4
Bacteriological										
E-Coli, MF		SM9213D	#/100m					21		
			Discharge (cfs)	0.18		1.85	11.03	2.73	0.01	0.06
		Hydrolab Readings								
			pH	7.91		6.79	6.48	7.35	7.03	7.09
			Conductivity	84.7		56.3	36.2	20.7	107.5	83
			D.O. (mg/L)	6.85		13.05	11.83	10.46	5.46	7.95
			Temp C	1.24		0.42	6.74	6.29	16.25	16.19

Table B-29. Complete set of water quality data for SF Hangman-Upper RM 1.7 during the water years 2004-5.

			STL		9555
			Site Code	02SH020000	02SH020000
			Sample Date	4/21/04	8/10/04
ANALYSIS PARAMETERS	**Detection**	METHOD	UNITS		
PHYSICAL PROPERTIES	**limit**				
Total Suspended Solids	2	EPA 160.2	mg/L	<2	<2
Turbidity	0.02	EPA 180.1	NTU	6.82	2.24
INORGANIC, NON-METALLICS					
Chloride, Cl	0.02	EPA 300.0	mg/L	0.61	1.05
Fluoride, F	0.02	EPA 300.0	mg/L	0.08	0.07
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01	0.01
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.033	0.032
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.023	0.01
Sulfate	0.03	EPA 300.0	mg/L	2.26	1.28
TKN	0.02	EPA 351.2	mg/L	0.14	0.1
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	<0.01
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	22.3	38.6
Bacteriological					
E-Coli, MF		SM9213D	#/100m		
			Discharge (cfs)	1.34	0.01
			Hydrolab Readings		
			pH	7.57	7.03
			Conductivity	17	77.5
			D.O. (mg/L)	10.76	7.61
			Temp C	5.13	14.04

Table B-30. Complete set of water quality data for Conrad Creek RM 0.0 during the water years 2004-5.

			STL ID	8524
			Site Code	01SH020100
			Sample Date	4/21/04
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS	
PHYSICAL PROPERTIES				
Total Suspended Solids	2	EPA 160.2	mg/L	6
Turbidity	0.02	EPA 180.1	NTU	4.84
INORGANIC, NON-METALLICS				
Chloride, Cl	0.02	EPA 300.0	mg/L	1.03
Fluoride, F	0.02	EPA 300.0	mg/L	0.12
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.046
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.025
Sulfate	0.03	EPA 300.0	mg/L	1.48
TKN	0.02	EPA 351.2	mg/L	0.18
Ammonia as N	0.01	EPA350.3	mg/L	<0.01
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	18.3
Bacteriological				
E-Coli, MF		SM9213D	#/100m	
			Discharge (cfs)	0.40
			Hydrolab Readings	
			pH	7.73
			Conductivity	14.6
			D.O. (mg/L)	10.5
			Temp C	6.9

Table B-31. Complete set of water quality data for Martin Creek RM 0.1 during the water years 2004-5.

			STL ID	7801	8532	9589	
			Site Code	01 SH020200	01SH020200	01SH020200	01SH020200
				Martin	Martin	Martin	Martin
			Sample Date	12/16/03	4/22/04	8/11/04	8/11/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS				
PHYSICAL PROPERTIES							
Total Suspended Solids	2	EPA 160.2	mg/L	<2	8	<2	2
Turbidity	0.02	EPA 180.1	NTU	4	6.39	1.34	2.4
INORGANIC, NON-METALLICS							
Chloride, Cl	0.02	EPA 300.0	mg/L	1.05	0.78	1.15	0.8
Fluoride, F	0.02	EPA 300.0	mg/L	0.12	0.06	<0.05	0.09
Ammonia as N	0.005	EPA 350.1	mg/L				0.01
Nitrate as N	0.005	EPA 300.0	mg/L	0.01	<0.01	0.01	0.04
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.032	0.031	0.04	0.3
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.024	0.02	0.03	
ortho-Phosphate as P	0.01	EPA 365.1	mg/L				0.037
Sulfate	0.03	EPA 300.0	mg/L	4.49	2.98	3.36	3.26
TKN	0.02	EPA 351.2	mg/L	0.12	0.09	0.08	0.06
Ammonia as N	0.01	EPA350.3	mg/L	0.02	<0.01	0.02	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L		26.4	46.7	45.1
Bacteriological							
E-Coli, MF		SM9213D	#/100m				
			Discharge (cfs)		0.67	0.09	0.03
			Hydrolab Readings				
			pH		7.24	7.36	7.41
			Conductivity		21.9	102.1	98
			D.O. (mg/L)		10.32	8.38	9.29
			Temp C		6.8	14.28	12.48

Table B-32. Complete set of water quality data for Hill Creek RM 0.0 during the water years 2004-5.

			STL ID	8513	9593	
			Site Code	01SH024000	01SH024000	01SH024000
			Sample Date	4/20/04	8/11/04	8/10/05
ANALYSIS PARAMETERS	**Detection**	METHOD	UNITS			
PHYSICAL PROPERTIES	**limit**					
Total Suspended Solids	2	EPA 160.2	mg/L	3	<2	nd
Turbidity	0.02	EPA 180.1	NTU	5.54	2.34	2.46
INORGANIC, NON-METALLICS						
Chloride, Cl	0.02	EPA 300.0	mg/L	0.69	0.87	0.7
Fluoride, F	0.02	EPA 300.0	mg/L	0.07	0.06	0.07
Ammonia as N	0.005	EPA 350.1	mg/L			nd
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01	0.02	0.04
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.02	0.025	0.026
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.009	<0.01	nd
ortho-Phosphate as P	0.01	EPA 365.1	mg/L			0.021
Sulfate	0.03	EPA 300.0	mg/L	1.53	1.19	1.17
TKN	0.02	EPA 351.2	mg/L	0.11	0.16	0.08
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.02	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	12.2	20.3	20.5
Bacteriological						
E-Coli, MF		SM9213D	#/100m			
			Discharge (cfs)	0.69	0.01	0.01
		Hydrolab Readings				
			pH	6.92	7.13	7.07
			Conductivity	27.6	38.9	42
			D.O. (mg/L)	8.28	8.63	7.85
			Temp C	6.03	14.53	13.01

Table B-33. Complete set of water quality data for Benak Creek RM 0.0 during the water years 2004-5.

			STL ID	8514	9595
			Site Code	01SH023000	02SH023000
			Sample Data	4/20/04	8/11/04
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS		
PHYSICAL PROPERTIES					
Total Suspended Solids	2	EPA 160.2	mg/L	3	8
Turbidity	0.02	EPA 180.1	NTU	9.1	5.3
INORGANIC, NON-METALLICS					
Chloride, Cl	0.02	EPA 300.0	mg/L	0.7	0.74
Fluoride, F	0.02	EPA 300.0	mg/L	<0.05	0.06
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01	0.01
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.035	0.025
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.012	<0.01
Sulfate	0.03	EPA 300.0	mg/L	2.15	1.83
TKN	0.02	EPA 351.2	mg/L	0.11	0.12
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.01
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	14.2	20.3
Bacteriological					
E-Coli, MF		SM9213D	#/100m		
			Discharge (cfs)	0.02	0.00
			Hydrolab Readings		
			pH	7.29	7.02
			Conductivity	34.9	28.1
			D.O. (mg/L)	8.3	7.34
			Temp C	6.41	16.12

Table B-34. Complete set of water quality data for Parrot RM 0.0 during the water years 2004-5.

			STL ID	9591	
			Site Code	01SH025100	01SH025100
			Sample Data	8/11/04	8/10/05
ANALYSIS PARAMETERS	**Detection**	METHOD	UNITS		
PHYSICAL PROPERTIES	**limit**				
Total Suspended Solids	2	EPA 160.2	mg/L	3	2
Turbidity	0.02	EPA 180.1	NTU	1.9	2.79
INORGANIC, NON-METALLICS					
Chloride, Cl	0.02	EPA 300.0	mg/L	0.79	0.85
Fluoride, F	0.02	EPA 300.0	mg/L	0.06	0.08
Ammonia as N	0.005	EPA 350.1	mg/L		nd
Nitrate as N	0.005	EPA 300.0	mg/L	0.03	0.08
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.02	0.028
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	<0.01	nd
ortho-Phosphate as P	0.01	EPA 365.1	mg/L		0.031
Sulfate	0.03	EPA 300.0	mg/L	2.59	2.24
TKN	0.02	EPA 351.2	mg/L	0.06	0.09
Ammonia as N	0.01	EPA350.3	mg/L	0.01	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	22.3	39
Bacteriological					
E-Coli, MF		SM9213D	#/100m		
			Discharge (cfs)	0.04	0.01
		Hydrolab Readings			
			pH	7.13	6.77
			Conductivity	50.2	179
			D.O. (mg/L)	8.87	1.81
			Temp C	13.73	12

Table B-35. Complete set of water quality data for Bunnel RM 0.2 during the water years 2004-5.

			STL ID	8511	9592	
			Site Code	02SH025000	02SH025000	02SH025000
				Bunnel	Bunnel	Bunnel
			Sample Date	4/20/04	8/11/04	8/10/05
ANALYSIS PARAMETERS	**Detect**	METHOD	UNITS			
PHYSICAL PROPERTIES	**limit**					
Total Suspended Solids	2	EPA 160.2	mg/L	4	<2	4
Turbidity	0.02	EPA 180.1	NTU	10.3	2.55	2.92
INORGANIC, NON-METALLICS						
Chloride, Cl	0.02	EPA 300.0	mg/L	0.67	0.91	0.9
Fluoride, F	0.02	EPA 300.0	mg/L	0.07	0.08	0.06
Ammonia as N	0.005	EPA 350.1	mg/L			nd
Nitrate as N	0.005	EPA 300.0	mg/L	0.05	0.04	0.05
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.039	0.029	0.033
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.02	<0.01	nd
ortho-Phosphate as P	0.01	EPA 365.1	mg/L			0.019
Sulfate	0.03	EPA 300.0	mg/L	2.33	2.01	2.64
TKN	0.02	EPA 351.2	mg/L	0.1	0.15	0.06
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.02	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	20.3	40.6	24.6
Bacteriological						
E-Coli, MF		SM9213D	#/100m			
			Discharge (cfs)	0.06	0.01	0.03
			Hydrolab Readings			
			pH	7.16	7.14	7.39
			Conductivity	46.1	88.3	50.0
			D.O. (mg/L)	8.56	8.37	9.41
			Temp C	4.79	13.58	13.34

Table B-36. Complete set of water quality data for Rose RM 0.0 during the water years 2004-5.

			STL ID		7806	8451	9545
			Site Code	01-SH004200	01 SH004200	01SH004200	01SH004200
			Sample Date	11/12/03	12/16/03	4/19/04	8/9/04
ANALYSIS PARAMETERS	**Detection**	METHOD	UNITS				
PHYSICAL PROPERTIES	**limit**						
Total Dissolved Solids	7	EPA 160.1	mg/L				
Total Suspended Solids	2	EPA 160.2	mg/L	<2	3	3	7
Turbidity	0.02	EPA 180.1	NTU	3.16	14.6	2.06	2.06
Hardness as CaCO3	0.33	EPA 200.7	mg/L				
NORGANIC, NON-METALLICS							
Chloride, Cl	0.02	EPA 300.0	mg/L	4.09	5.02	3.99	8.53
Fluoride, F	0.02	EPA 300.0	mg/L	0.33	0.21	0.18	0.39
Nitrate as N	0.005	EPA 300.0	mg/L	1.18	6.97	2.12	0.9
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	0.03	<0.01	0.03
Total Phosphorous	0.005	EPA 200.7	mg/L	0.033	0.133	0.035	0.097
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.023	0.103	0.021	0.04
Sulfate	0.03	EPA 300.0	mg/L	15.2	22	12.1	17.3
TKN	0.02	EPA 351.2	mg/L	0.3	0.75	0.62	0.73
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.02	0.01	0.09
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	109.6	590	91.4	142.1
Bacteriological							
E-Coli, MF		SM9213D	#/100m				
			Discharge (cfs)	0.33		3.10	0.06
		Hydrolab Readings					
			pH			7.72	7.36
			Conductivity			240	357
			D.O. (mg/L)			13	3.26
			Temp C			8.38	16.93

Table B-37. Complete set of water quality data for NF Rock Creek RM 0.0 during the water years 2004-5.

			STL ID	8452	9544
			Site Code	01SH004100	01SH004100
			Sample Date	4/19/04	8/9/04
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS		
PHYSICAL PROPERTIES					
Total Suspended Solids	2	EPA 160.2	mg/L	12	3
Turbidity	0.02	EPA 180.1	NTU	4.3	3.56
INORGANIC, NON-METALLICS					
Chloride, Cl	0.02	EPA 300.0	mg/L	9.66	20.9
Fluoride, F	0.02	EPA 300.0	mg/L	0.11	0.33
Nitrate as N	0.005	EPA 300.0	mg/L	1.11	<0.01
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.043	0.114
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.017	0.04
Sulfate	0.03	EPA 300.0	mg/L	13.2	2.33
TKN	0.02	EPA 351.2	mg/L	0.74	0.58
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.02
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	93.4	180.6
Bacteriological					
Fecal Coliform, MF		SM9222D	#/100m		
E-Coli, MF		SM9213D	#/100m	3	
			Discharge (cfs)	3.52	0
			Hydrolab Readings		
			pH	7.12	7.53
			Conductivity	252	450
			D.O. (mg/L)	9.07	4.16
			Temp C	7.2	17.71

Table B-38. Complete set of water quality data for Rock Creek RM 0.0 during the water years 2004-5.

			STL ID	9546
			Site Code	02SH004000
			Sample Date	8/9/04
ANALYSIS PARAMETERS	**Detection**	METHOD	UNITS	
PHYSICAL PROPERTIES	**limit**			
Total Suspended Solids	2	EPA 160.2	mg/L	4
Turbidity	0.02	EPA 180.1	NTU	2.02
INORGANIC, NON-METALLICS				
Chloride, Cl	0.02	EPA 300.0	mg/L	1.76
Fluoride, F	0.02	EPA 300.0	mg/L	0.5
Nitrate as N	0.005	EPA 300.0	mg/L	<0.01
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.043
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	<0.01
Sulfate	0.03	EPA 300.0	mg/L	1.25
TKN	0.02	EPA 351.2	mg/L	0.36
Ammonia as N	0.01	EPA350.3	mg/L	0.01
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	113.7
Bacteriological				
E-Coli, MF		SM9213D	#/100m	
			Discharge (cfs)	0.03
			Hydrolab Readings	
			pH	8.98
			Conductivity	227
			D.O. (mg/L)	4.78
			Temp C	28.61

Table B-39. Complete set of water quality data for Moctilimne Creek RM 0.2 during the water years 2004-5.

			STL ID	9547
			Site Code	01SH007100
			Sample Date	8/9/04
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS	
PHYSICAL PROPERTIES				
Total Suspended Solids	2	EPA 160.2	mg/L	6
Turbidity	0.02	EPA 180.1	NTU	
INORGANIC, NON-METALLICS				
Chloride, Cl	0.02	EPA 300.0	mg/L	3.92
Fluoride, F	0.02	EPA 300.0	mg/L	0.28
Nitrate as N	0.005	EPA 300.0	mg/L	0.28
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01
Total Phosphorous	0.005	EPA 200.7	mg/L	0.076
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.03
Sulfate	0.03	EPA 300.0	mg/L	11.0
TKN	0.02	EPA 351.2	mg/L	0.42
Ammonia as N	0.01	EPA350.3	mg/L	0.01
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	123.8
Bacteriological				
E-Coli, MF		SM9213D	#/100m	
			Discharge (cfs)	0.207
			Hydrolab Readings	
			pH	7.63
			Conductivity	1
			D.O. (mg/L)	6.52
			Temp C	21.73

Table B-40. Complete set of water quality data for Moctilimne-Upper RM 4.7 during the water years 2004-5.

			STL ID	8453	9548	
			Site ID	02SH007100	02SH007100	02SH007100
			Sample Date	4/19/04	8/9/04	8/11/05
ANALYSIS PARAMETERS	**Detection limit**	METHOD	UNITS			
PHYSICAL PROPERTIES						
Total Suspended Solids	2	EPA 160.2	mg/L	45	3	7
Turbidity	0.02	EPA 180.1	NTU	28.3	6.49	6.61
INORGANIC, NON-METALLICS						
Chloride, Cl	0.02	EPA 300.0	mg/L	1.09	1.32	1.66
Fluoride, F	0.02	EPA 300.0	mg/L	0.05	0.2	0.24
Ammonia as N	0.005	EPA 350.1	mg/L			0.02
Nitrate as N	0.005	EPA 300.0	mg/L	0.45	0.06	0.11
Nitrite as N	0.01	EPA 300.0	mg/L	<0.01	<0.01	nd
Total Phosphorous	0.005	EPA 200.7	mg/L	0.073	0.04	0.035
ortho-Phosphate as P	0.01	EPA 300.0	mg/L	0.021	0.01	0.028
Sulfate	0.03	EPA 300.0	mg/L	3.04	3.45	4.7
TKN	0.02	EPA 351.2	mg/L	0.36	0.18	0.18
Ammonia as N	0.01	EPA350.3	mg/L	<0.01	0.01	
Total Alkalinity as CaCO3	1	EPA 310.1	mg/L	26.4	75.1	84
Bacteriological						
E-Coli, MF		SM9213D	#/100m			
			Discharge (cfs)	1.71	0.04	0.04
		Hydrolab Readings				
			pH	7.6	7.82	7.54
			Conductivity	64.5	158	171
			D.O. (mg/L)	12.35	8.76	7.97
			Temp C	6.25	18.12	12.34

9.4 Appendix C. Continuous Temperature Profiles

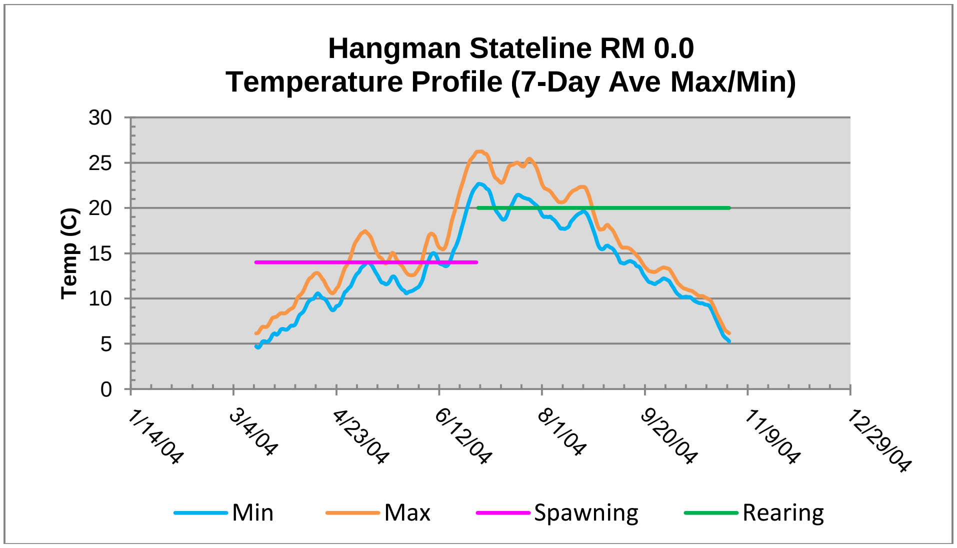


Figure C-1: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Stateline in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

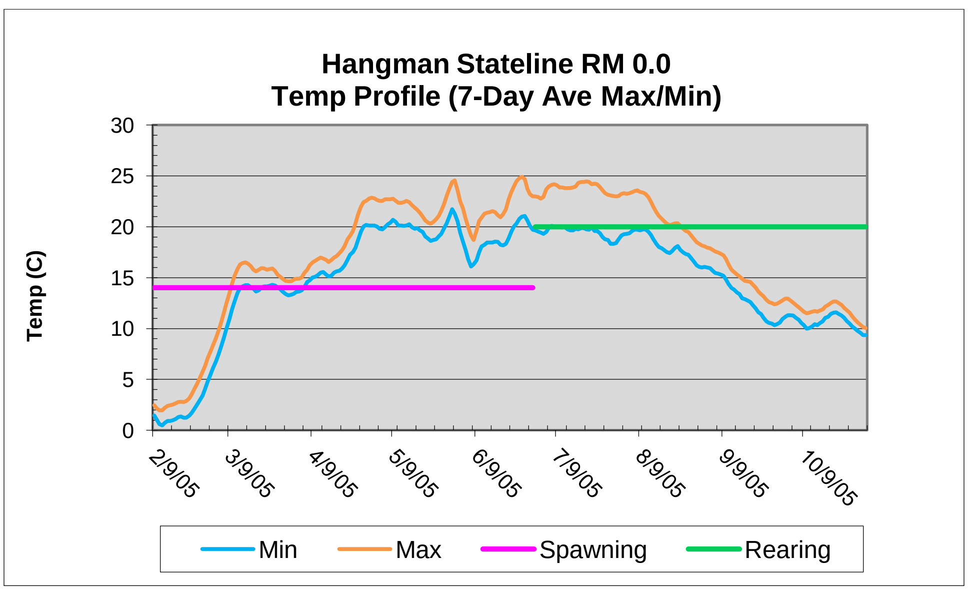


Figure C-2. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Stateline in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

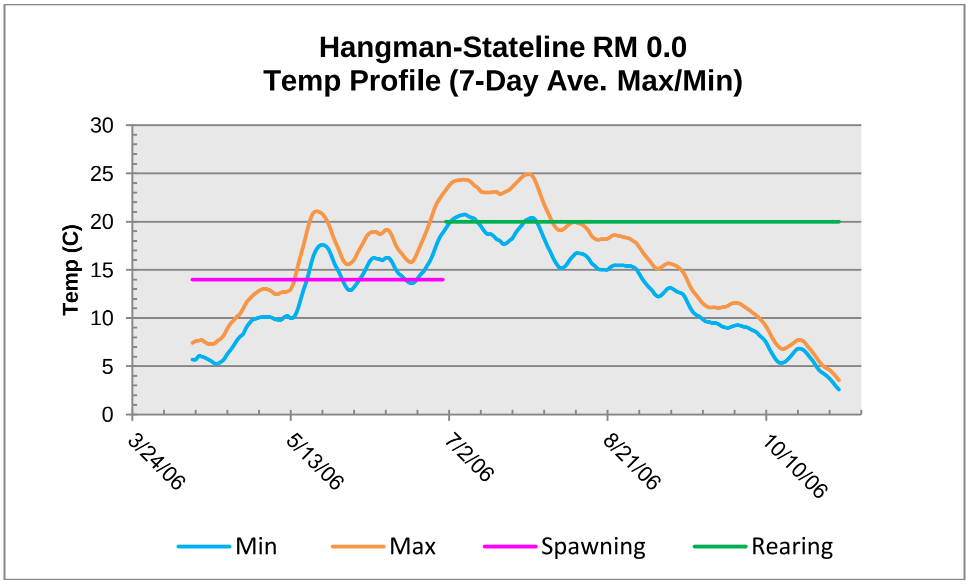


Figure C-3 Average weekly maximum/minimum temperature profiles of Hangman Cr. at Stateline in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

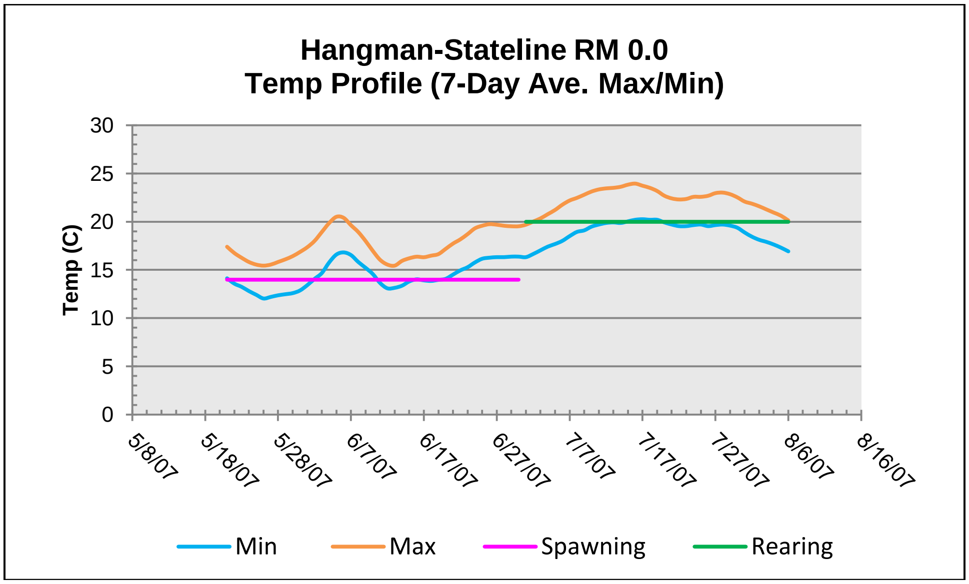


Figure C-4. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Stateline in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

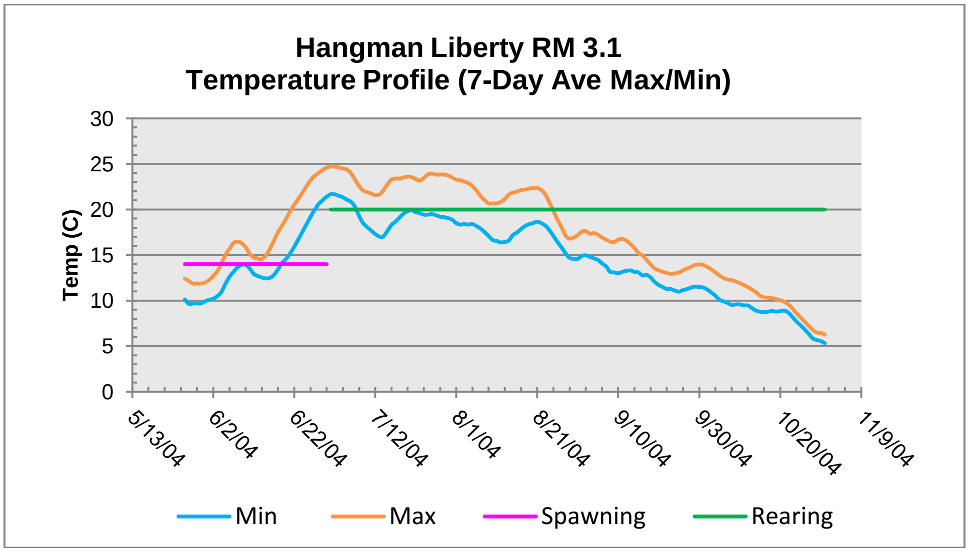


Figure C-5. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Liberty Butte in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

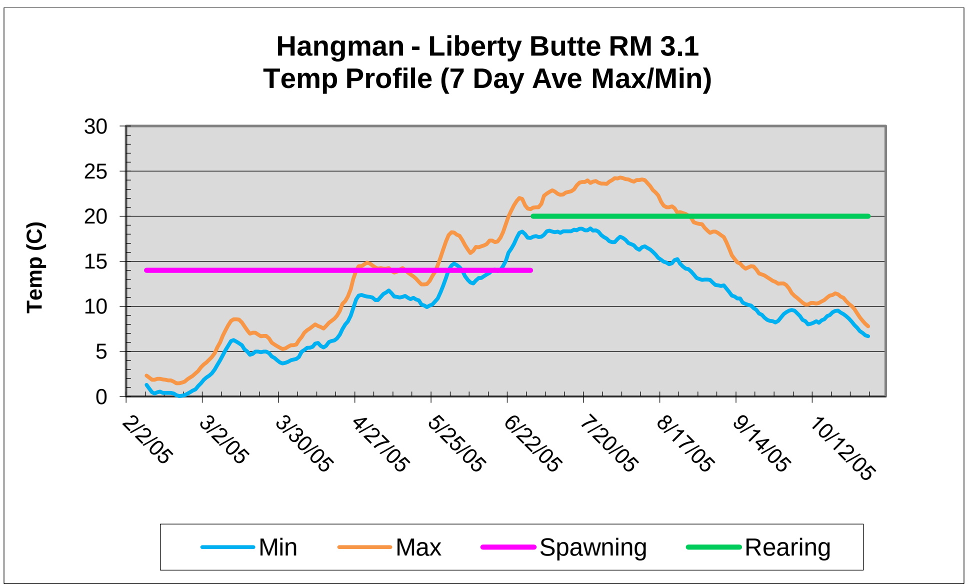


Figure C-6. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Liberty Butte in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

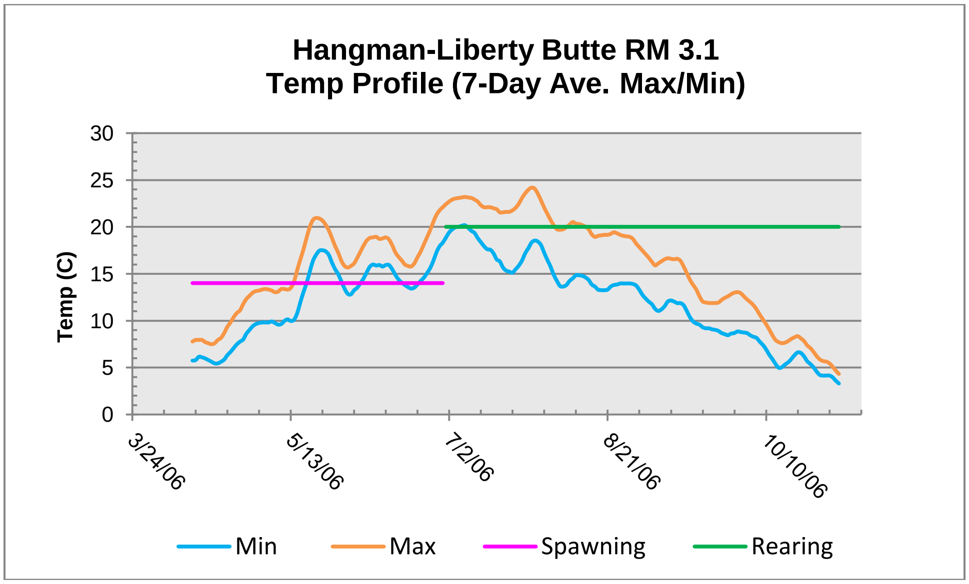


Figure C-7. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Liberty Butte in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

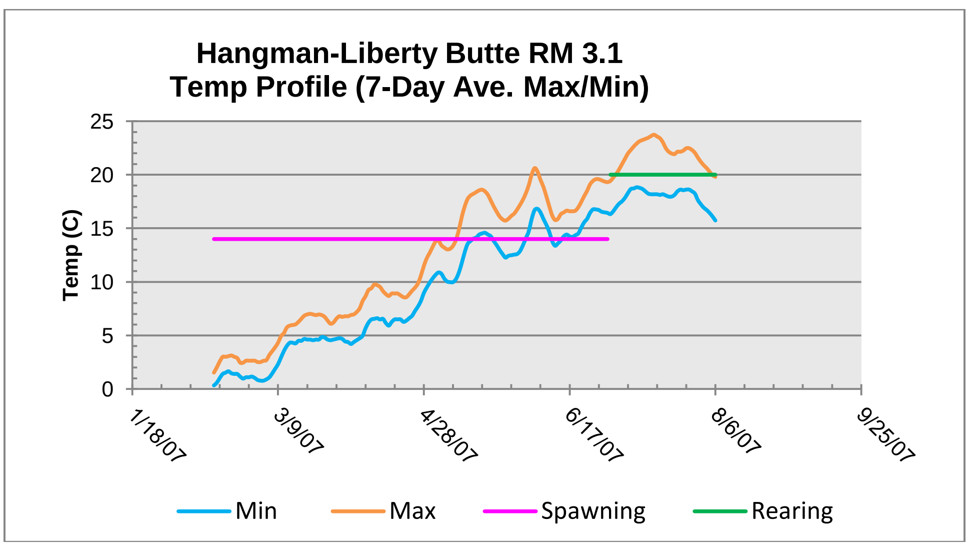


Figure C-8. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Liberty Butte in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

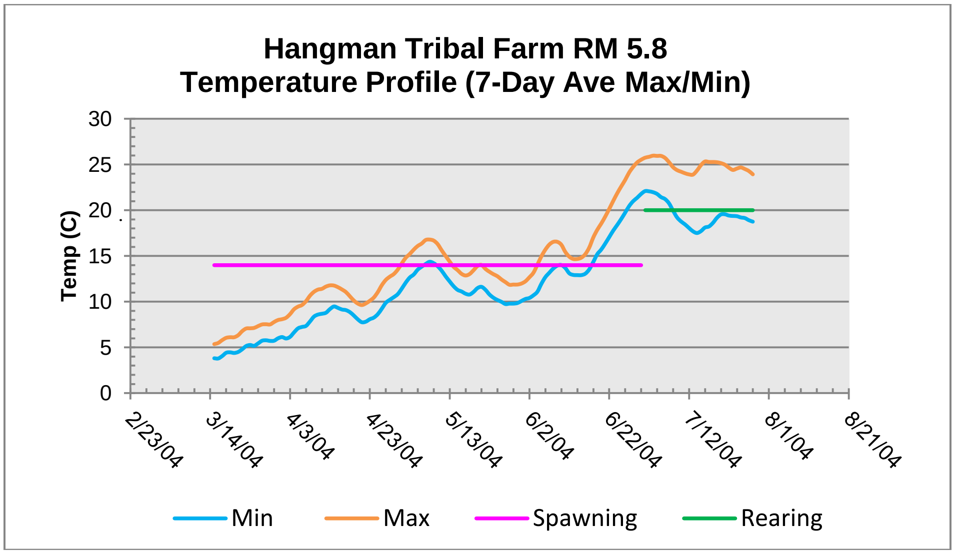


Figure C-9. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Tribal Farm in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

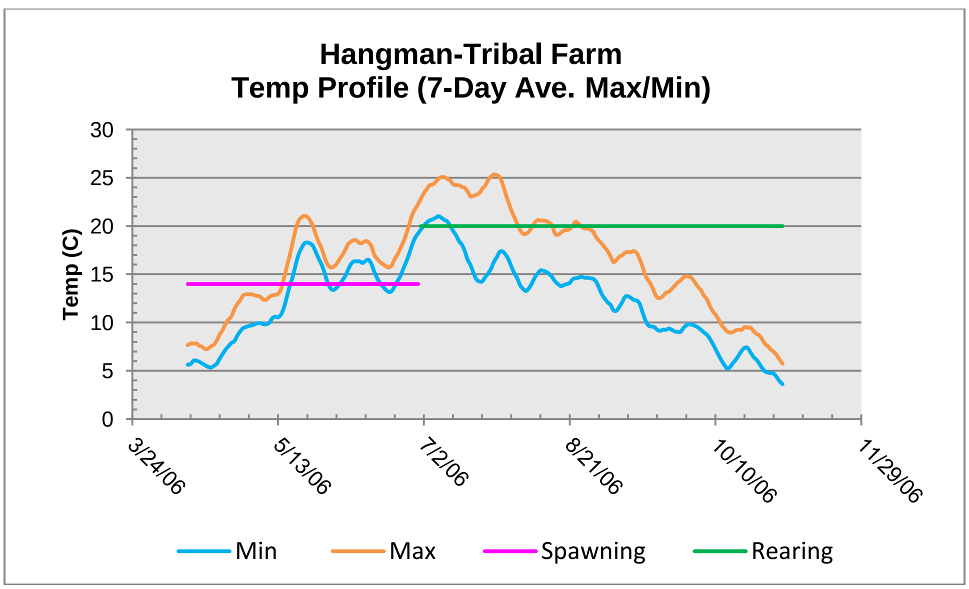


Figure C-10. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Tribal Farm in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

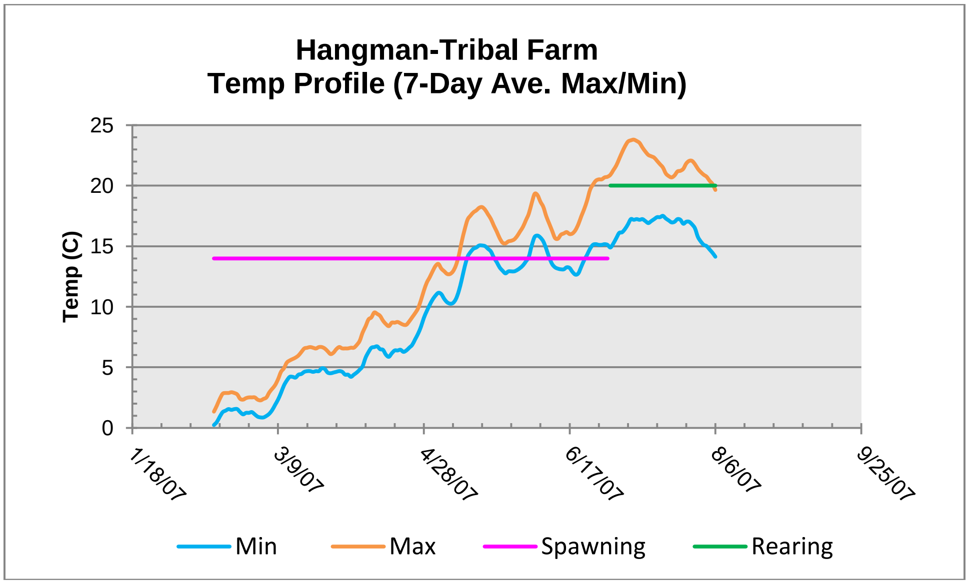


Figure C-11. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Tribal Farm in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

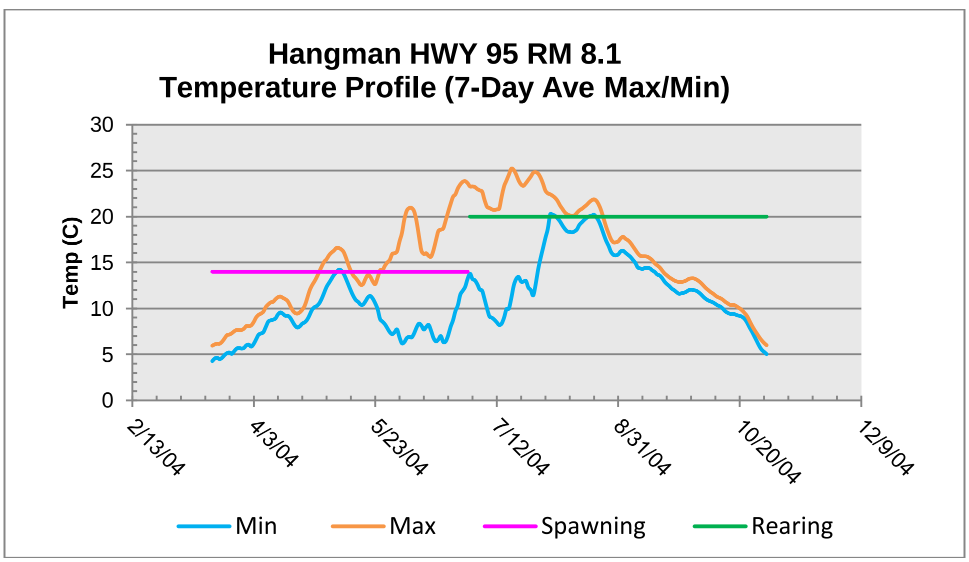


Figure C-12. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Highway 95 in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

**Out of water mid May till late July.*

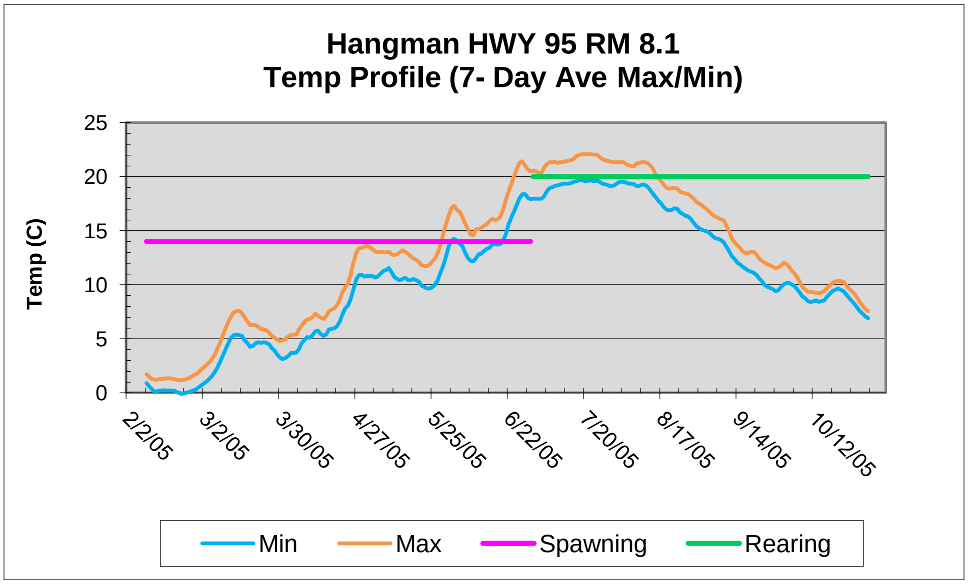


Figure C-13. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Highway 95 in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

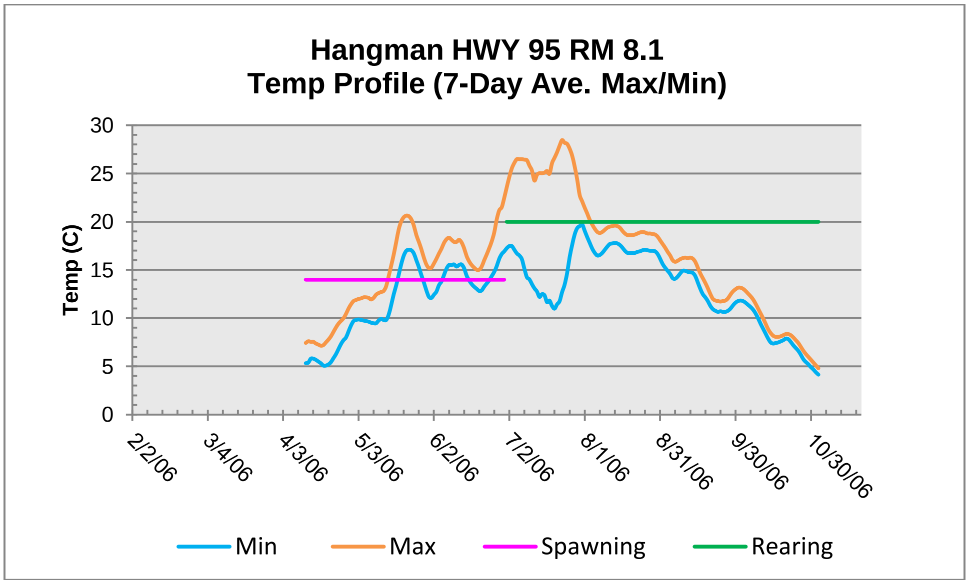


Figure C-14. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Highway 95 in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning. *Monitor was out of the water during July

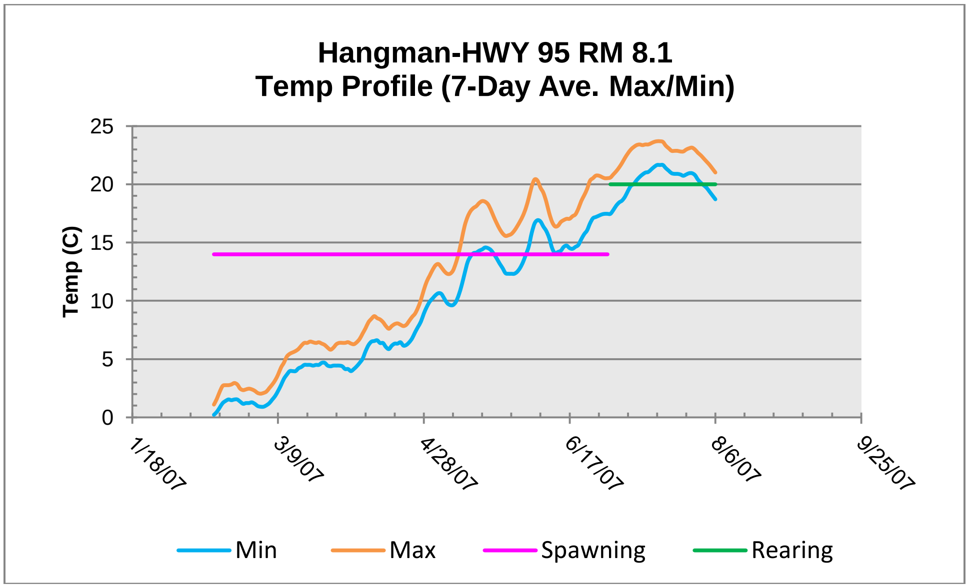


Figure C-15. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Highway 95 in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

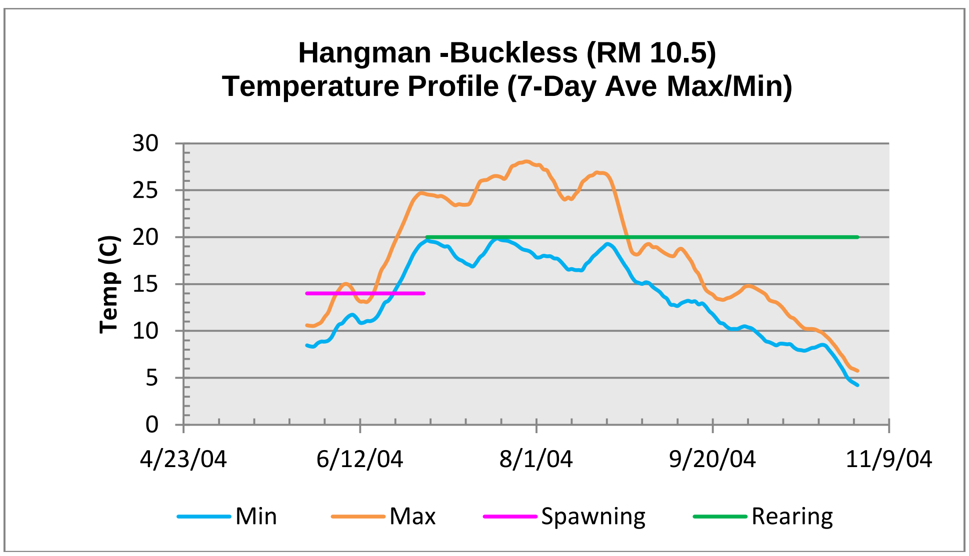


Figure C-16. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Buckless in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

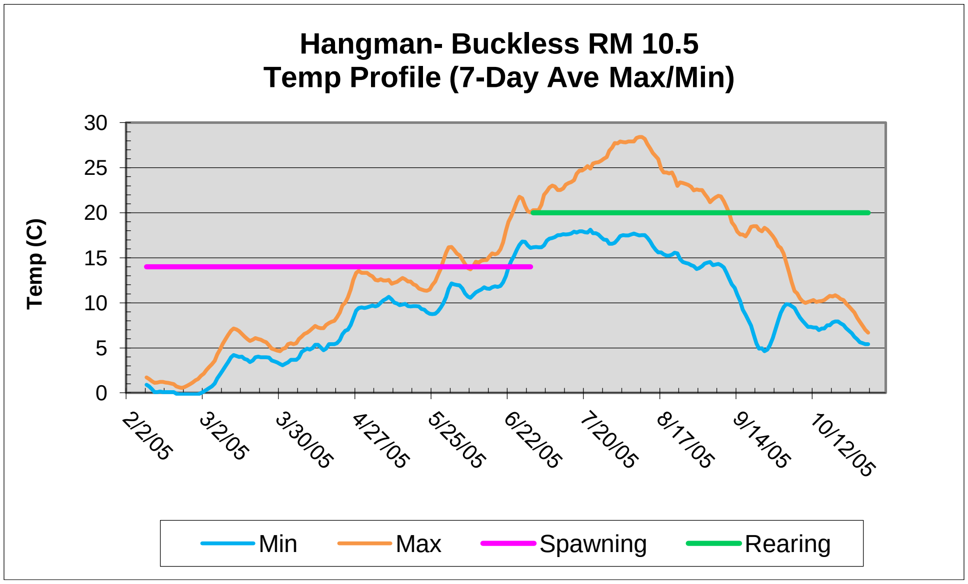


Figure C-17. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Buckless in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

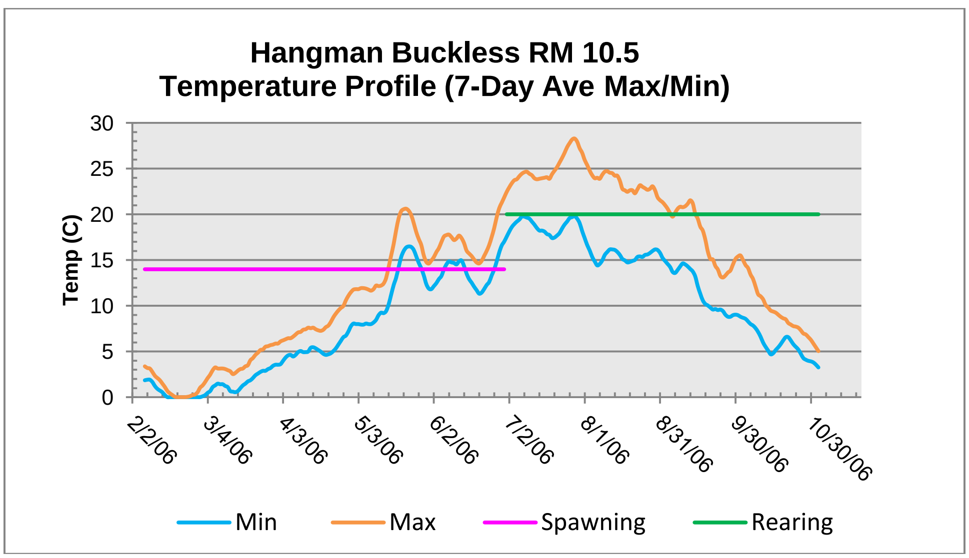


Figure C-18 Average weekly maximum/minimum temperature profiles of Hangman Cr. at Buckless in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

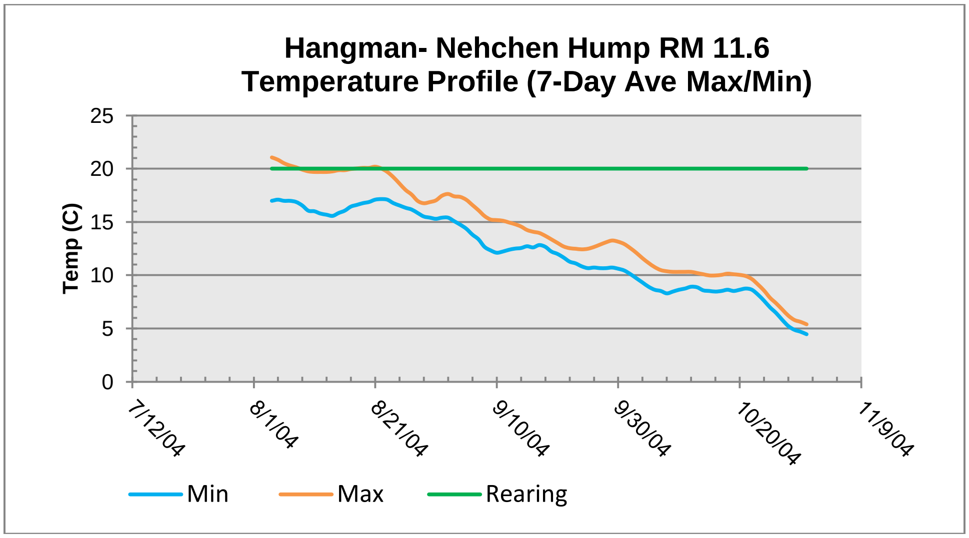


Figure C-19. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Nehchen Hump in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

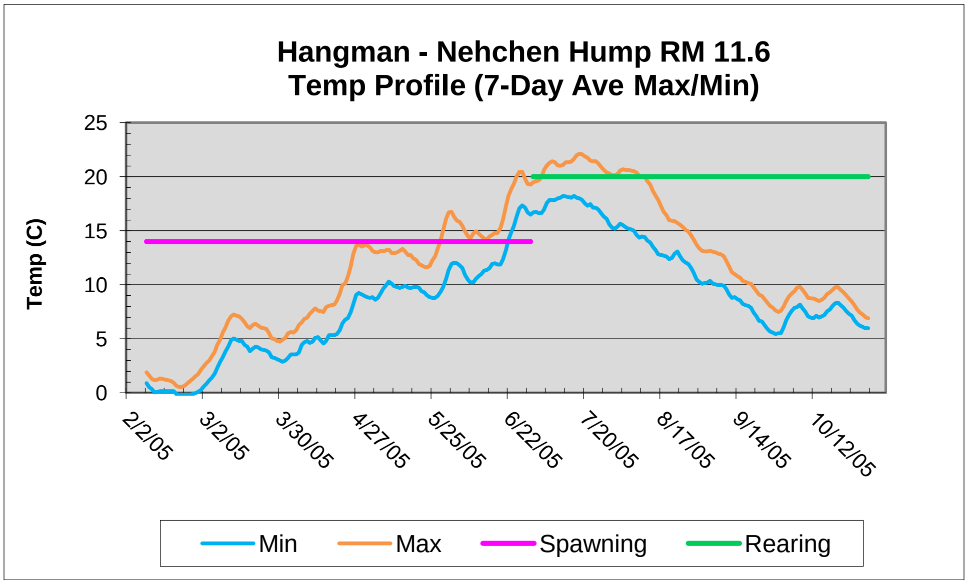


Figure C-20. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Nehchen Hump in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

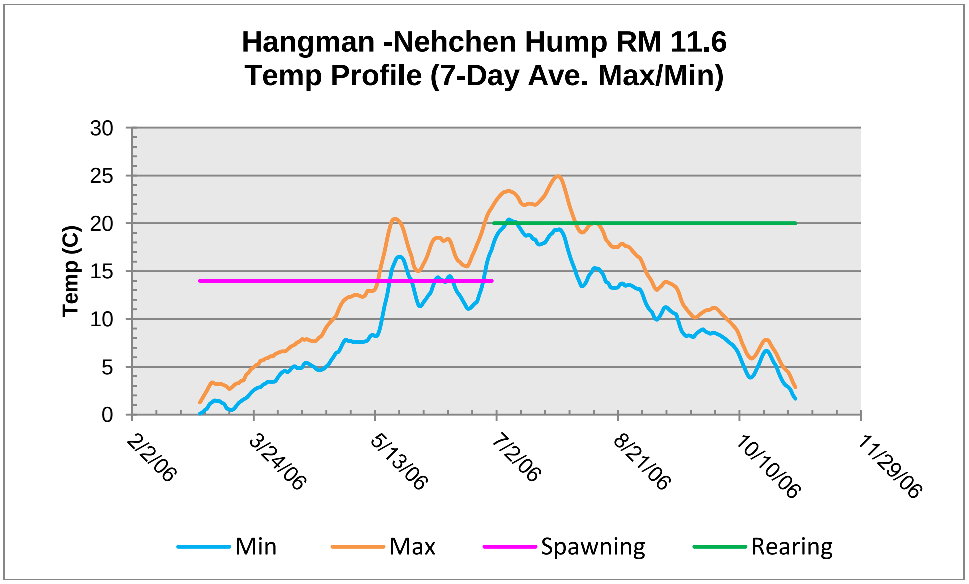


Figure C-21. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Nehchen Hump in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

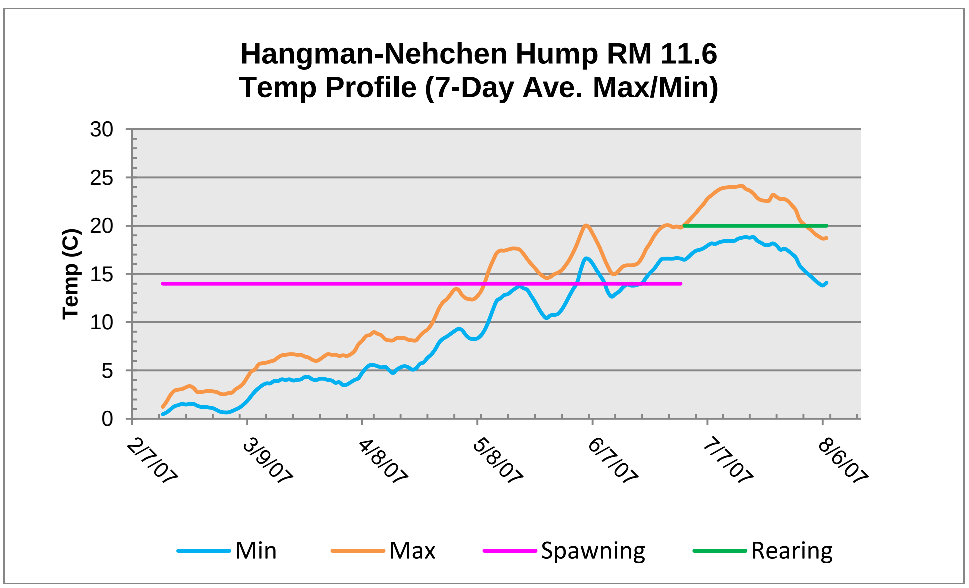


Figure C-22. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Nehchen Hump in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

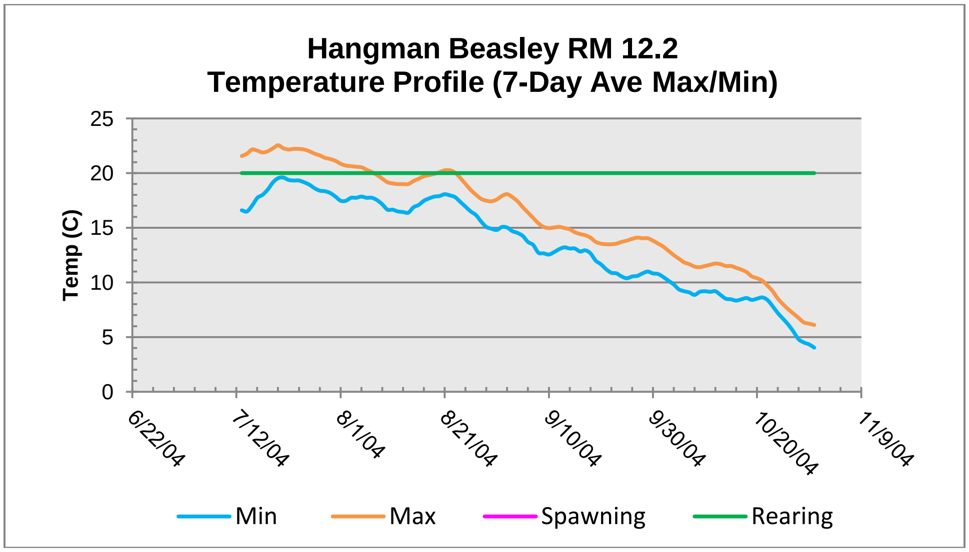


Figure C-23. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Beasely in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

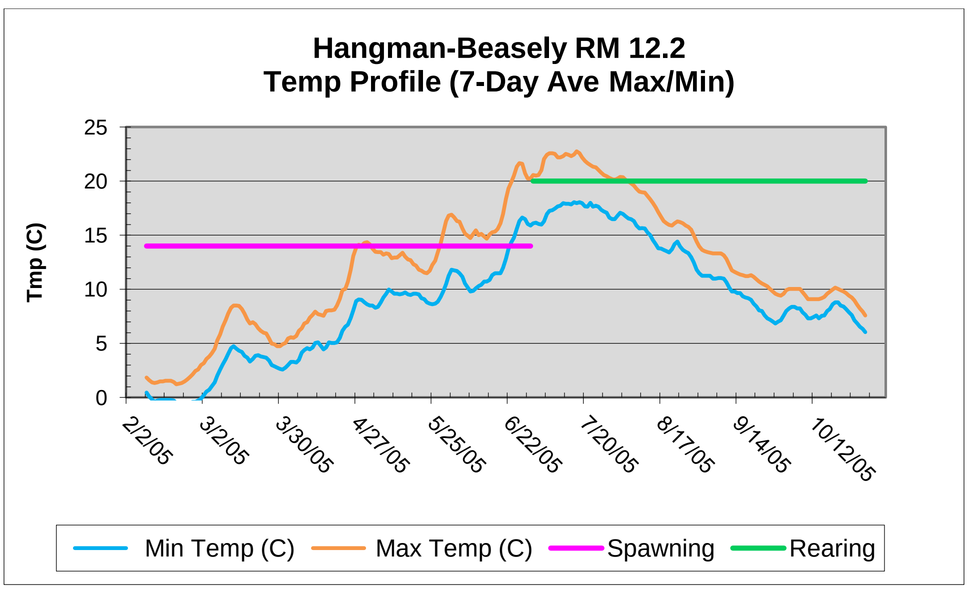


Figure C-24. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Beasely in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

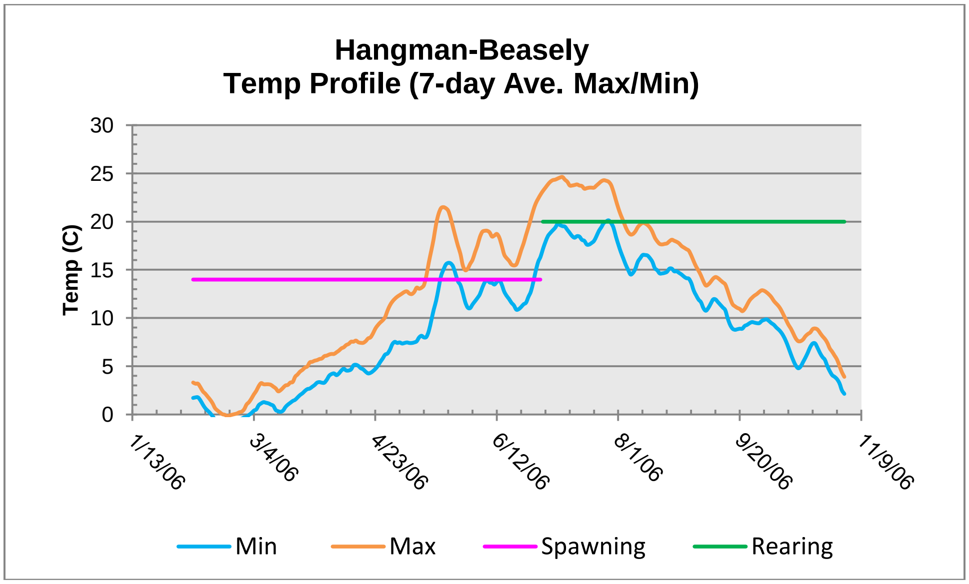


Figure C-25. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Beasely in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

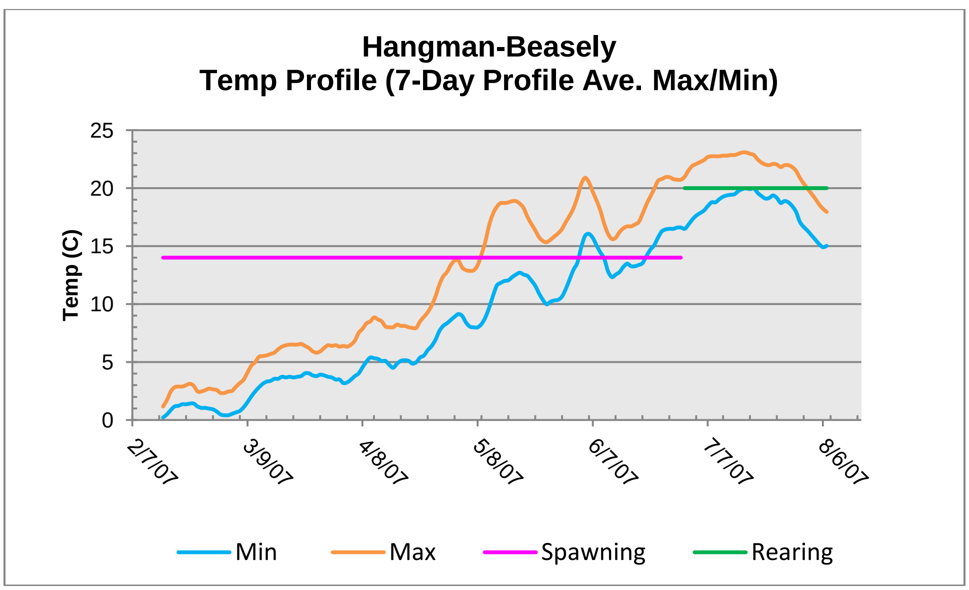


Figure C-26. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Beasely in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

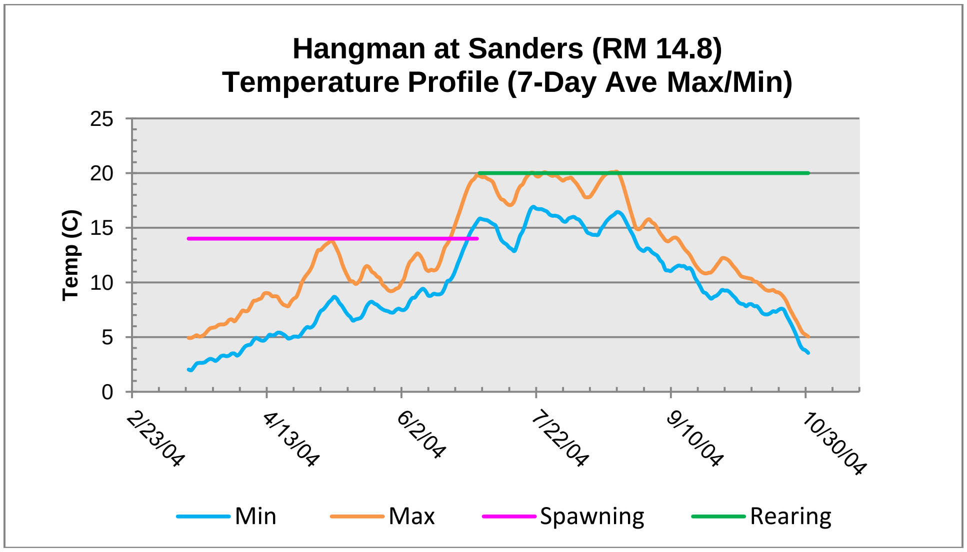


Figure C-27. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Sanders in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

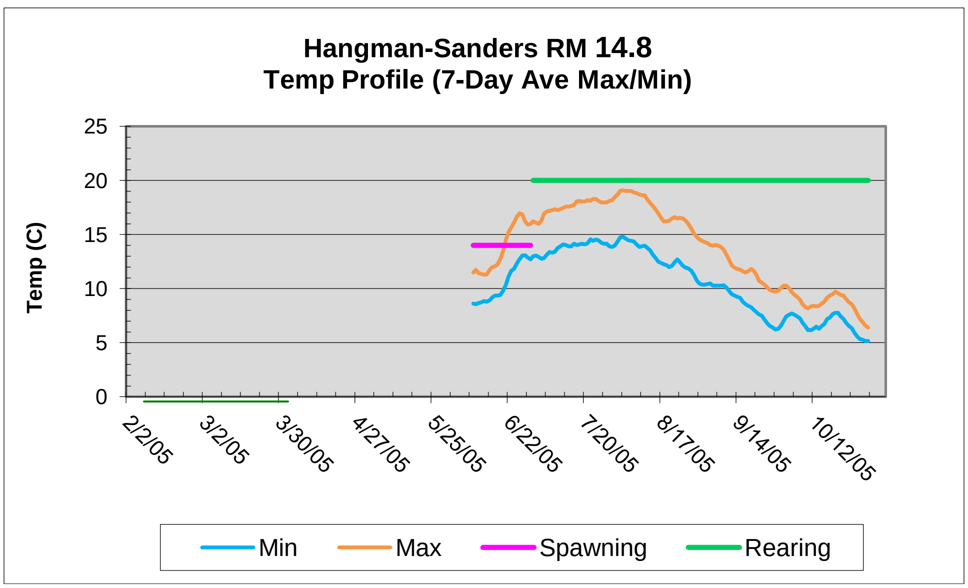


Figure C-28. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Sanders in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

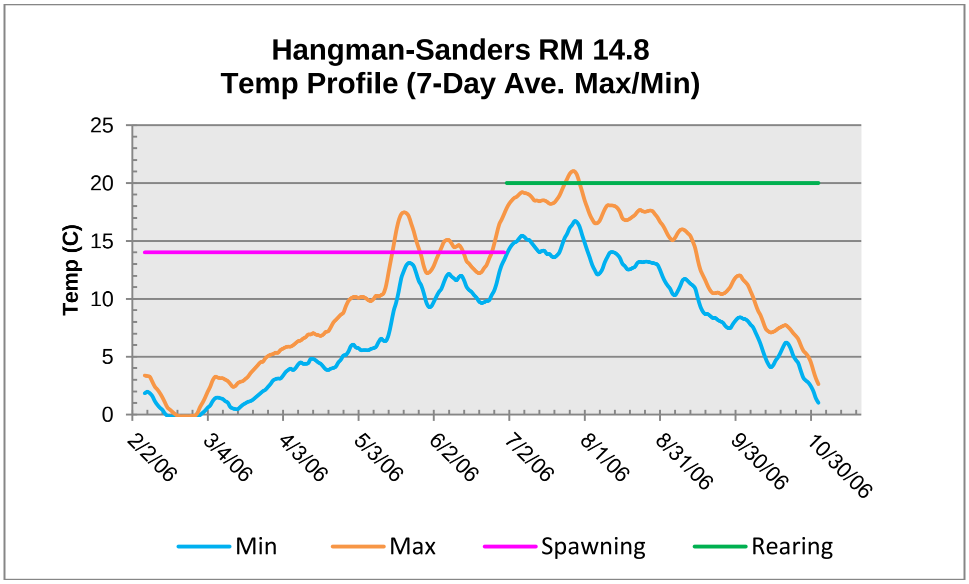


Figure C-29. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Sanders in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

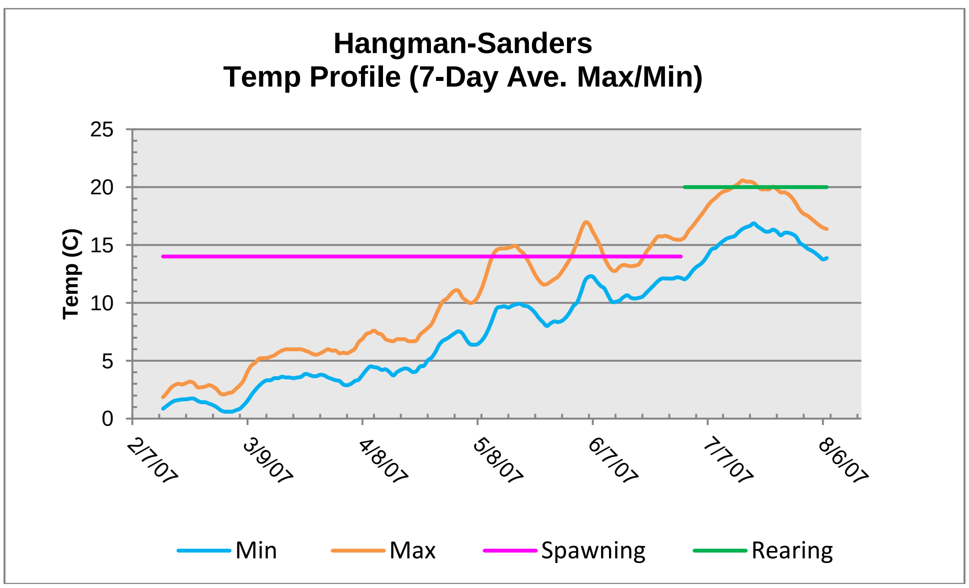


Figure C-30. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Sanders in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

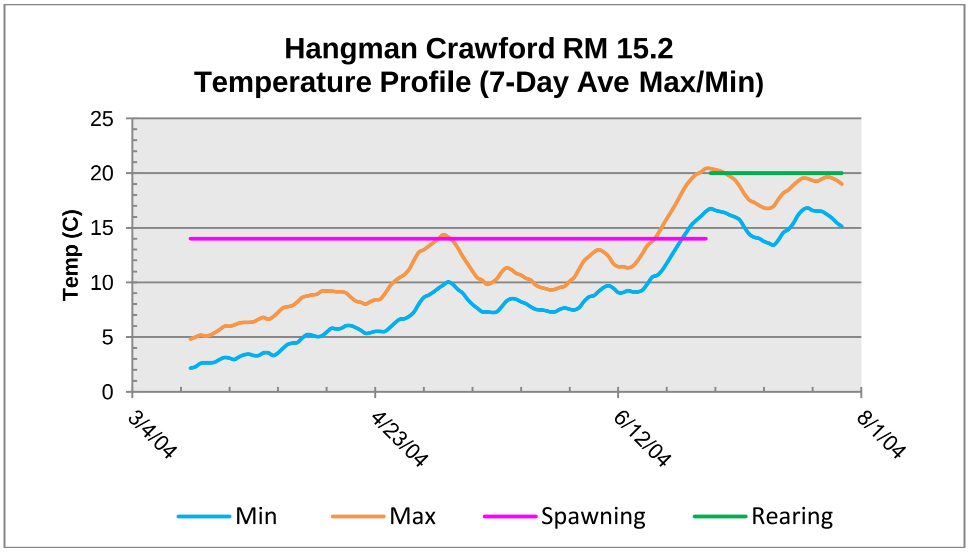


Figure C-31. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Crawford in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

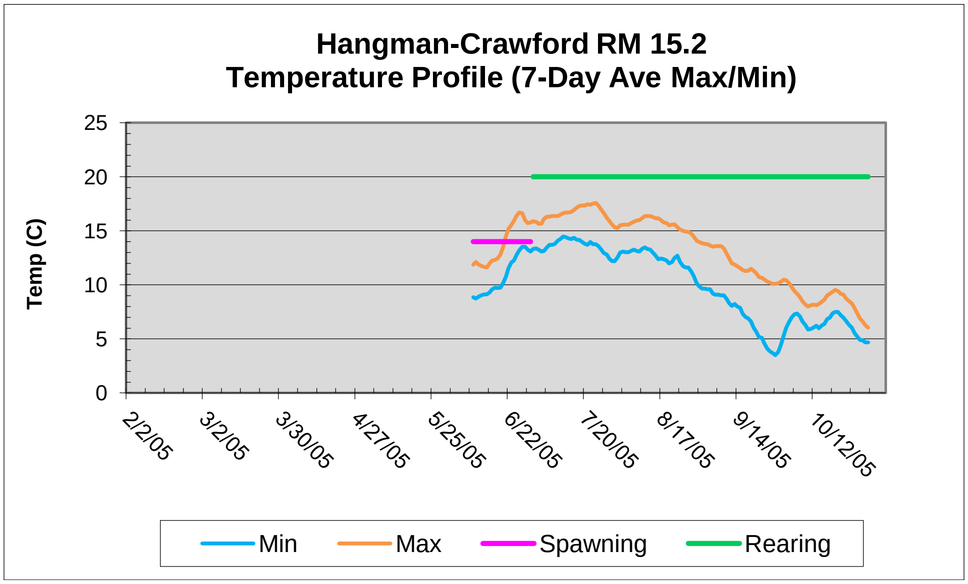


Figure C-32 Average weekly maximum/minimum temperature profiles of Hangman Cr. at Crawford in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

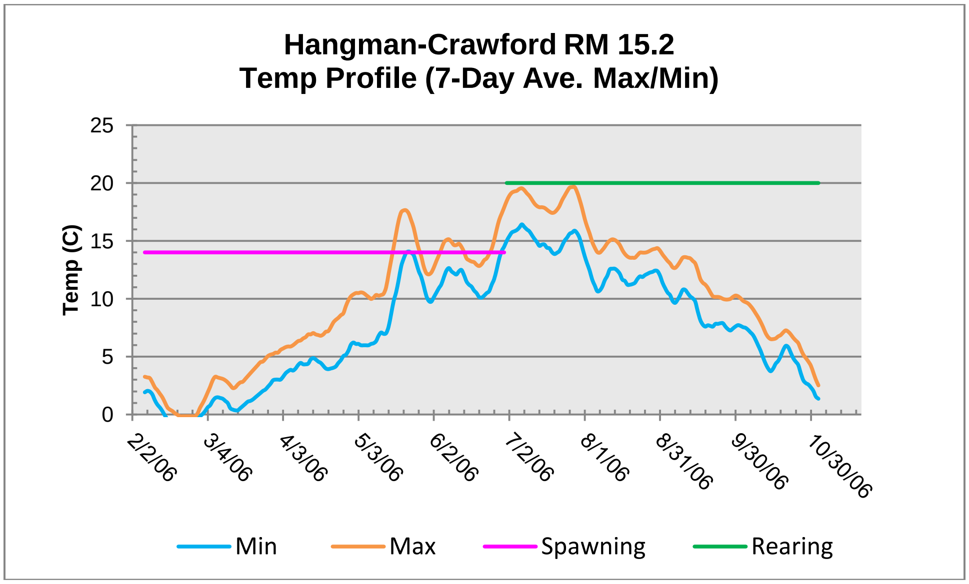


Figure C-33. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Crawford in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

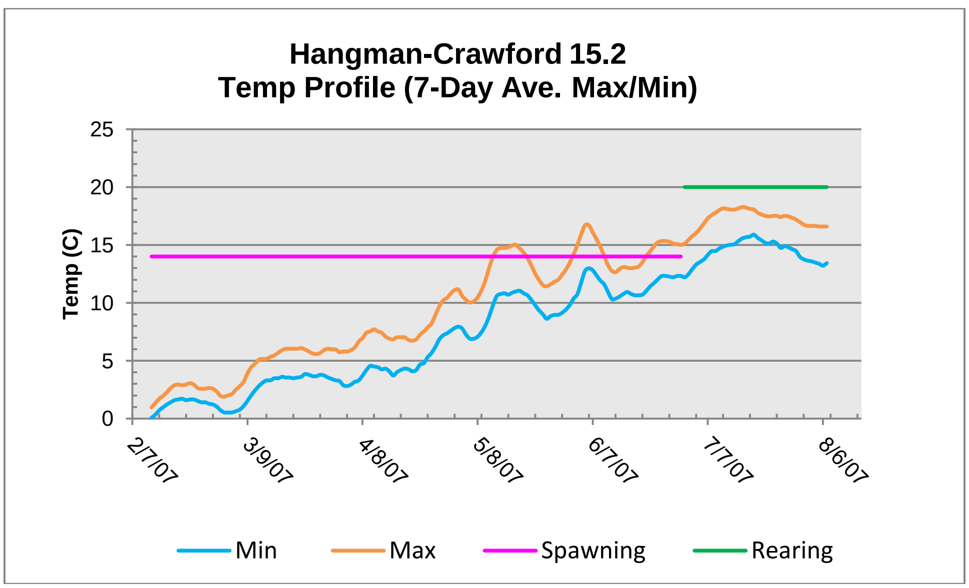


Figure C-34. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Crawford in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

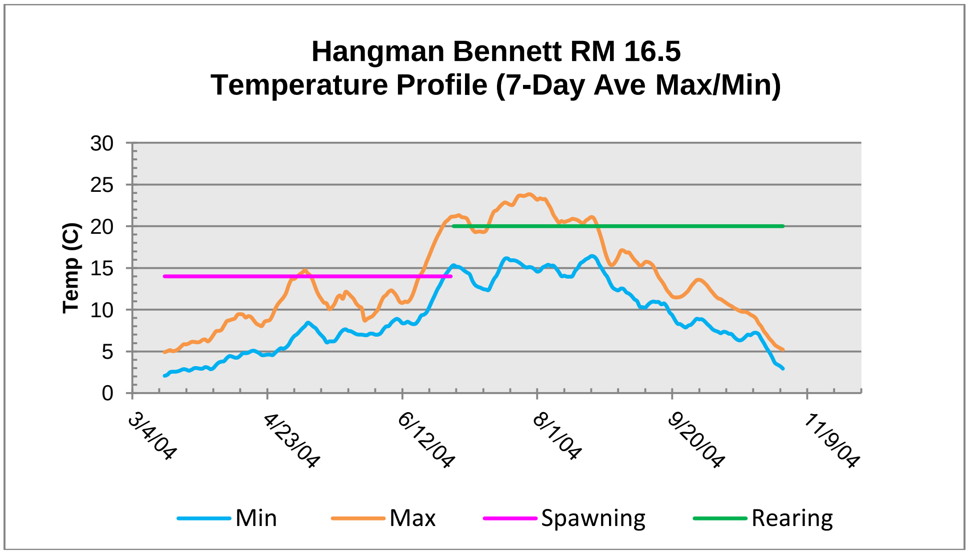


Figure C-35. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Bennett in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

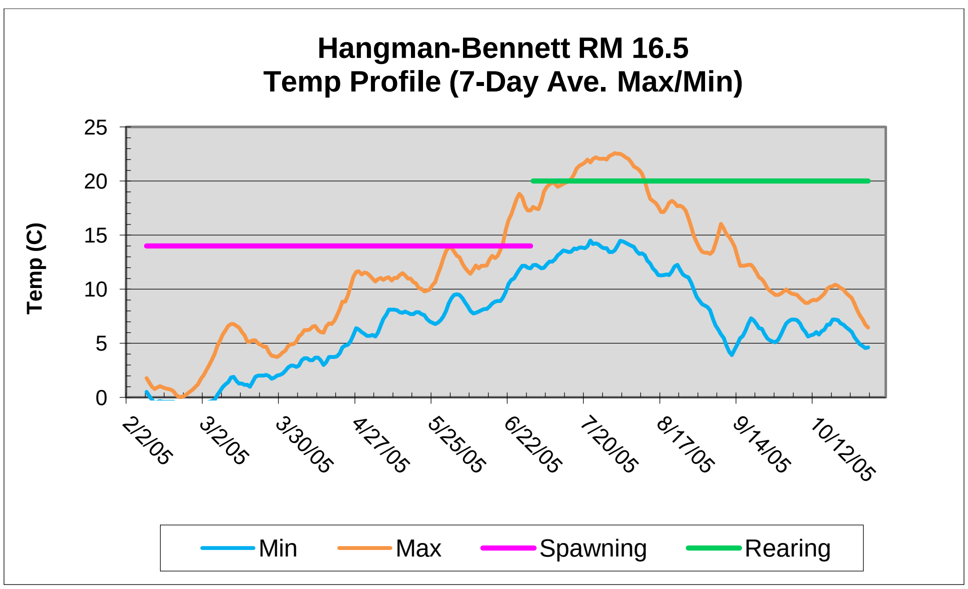


Figure C-36. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Bennett in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

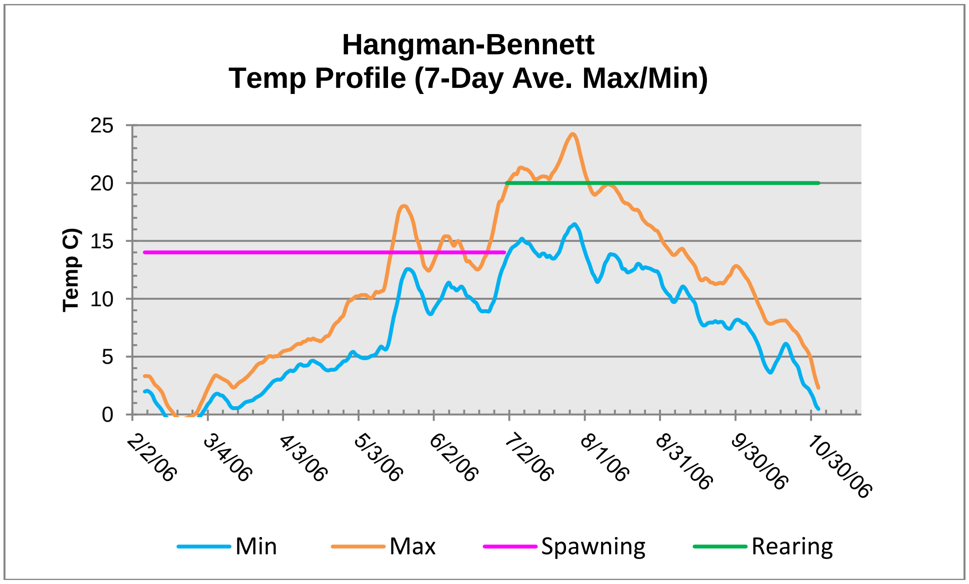


Figure C-37. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Bennett in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

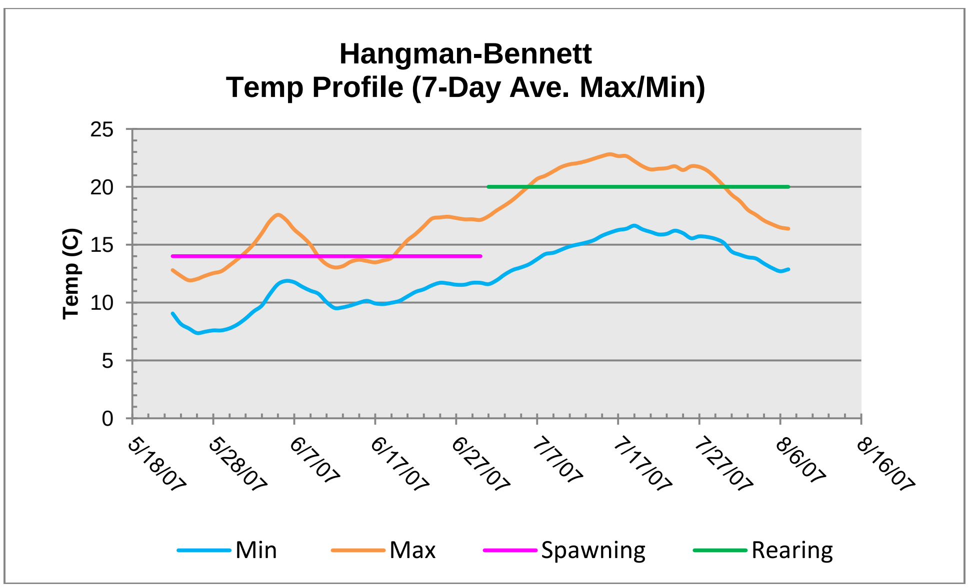


Figure C-38. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Bennett in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

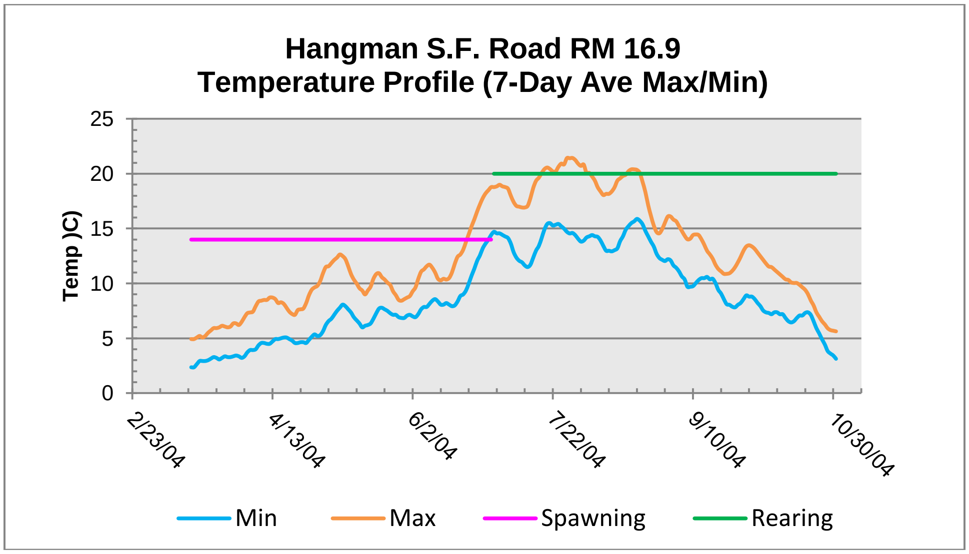


Figure C-39. Average weekly maximum/minimum temperature profiles of Hangman Cr. at SF Rd. in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

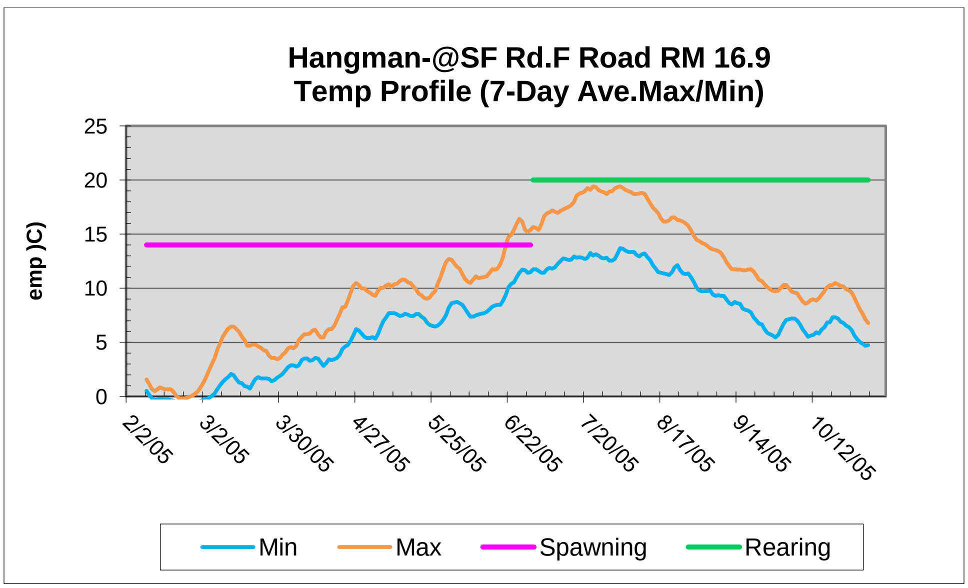


Figure C-40. Average weekly maximum/minimum temperature profiles of Hangman Cr. at SF Rd. in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

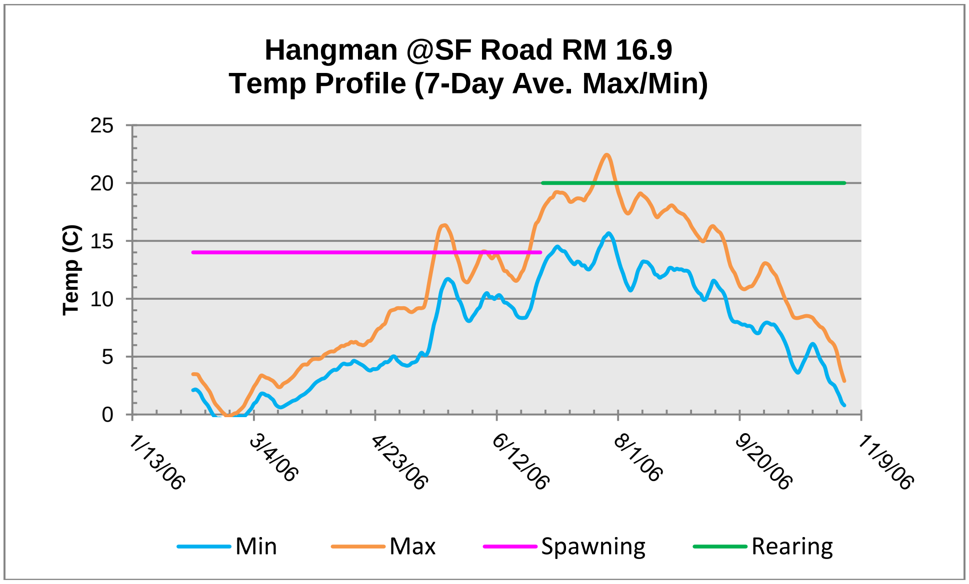


Figure C-41. Average weekly maximum/minimum temperature profiles of Hangman Cr. at SF Rd. in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

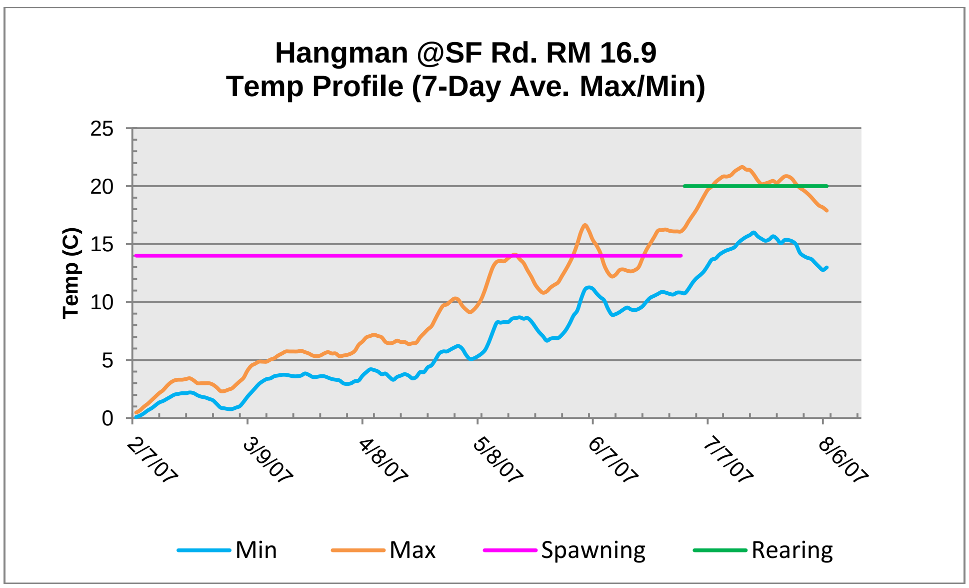


Figure C-42. Average weekly maximum/minimum temperature profiles of Hangman Cr. at SF Rd. in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

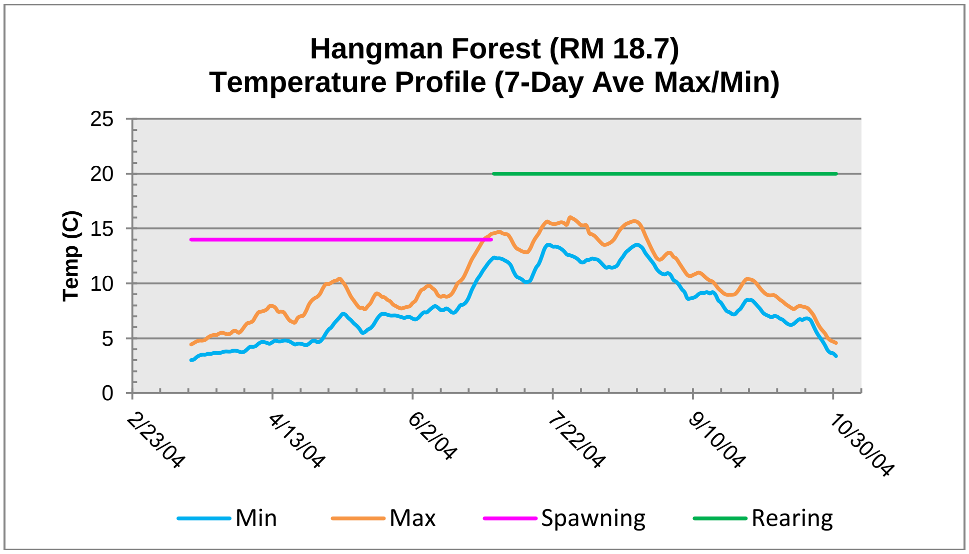


Figure C-43. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Forest in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

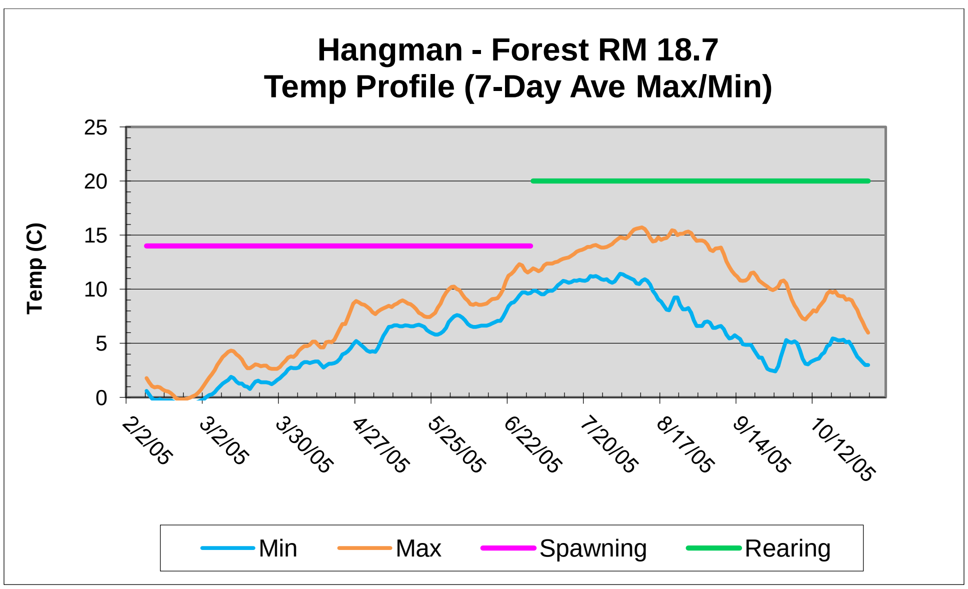


Figure C-44. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Forest in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

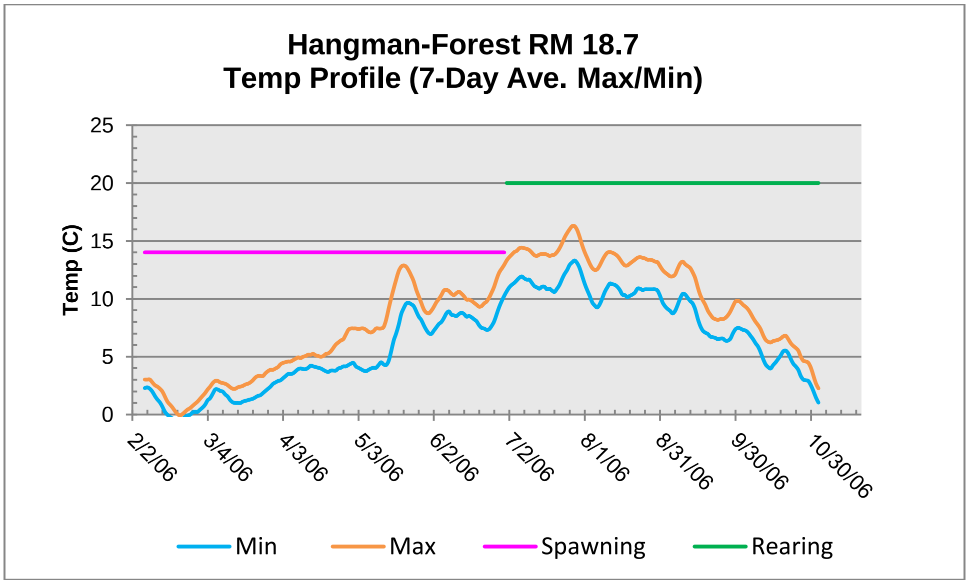


Figure C-45. Average weekly maximum/minimum temperature profiles of Hangman Cr. at Forest in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

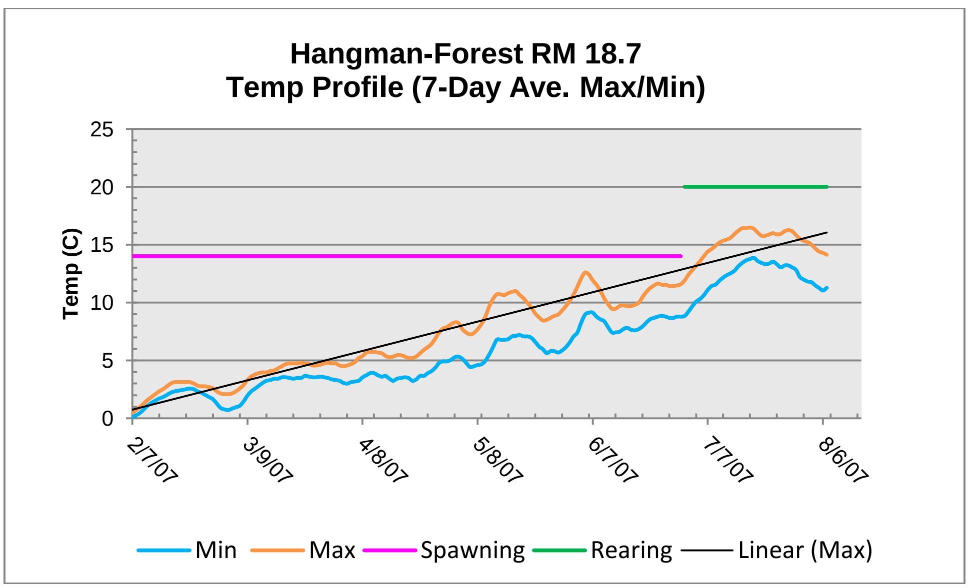


Figure C-46. Average weekly maximum/minimum temperature profiles of Hangman-Forest in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

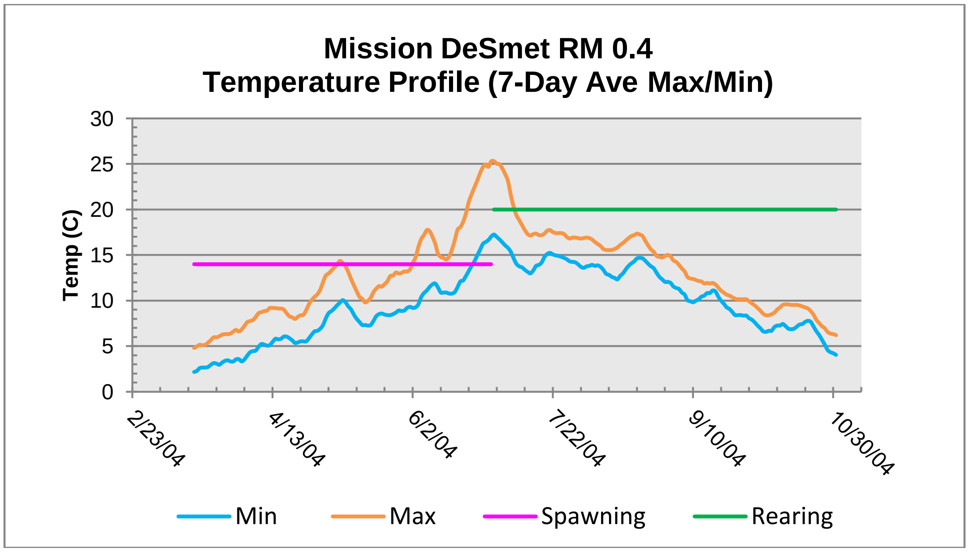


Figure C-47. Average weekly maximum/minimum temperature profiles of Mission Cr. at DeSmet in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

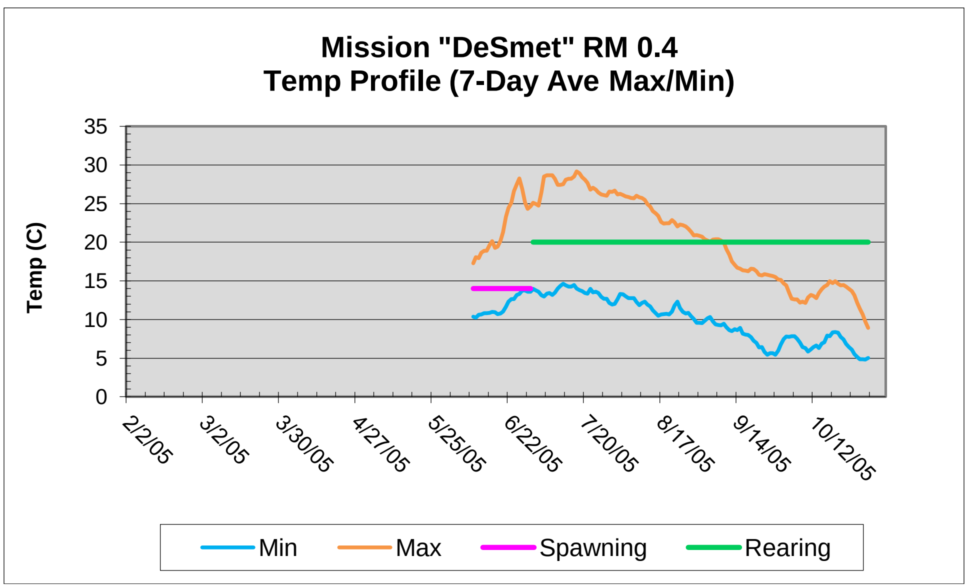


Figure C-48. Average weekly maximum/minimum temperature profiles of Mission Cr. at DeSmet in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

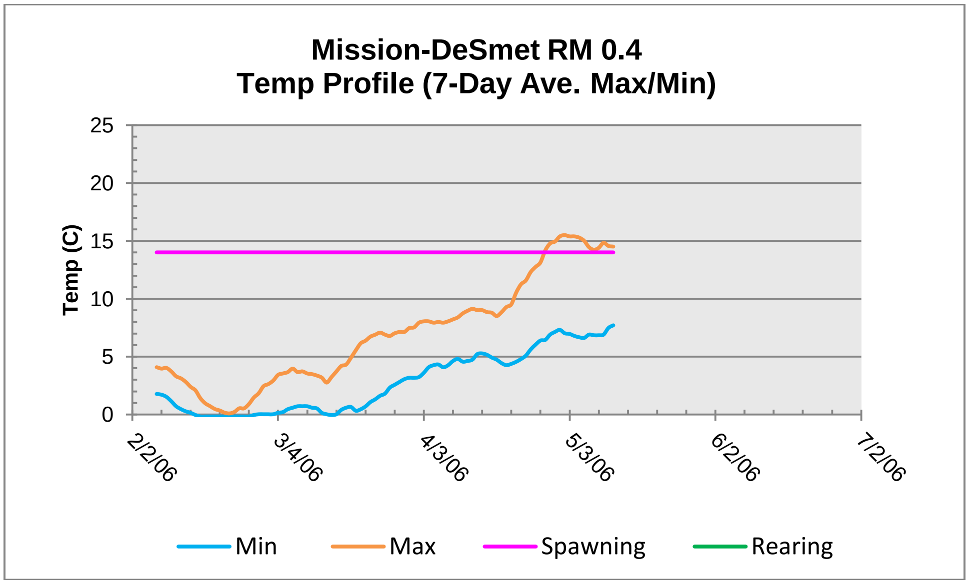


Figure C-49. Average weekly maximum/minimum temperature profiles of Mission Cr. at DeSmet in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

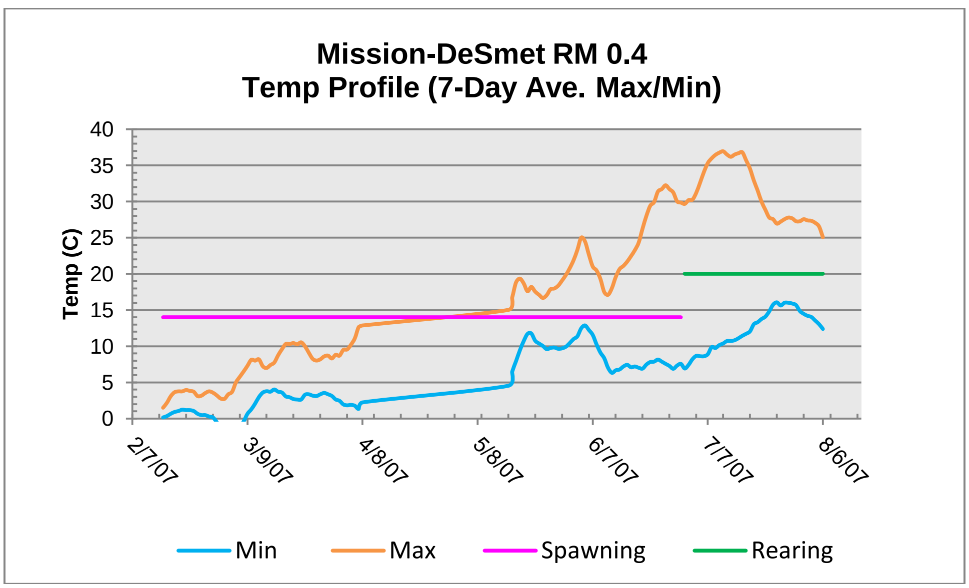


Figure C-50. Average weekly maximum/minimum temperature profiles of Mission Cr. at DeSmet in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning. * No data recorded early April-early May.

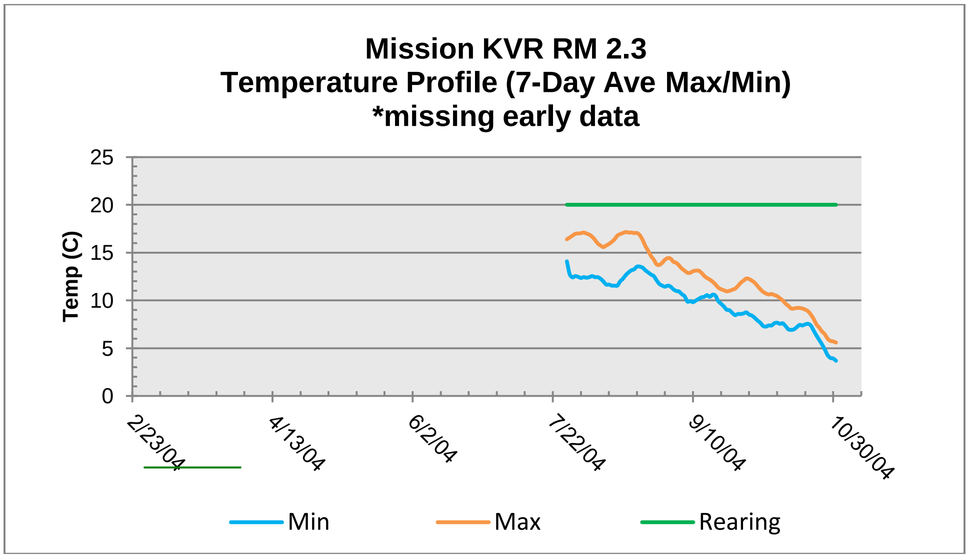


Figure C51. Average weekly maximum/minimum temperature profiles of Mission Cr. at King Valley Rd. in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

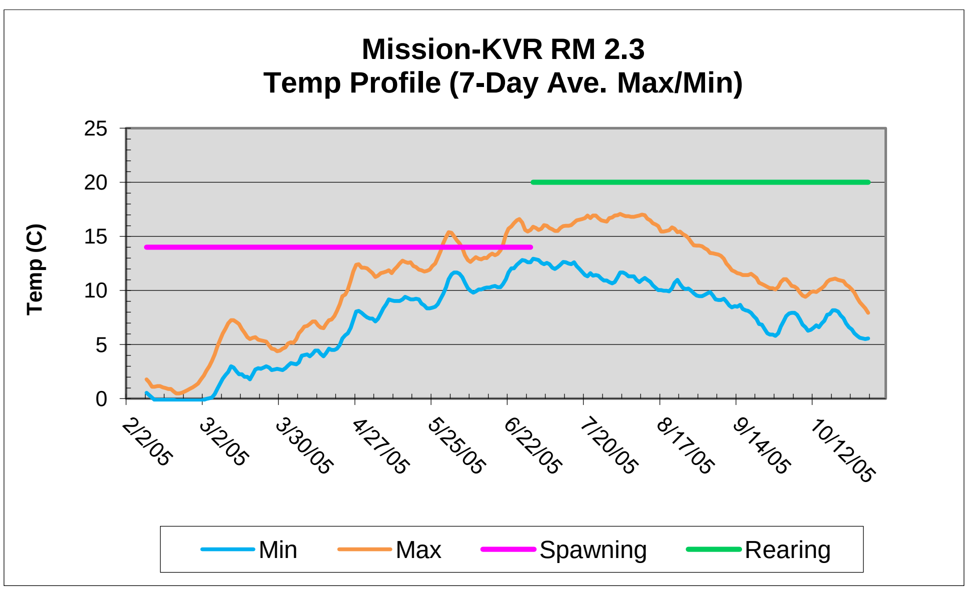


Figure C 52. Average weekly maximum/minimum temperature profiles of Mission Cr. at King Valley Rd. in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

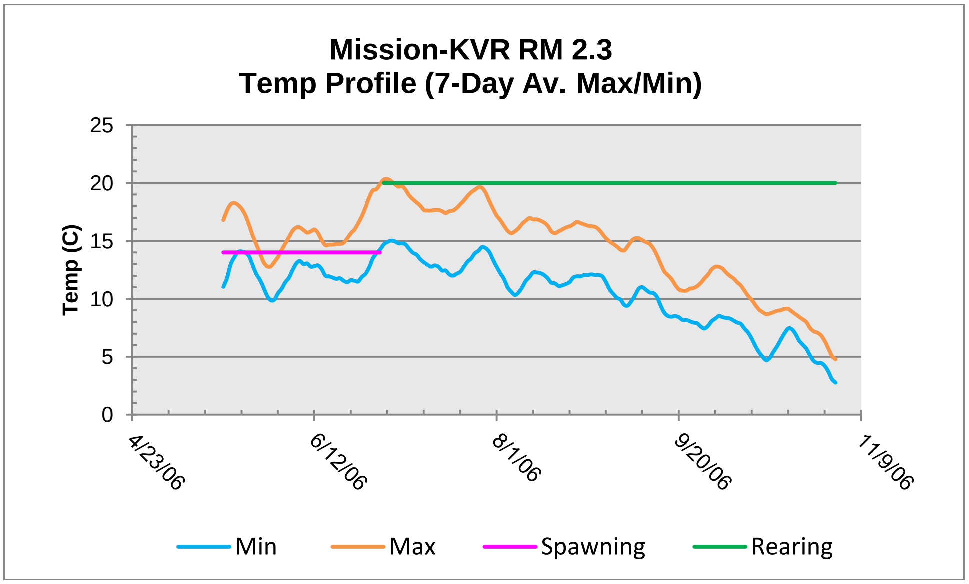


Figure C53. Average weekly maximum/minimum temperature profiles of Mission Cr. at King Valley Rd. in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

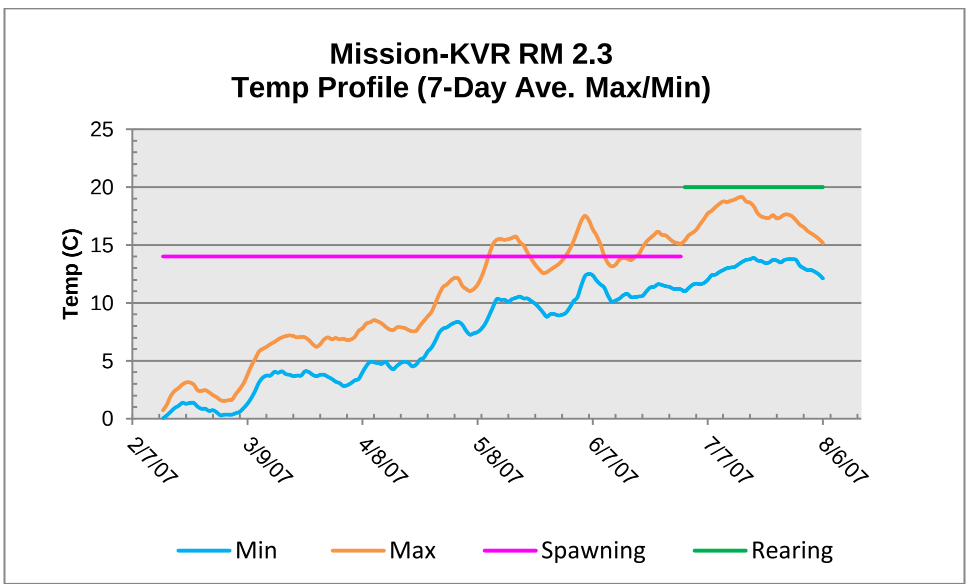


Figure C-54. Average weekly maximum/minimum temperature profiles of Mission Cr. at King Valley Rd. in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

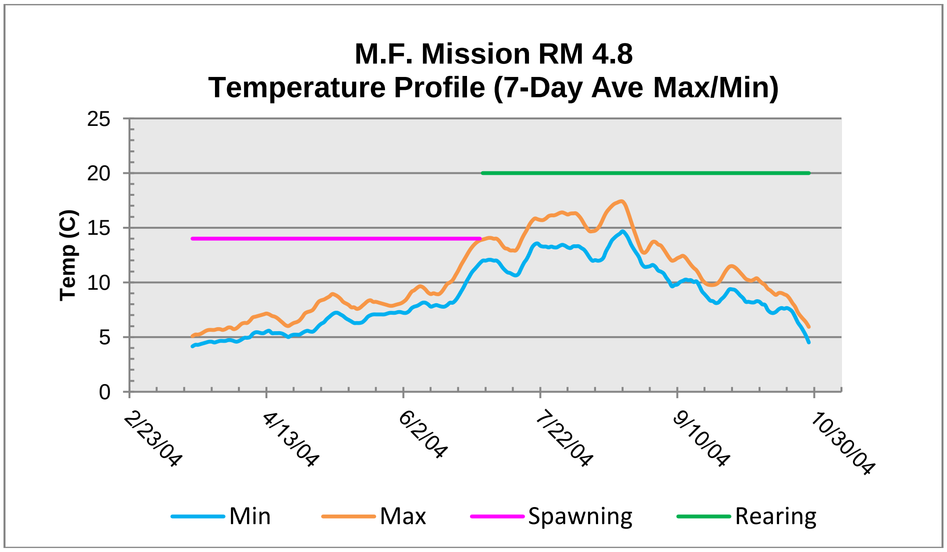


Figure C-55. Average weekly maximum/minimum temperature profiles of the MF Mission Creek in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

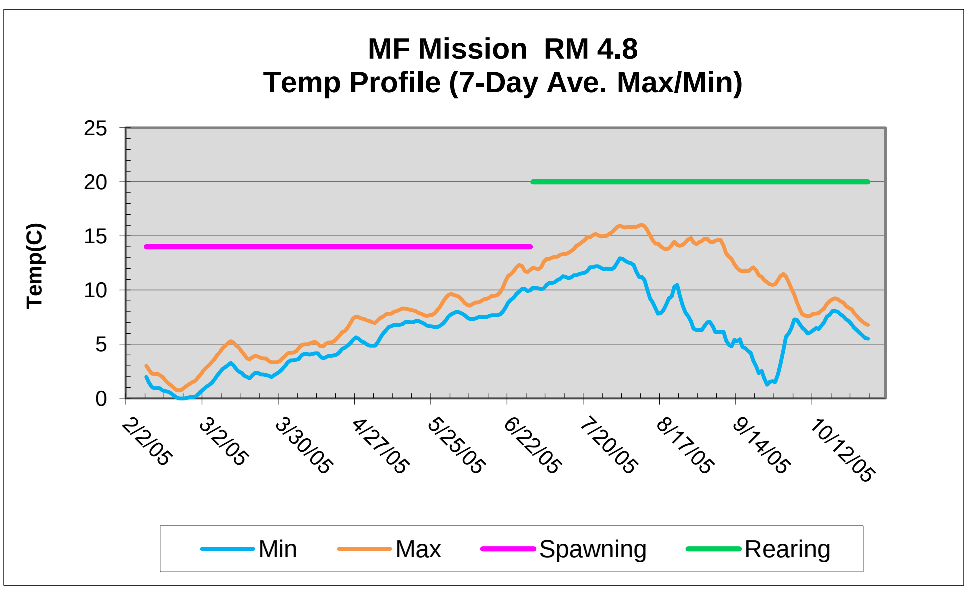


Figure C-56. Average weekly maximum/minimum temperature profiles of the MF Mission Creek in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

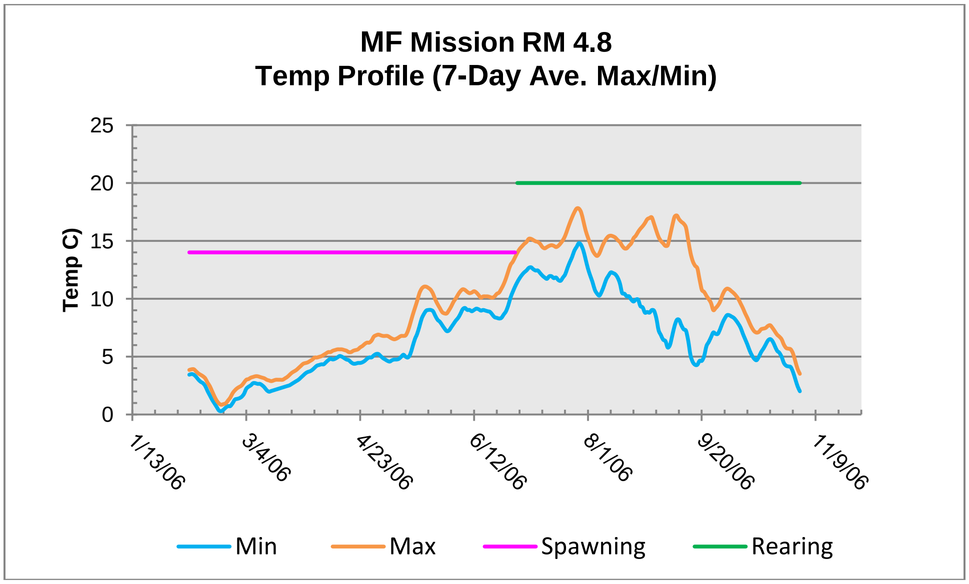


Figure C-57. Average weekly maximum/minimum temperature profiles of the MF Mission Creek in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

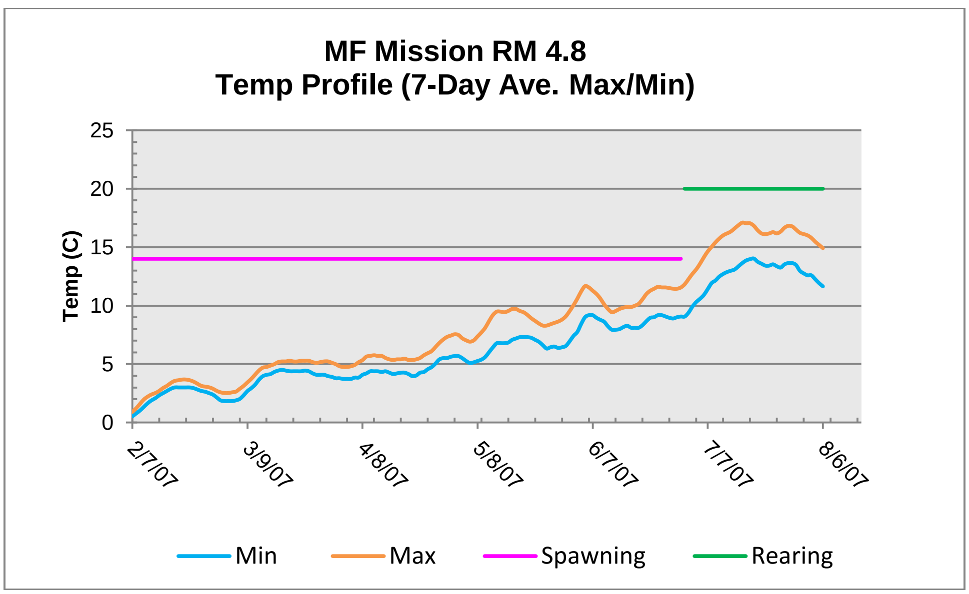


Figure C-58. Average weekly maximum/minimum temperature profiles of the MF Mission Creek in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

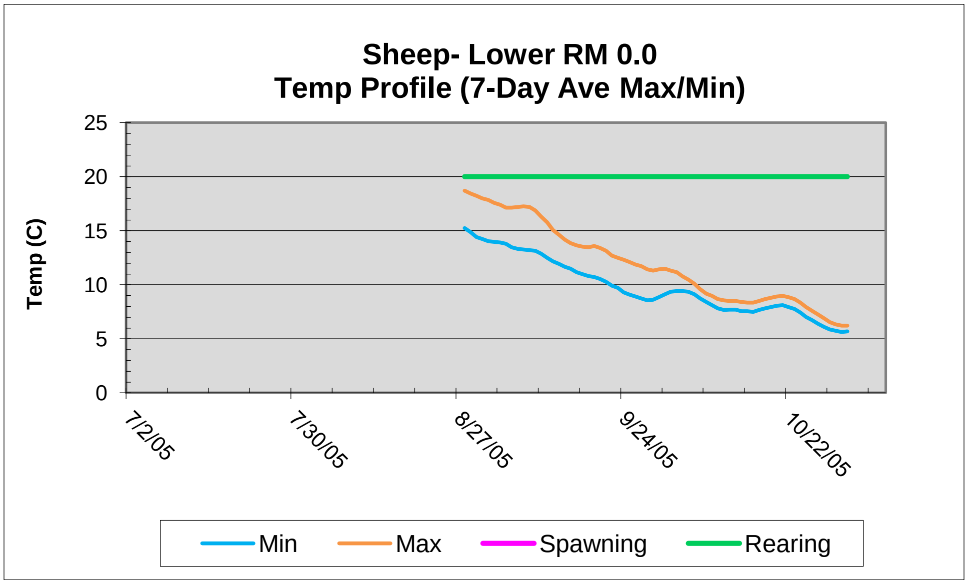


Figure C-59. Average weekly maximum/minimum temperature profiles of Lower Sheep Cr. in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

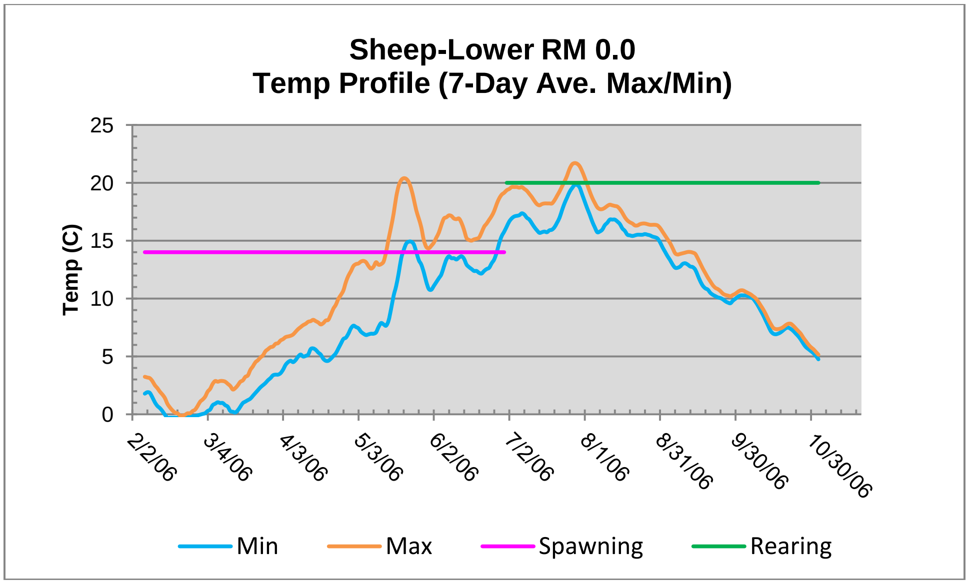


Figure C-60. Average weekly maximum/minimum temperature profiles of Lower Sheep Cr. in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

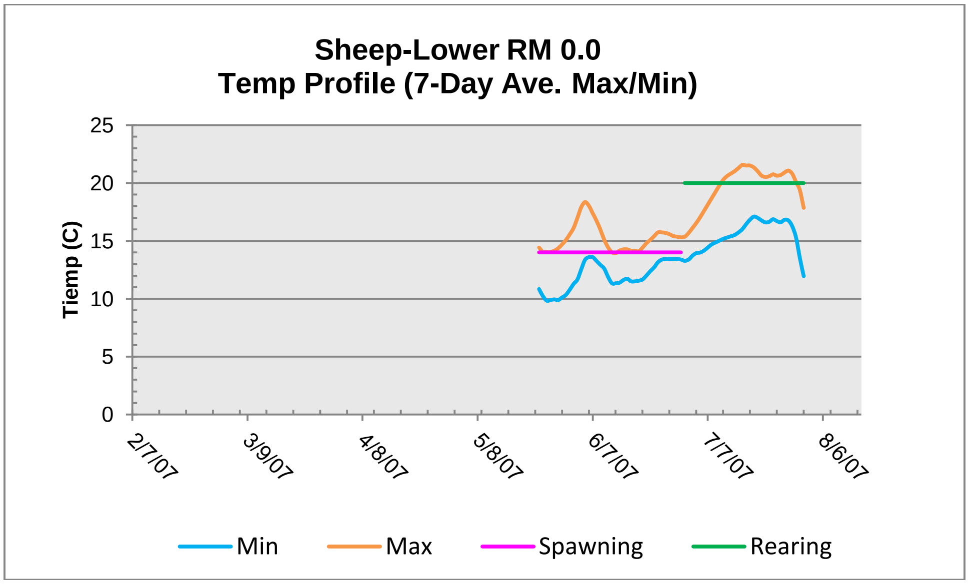


Figure C-61. Average weekly maximum/minimum temperature profiles of Lower Sheep Cr. in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

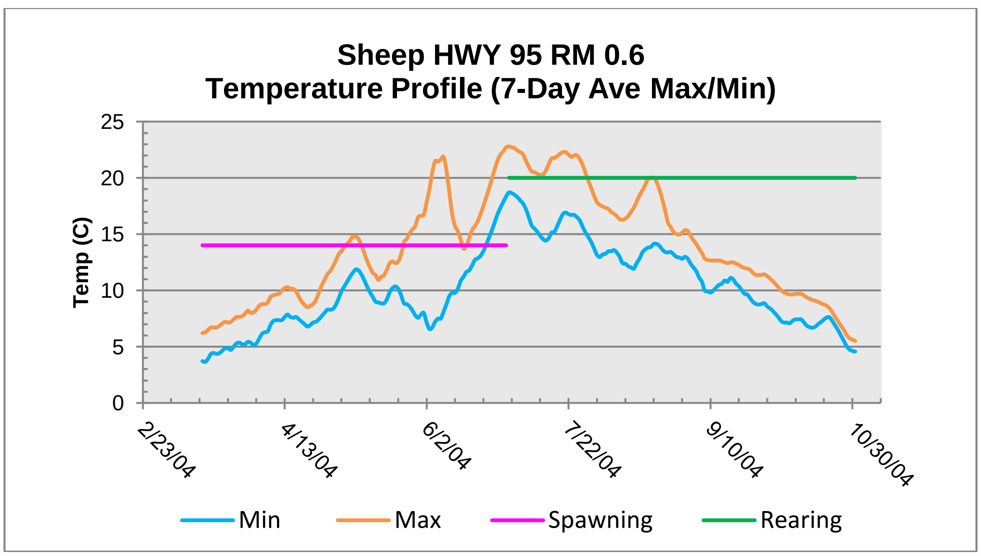


Figure C62. Average weekly maximum/minimum temperature profiles of Sheep Cr. at Highway 95 in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

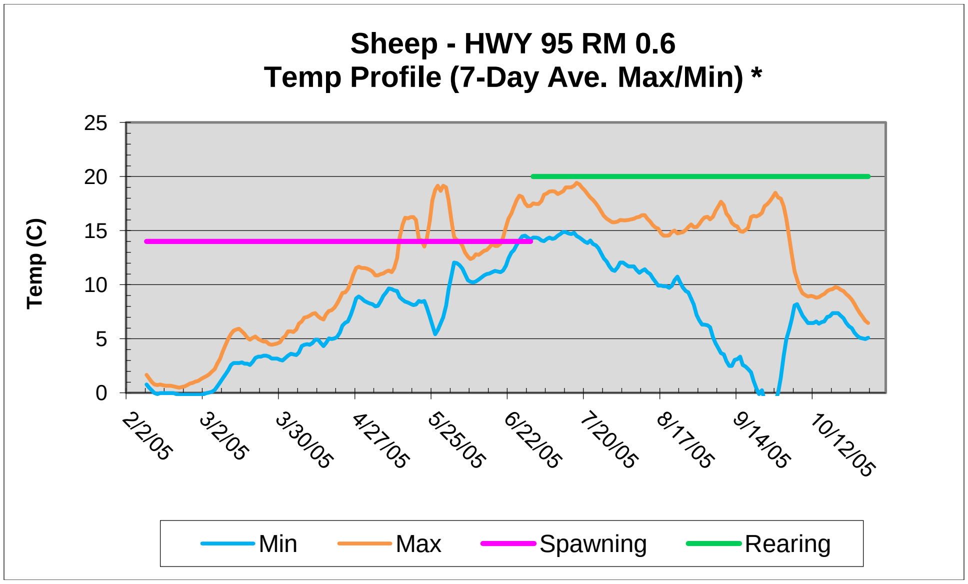


Figure C-63. Average weekly maximum/minimum temperature profiles of Sheep Cr. at Highway 95 in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning. *Device was in a stagnant pool mid August to early October

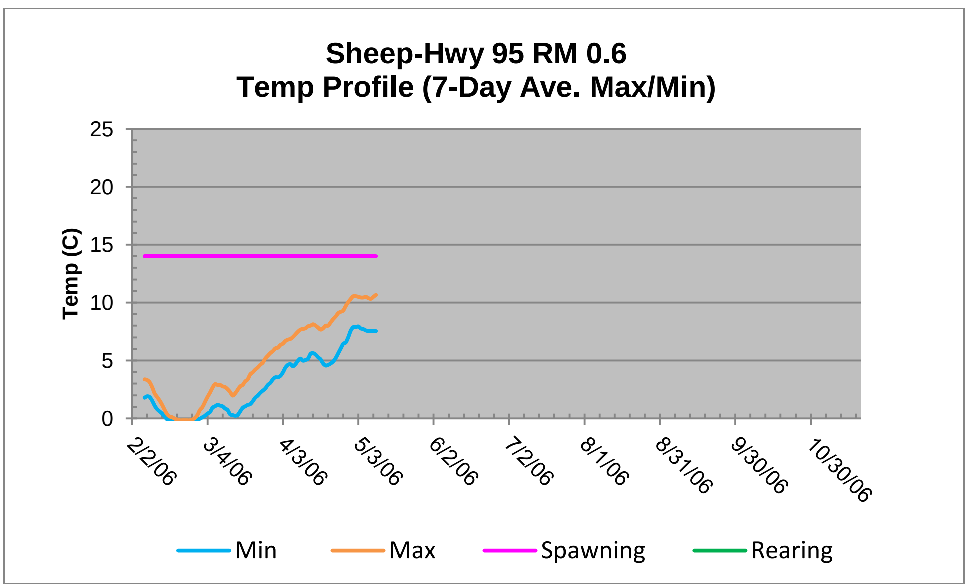


Figure C-64 Average weekly maximum/minimum temperature profiles of Sheep Cr. at Highway 95 in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning. Device was lost after May.

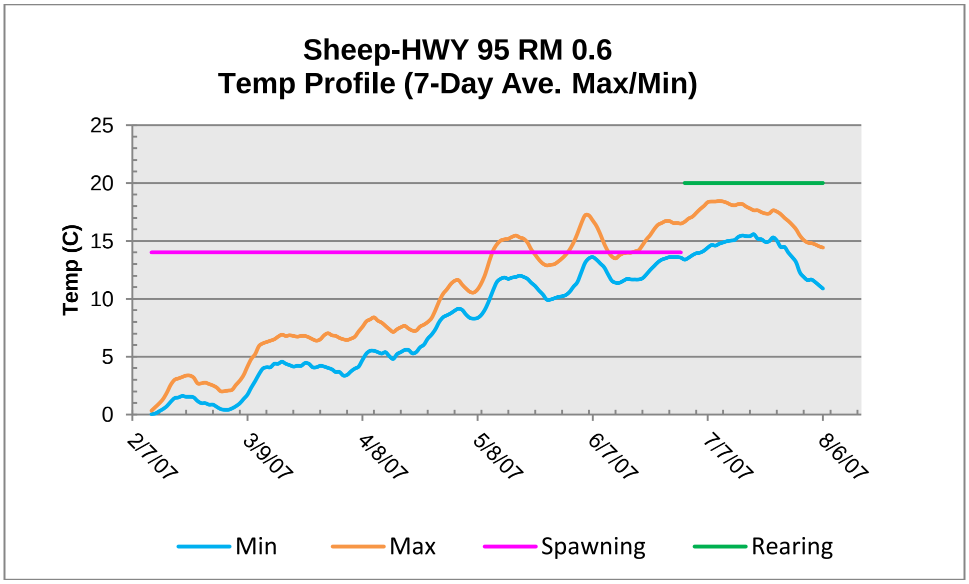


Figure C-65. Average weekly maximum/minimum temperature profiles of Sheep Cr. at Highway 95 in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

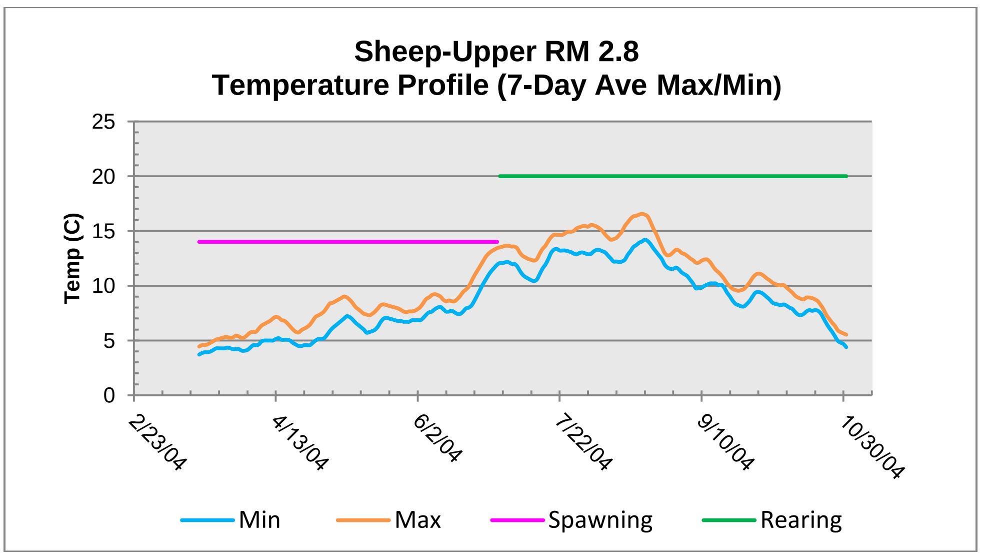


Figure C-66 Average weekly maximum/minimum temperature profiles of Upper Sheep Cr. in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

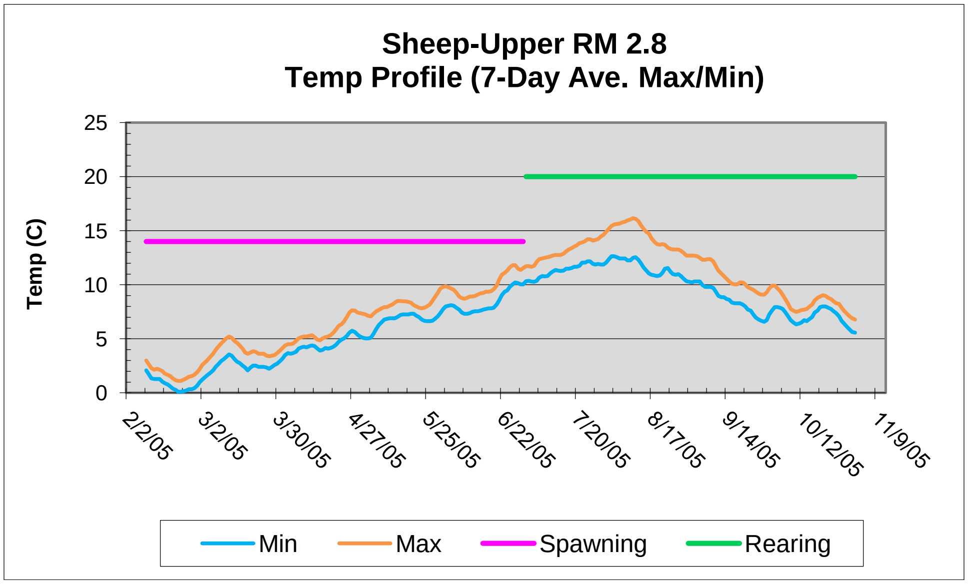


Figure C-67. Average weekly maximum/minimum temperature profiles of Upper Sheep Cr. in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

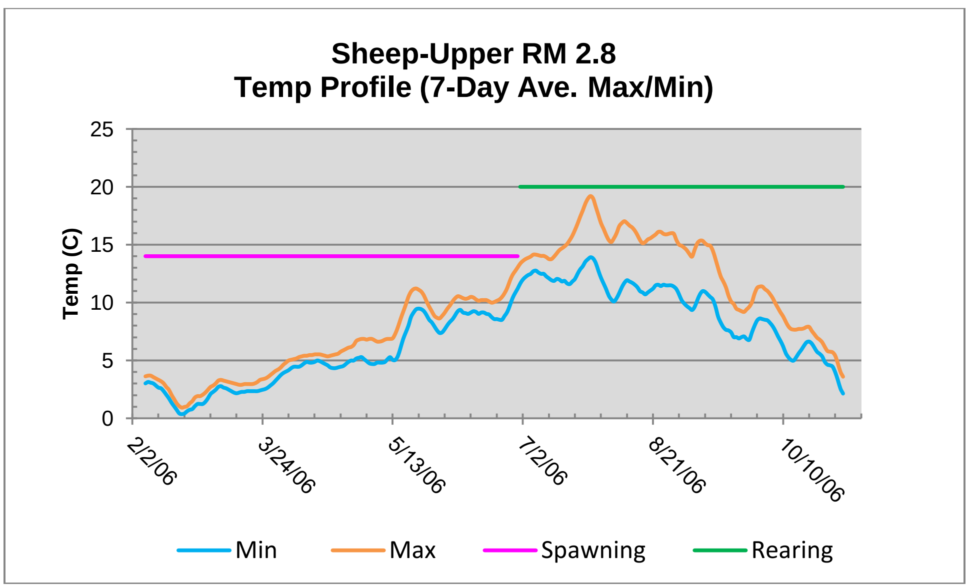


Figure C-68. Average weekly maximum/minimum temperature profiles of Upper Sheep Cr. in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

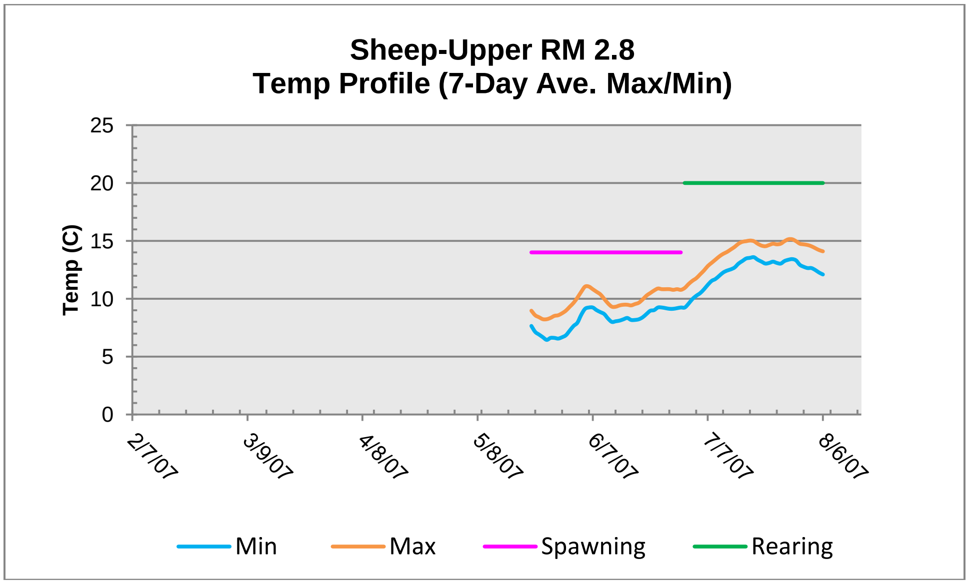


Figure C-69. Average weekly maximum/minimum temperature profiles of Upper Sheep Cr. in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

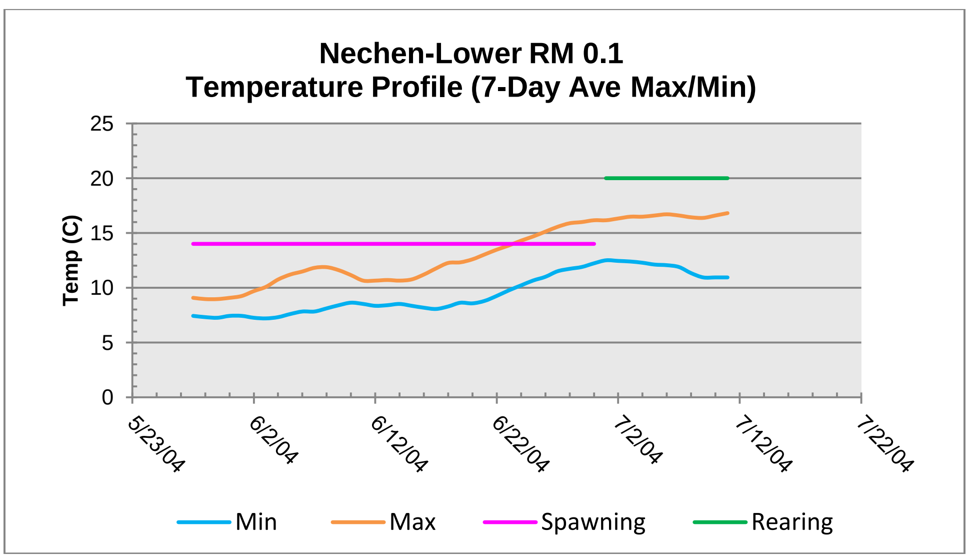


Figure C-70. Average weekly maximum/minimum temperature profiles of Lower Nehchen Cr. in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

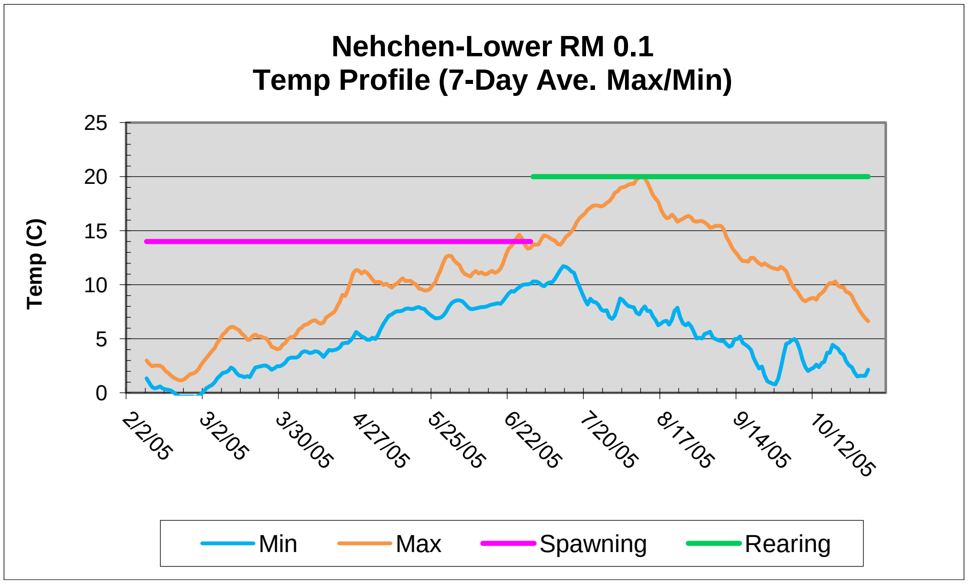


Figure C-71. Average weekly maximum/minimum temperature profiles of Lower Nehchen Cr. in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

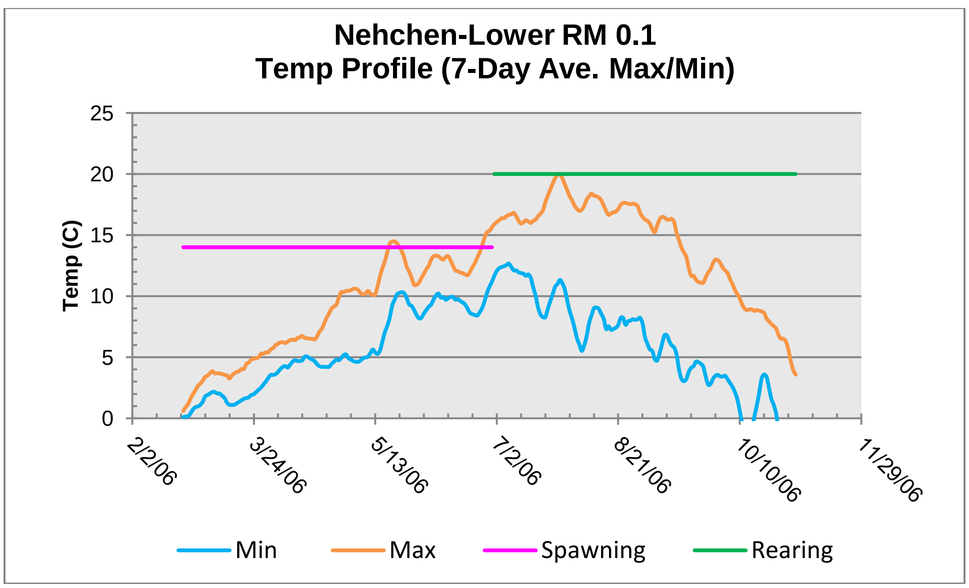


Figure C-72. Average weekly maximum/minimum temperature profiles of Lower Nehchen Cr. in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

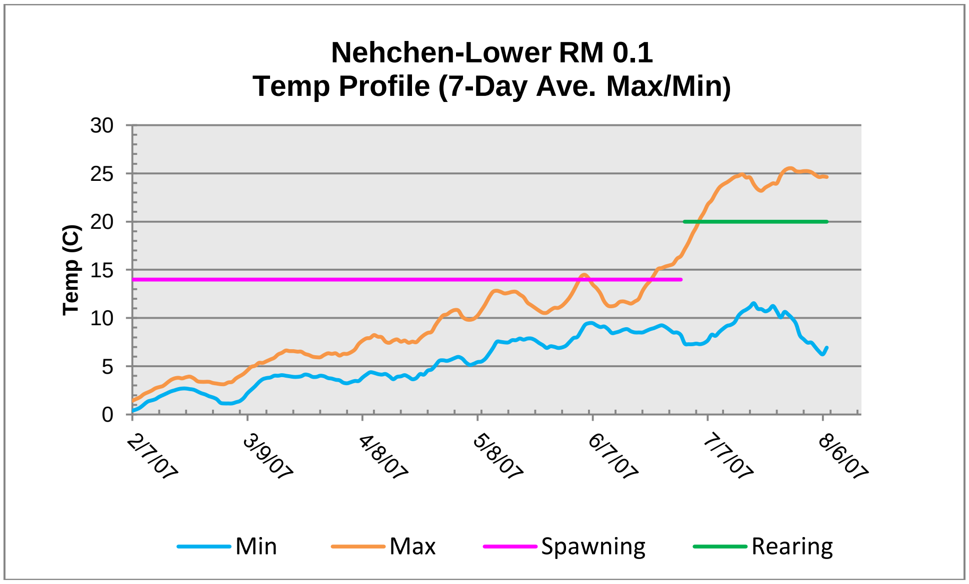


Figure C-73. Average weekly maximum/minimum temperature profiles of Lower Nehchen Cr. in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

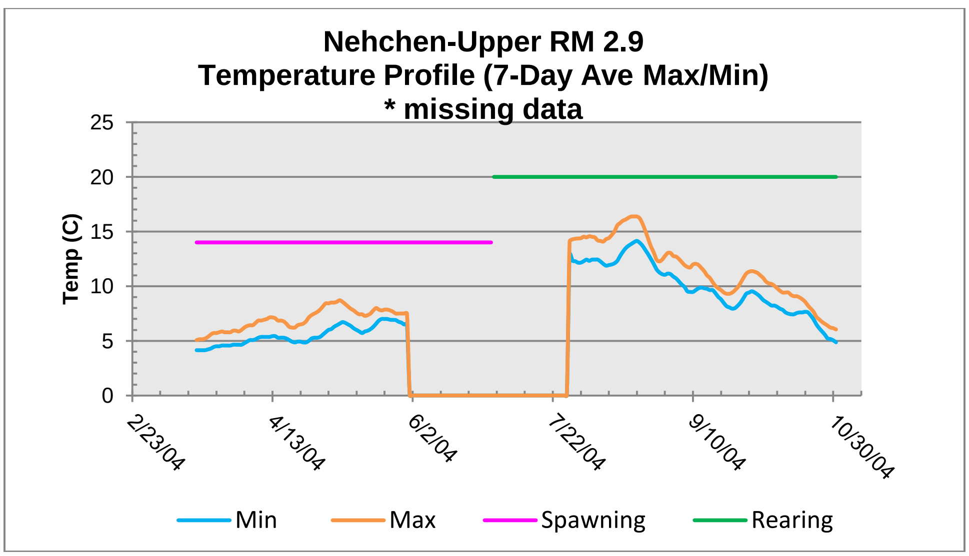


Figure C-74. Average weekly maximum/minimum temperature profiles of Upper Nehchen Cr. in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

* No data for June-July

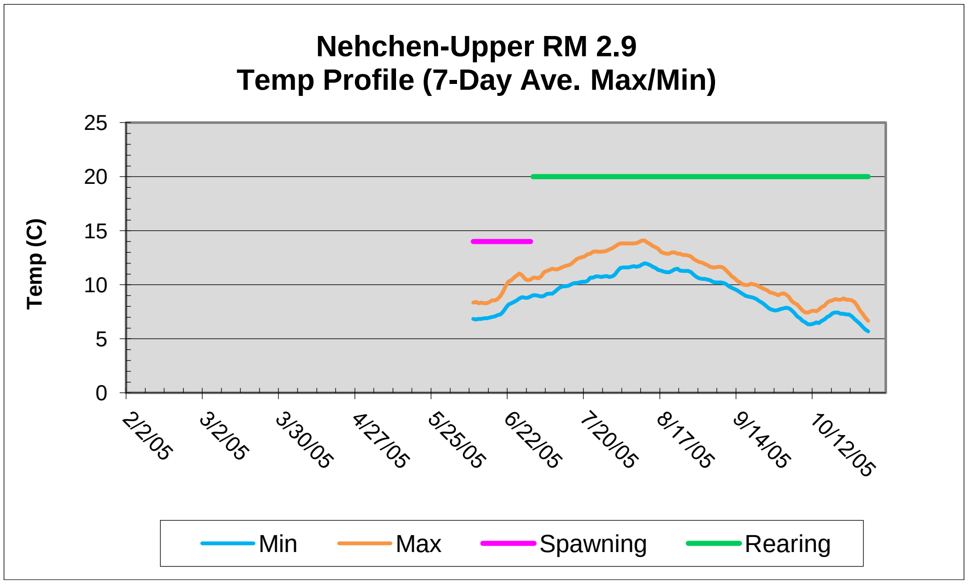


Figure C-75. Average weekly maximum/minimum temperature profiles of Upper Nehchen Cr. in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

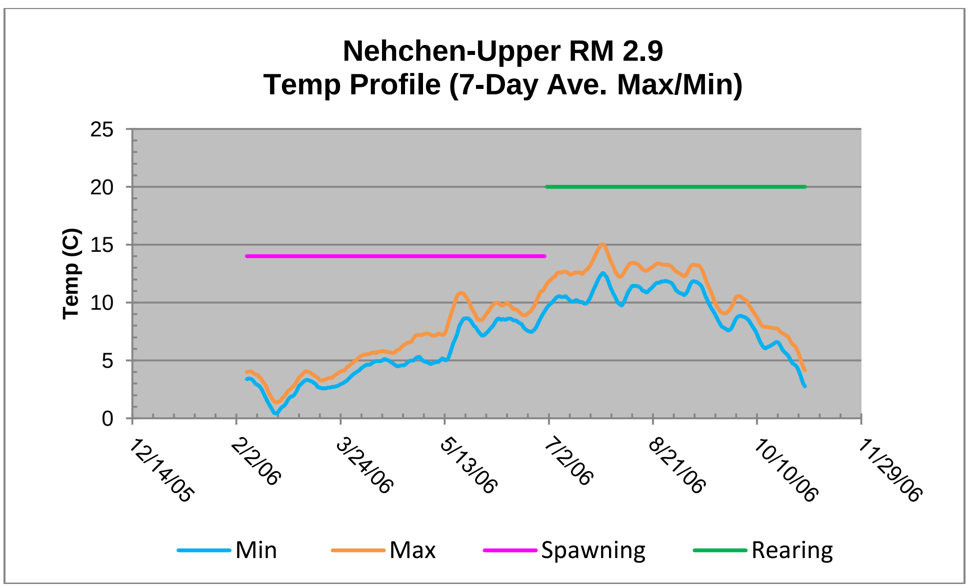


Figure C-76. Average weekly maximum/minimum temperature profiles of Upper Nehchen Cr. in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

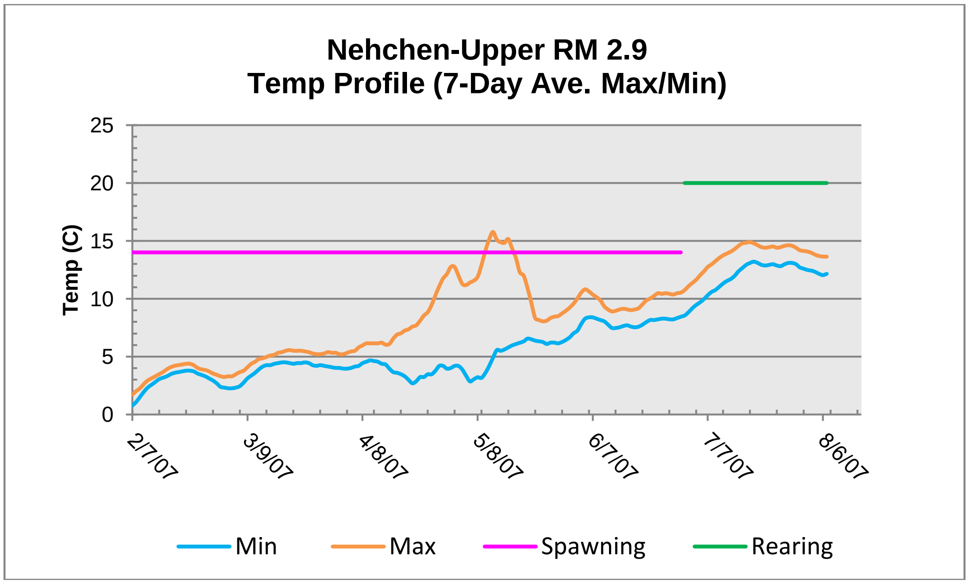


Figure C-77. Average weekly maximum/minimum temperature profiles of Upper Nehchen Cr. in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.*Temp Monitor was out of the water from 4/16/07 – 5/25/07.

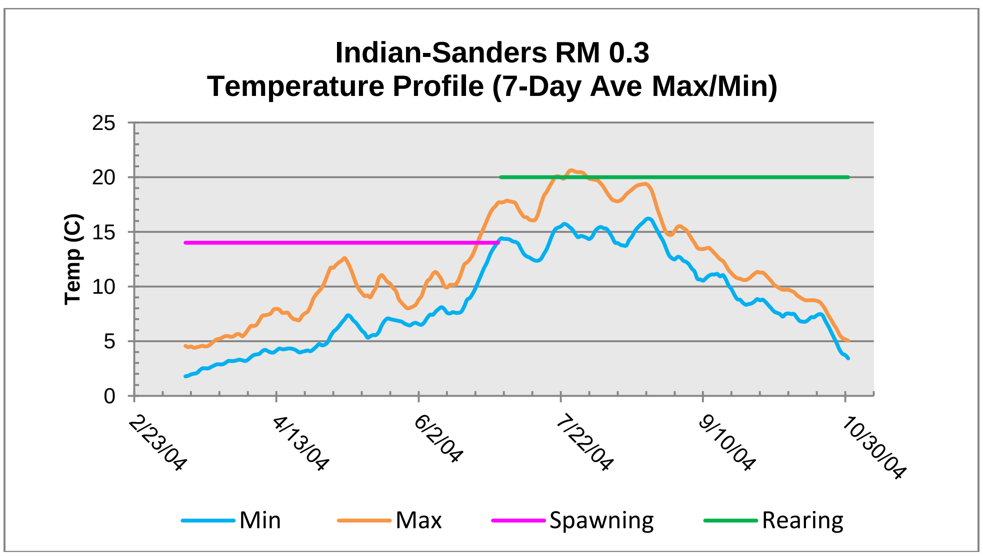


Figure C-78. Average weekly maximum/minimum temperature profiles of Indian Cr. at Sanders in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

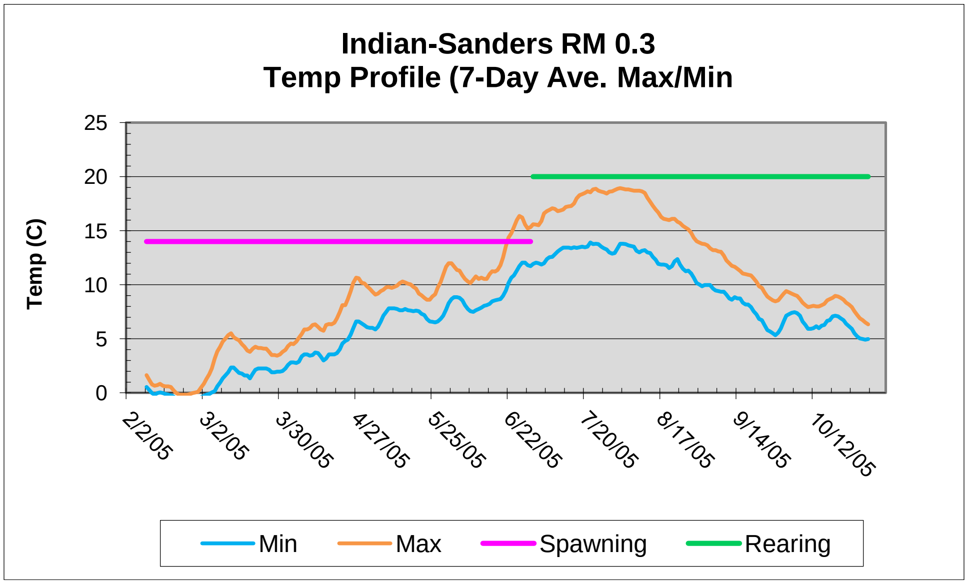


Figure C-79. Average weekly maximum/minimum temperature profiles of Indian Cr. at Sanders in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

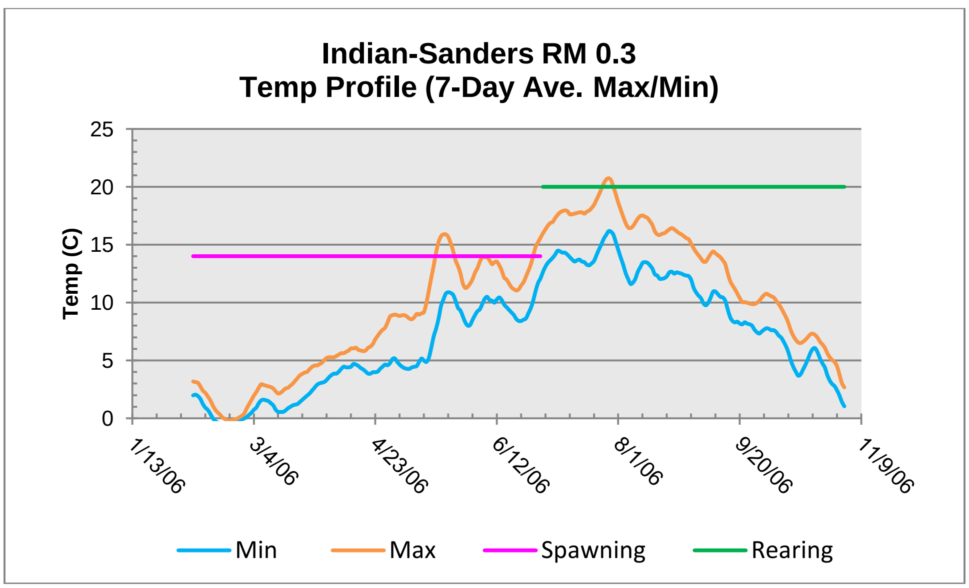


Figure C-80. Average weekly maximum/minimum temperature profiles of Indian Cr. at Sanders in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

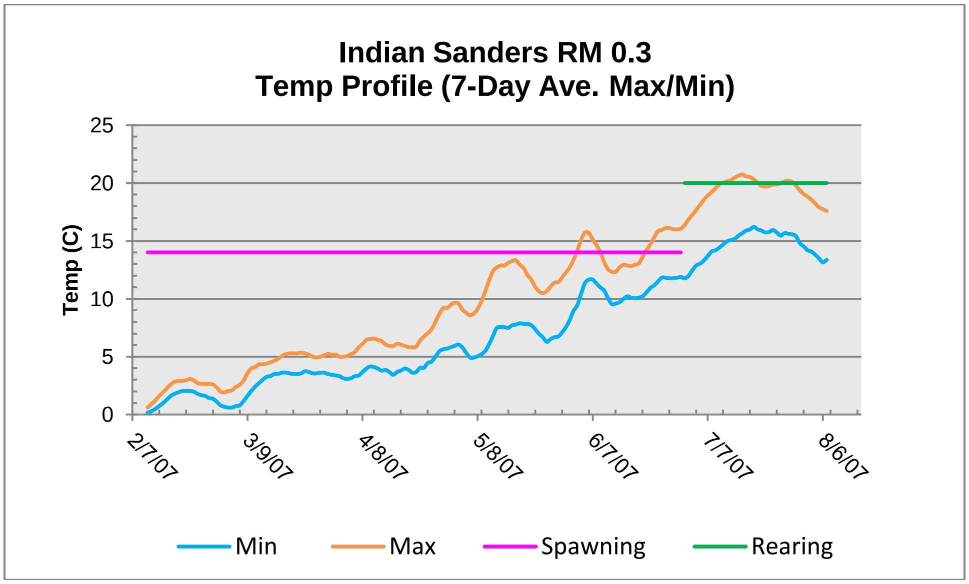


Figure C-81. Average weekly maximum/minimum temperature profiles of Indian Cr. at Sanders in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

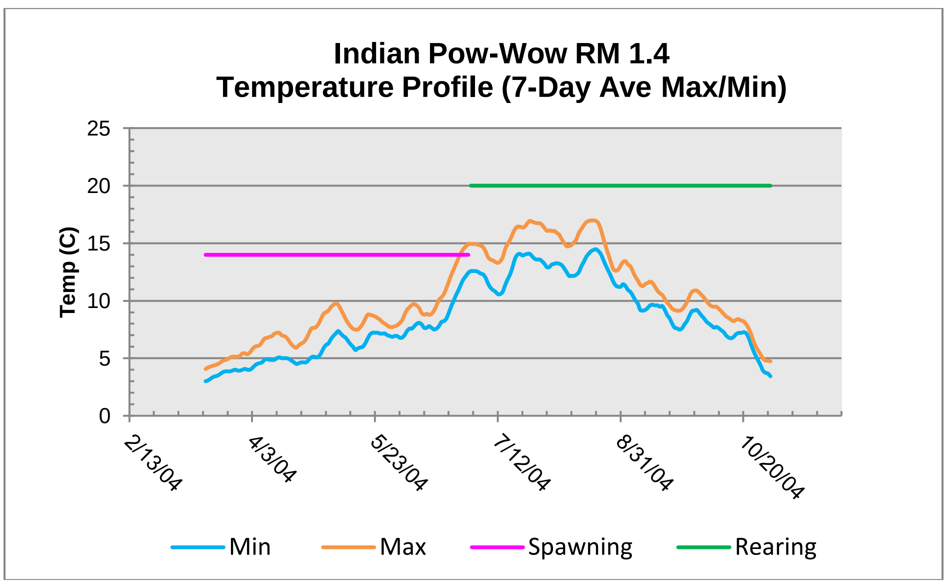


Figure C-82. Average weekly maximum/minimum temperature profiles of Indian Cr. at Pow Wow Grounds in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

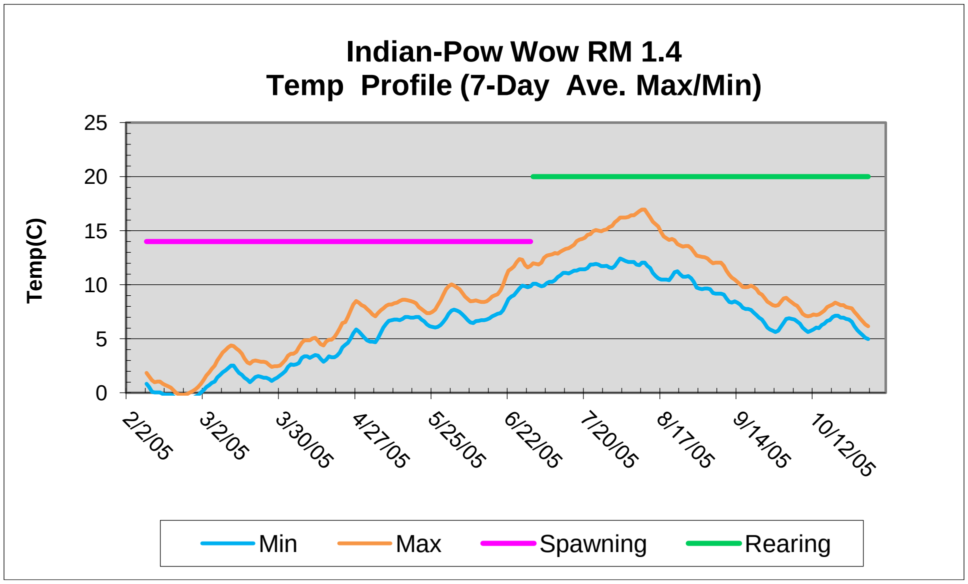


Figure C-83. Average weekly maximum/minimum temperature profiles of Indian Cr. at Pow Wow in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

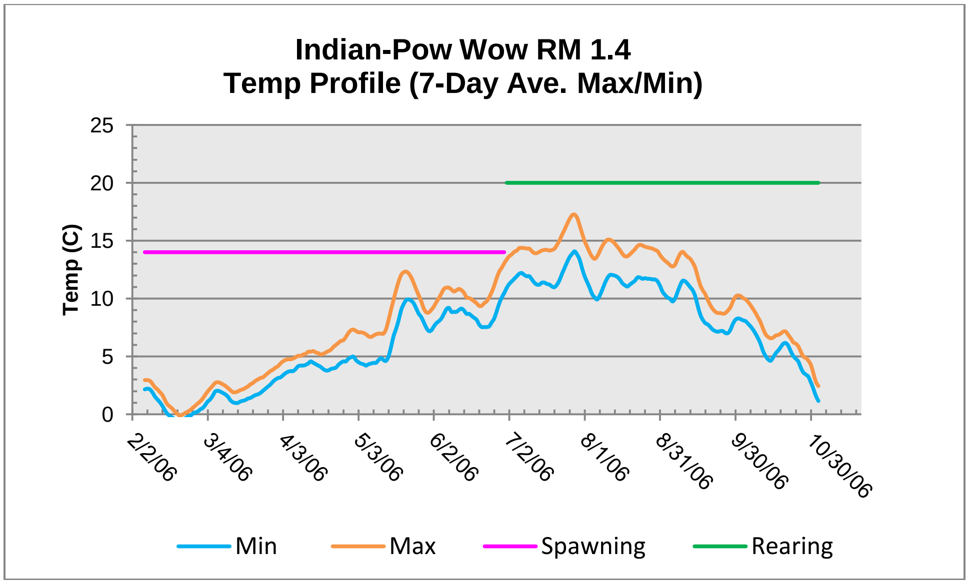


Figure C-84. Average weekly maximum/minimum temperature profiles of Indian Cr. at Pow Wow in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

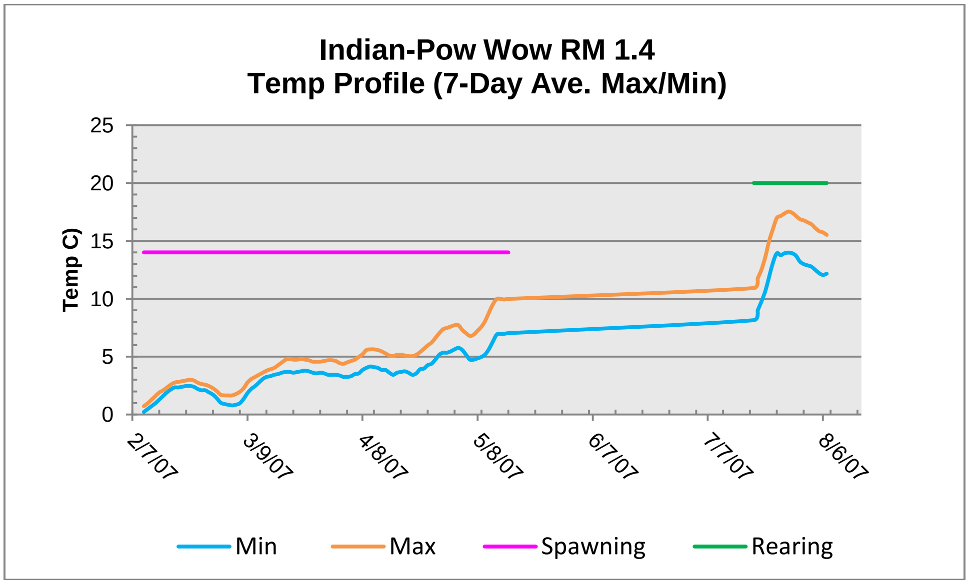


Figure C-85. Average weekly maximum/minimum temperature profiles of Indian Cr. at Pow Wow Grounds in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning. * No data early May-mid July

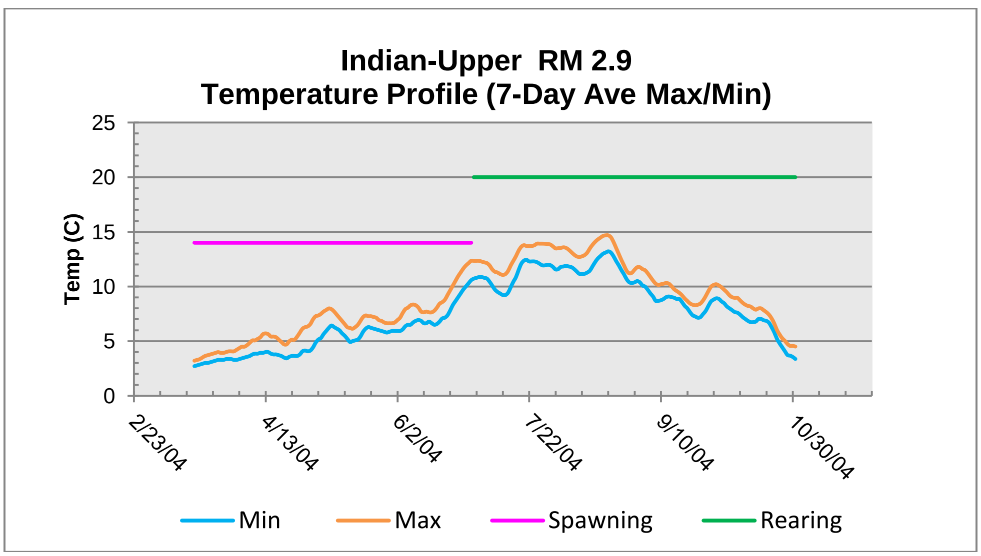


Figure C-86. Average weekly maximum/minimum temperature profiles of Upper Indian Cr. in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

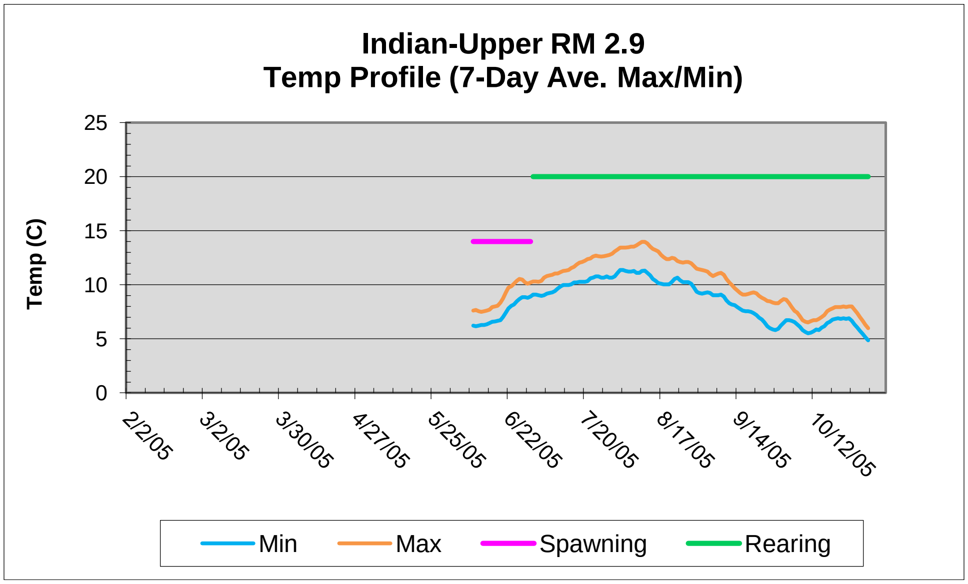


Figure C-87. Average weekly maximum/minimum temperature profiles of Upper Indian Cr. in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

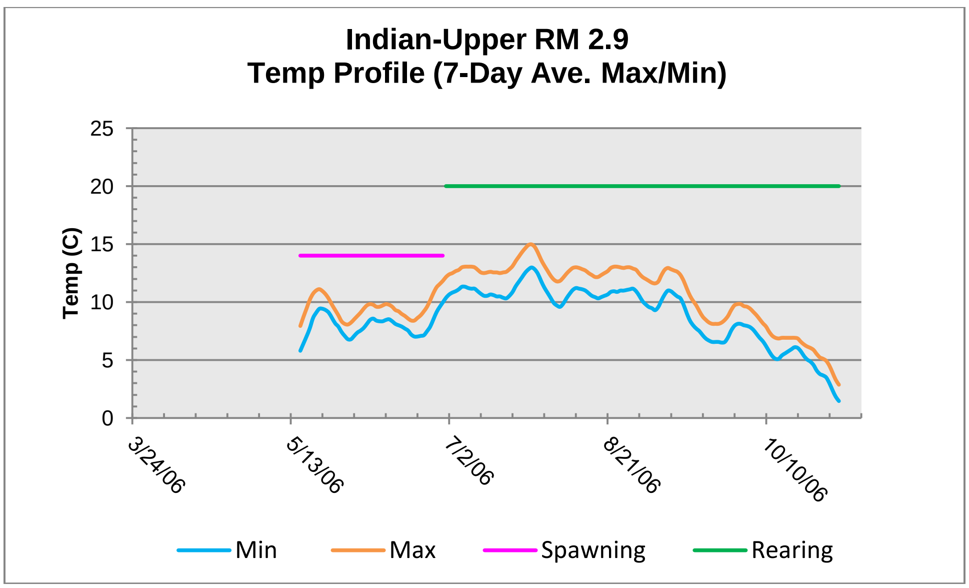


Figure C-88. Average weekly maximum/minimum temperature profiles of Upper Indian Cr. in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

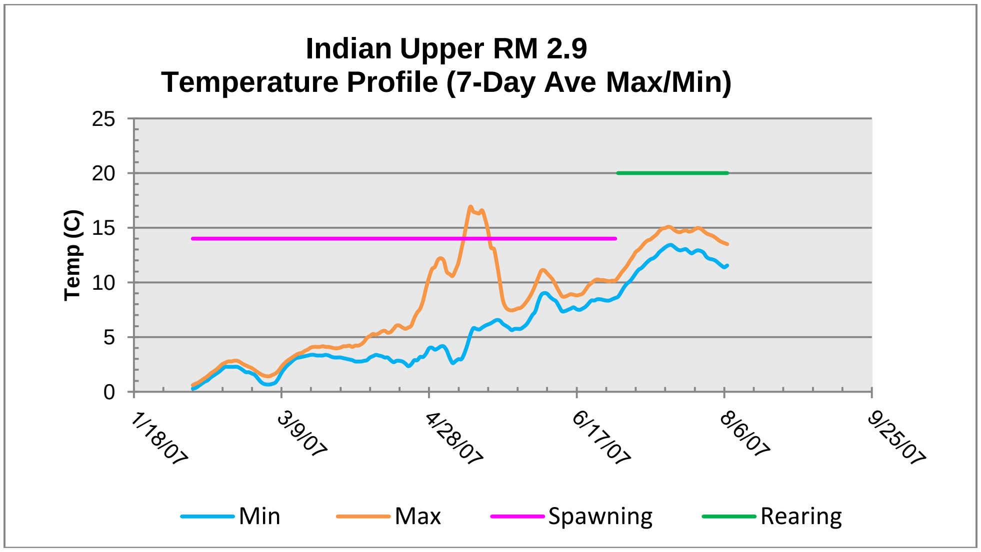


Figure C-89. Average weekly maximum/minimum temperature profiles of Upper Indian Cr. in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning. * Temp monitor was out of the water 4/4/07 – 5/23/07.

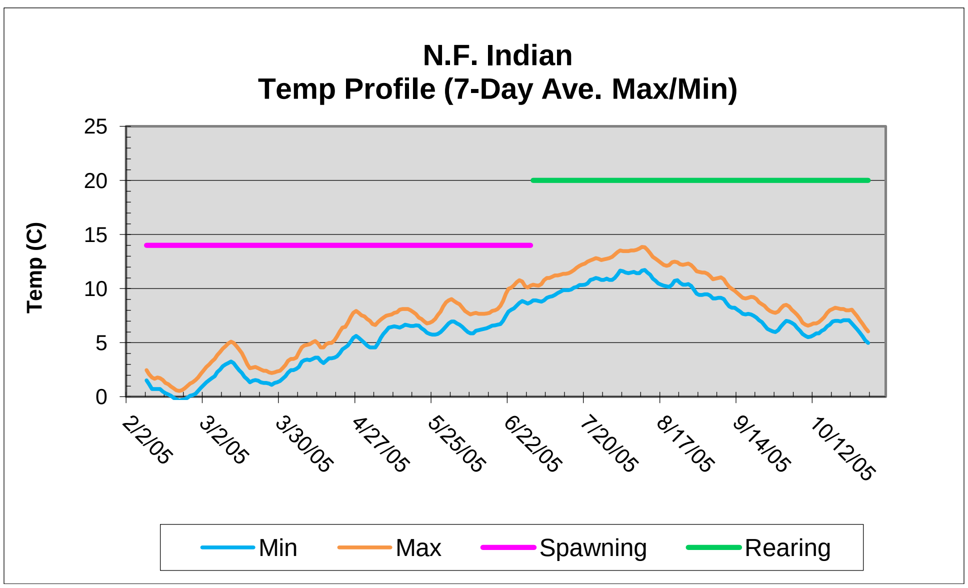


Figure C-90. Average weekly maximum/minimum temperature profiles of the NF Indian Cr. in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

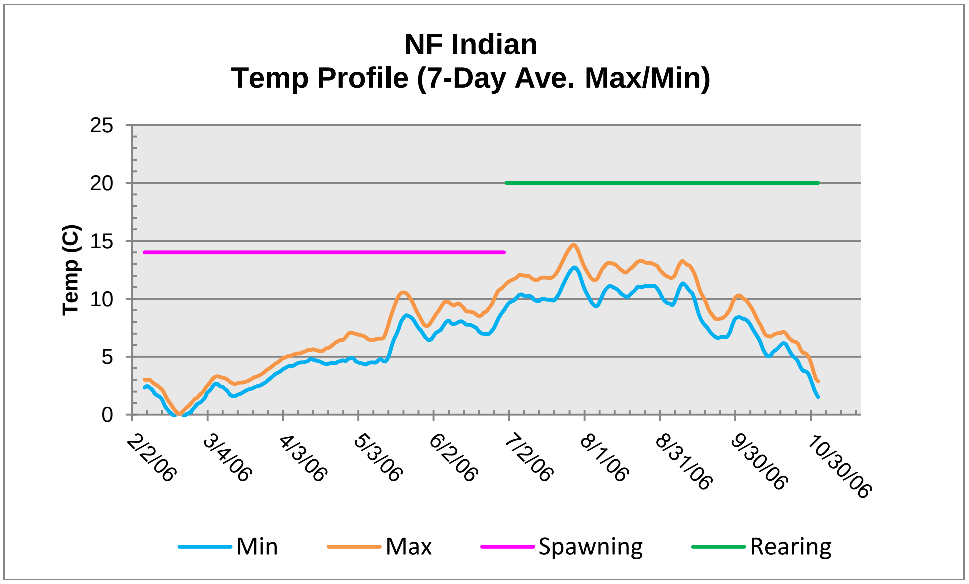


Figure C-91. Average weekly maximum/minimum temperature profiles of the NF Indian Cr. in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

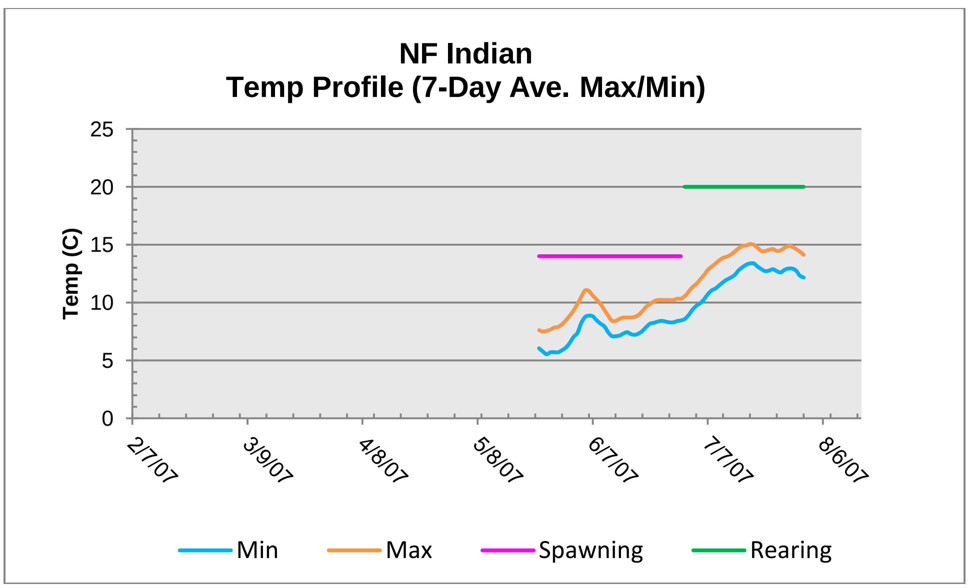


Figure C-92. Average weekly maximum/minimum temperature profiles of the NF Indian Cr. in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

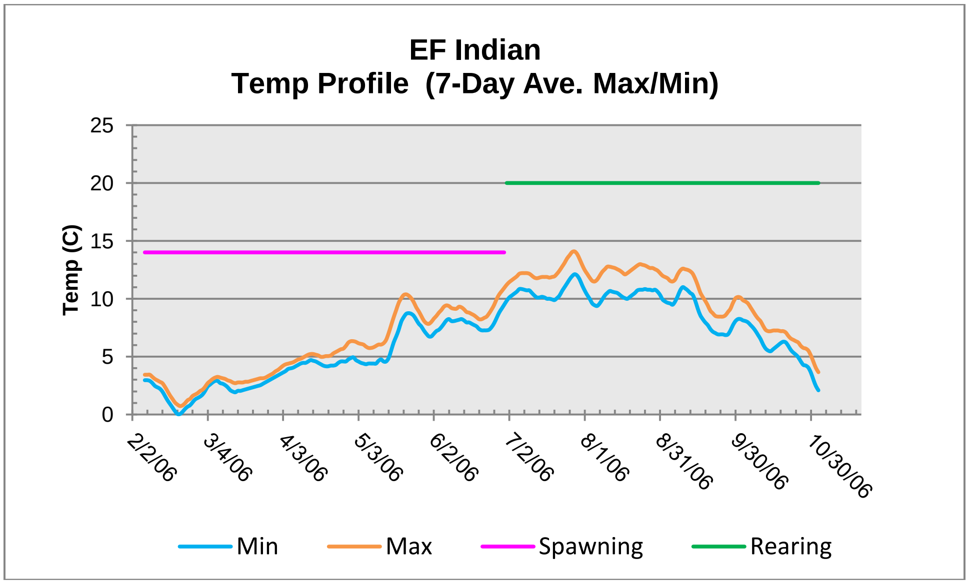


Figure C-93. Average weekly maximum/minimum temperature profiles of the EF Indian Cr. in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

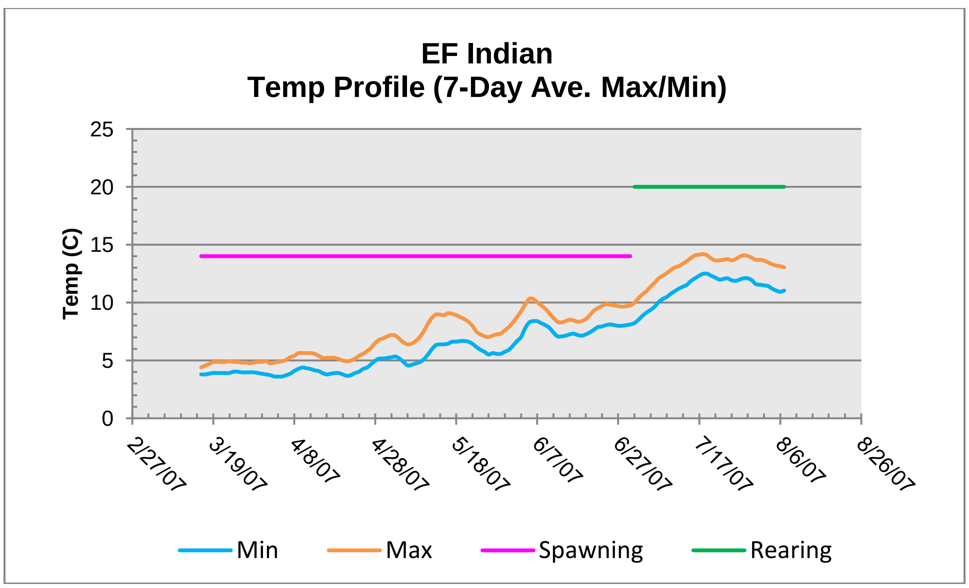


Figure C-94. Average weekly maximum/minimum temperature profiles of the EF Indian Cr. in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

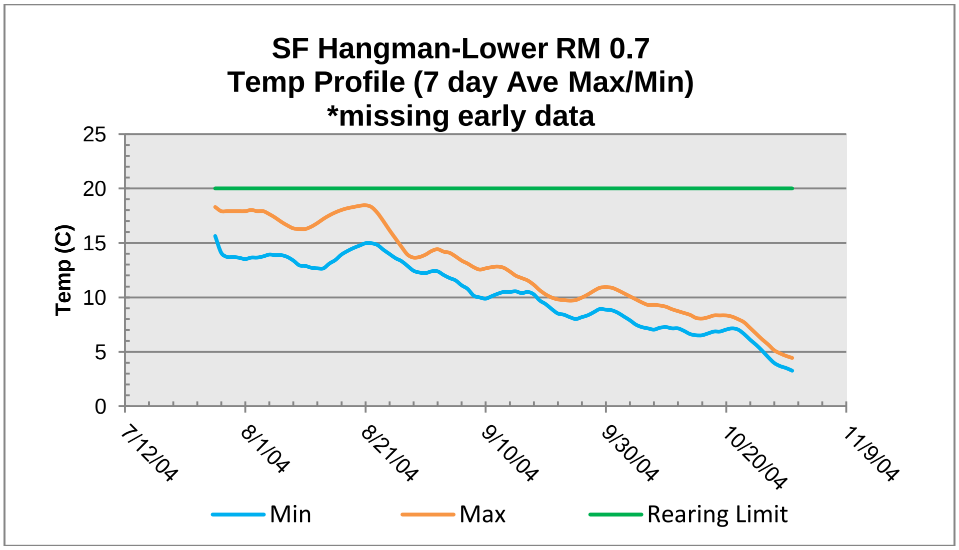


Figure C-95. Average weekly maximum/minimum temperature profiles of Lower SF Hangman Cr. in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

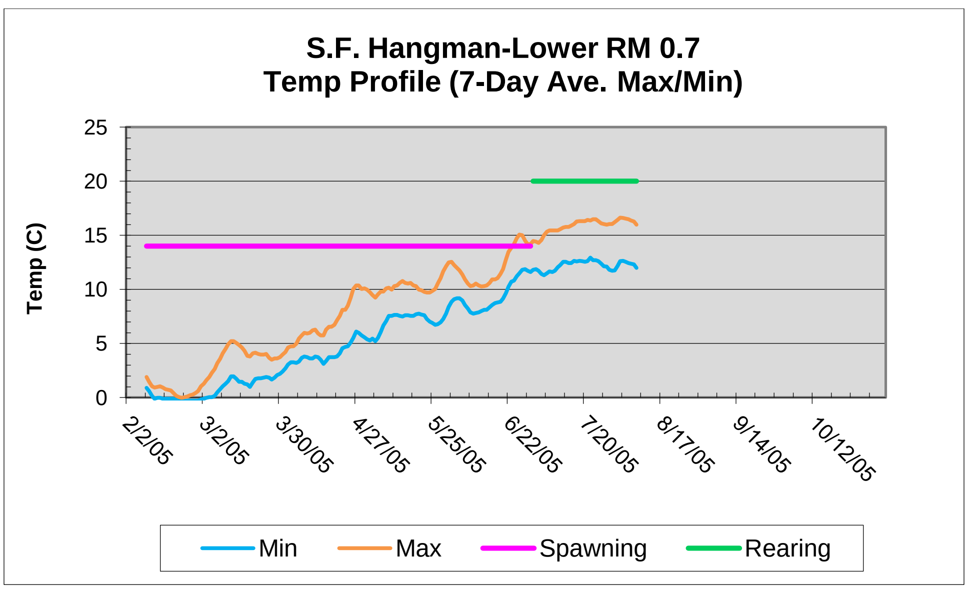


Figure C-96. Average weekly maximum/minimum temperature profiles of Lower SF Hangman Cr. in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

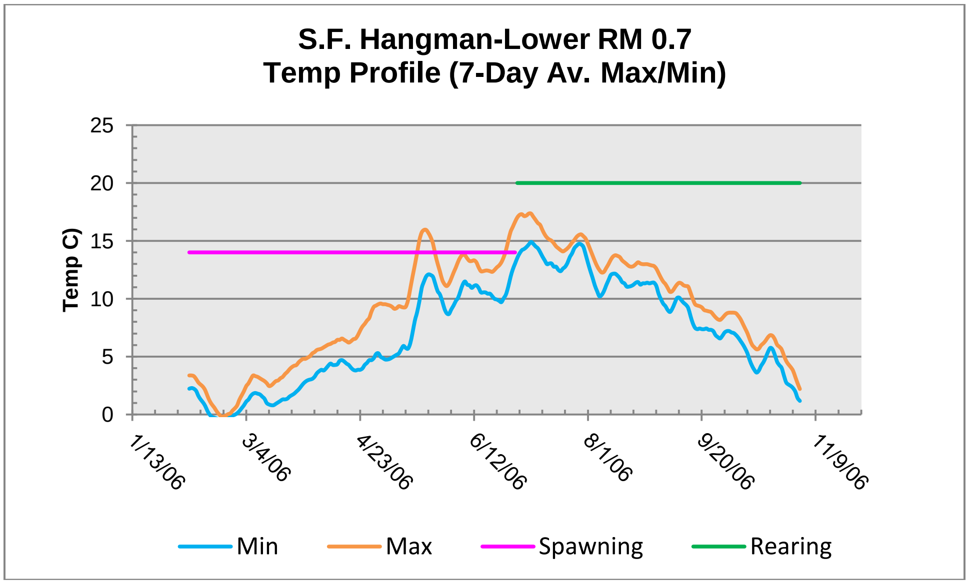


Figure C-97. Average weekly maximum/minimum temperature profiles of Lower SF Hangman Cr. in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

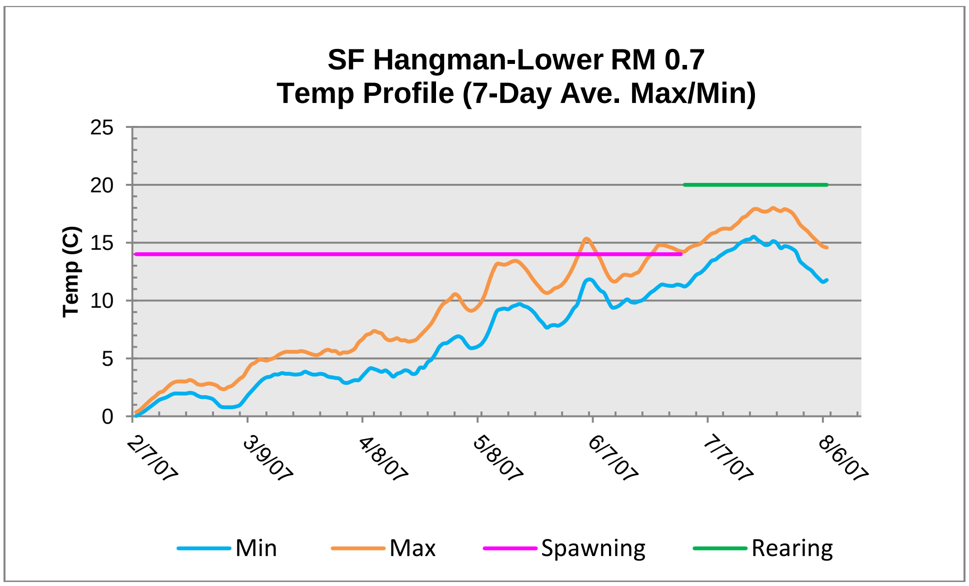


Figure C-98. Average weekly maximum/minimum temperature profiles of Lower SF Hangman Cr. in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

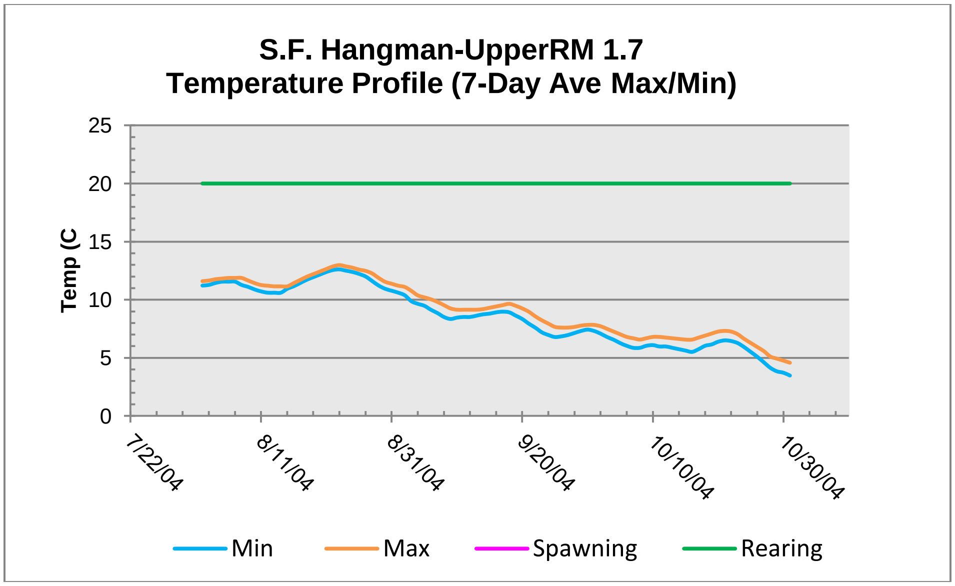


Figure C-99. Average weekly maximum/minimum temperature profiles of Upper SF Hangman Cr. in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

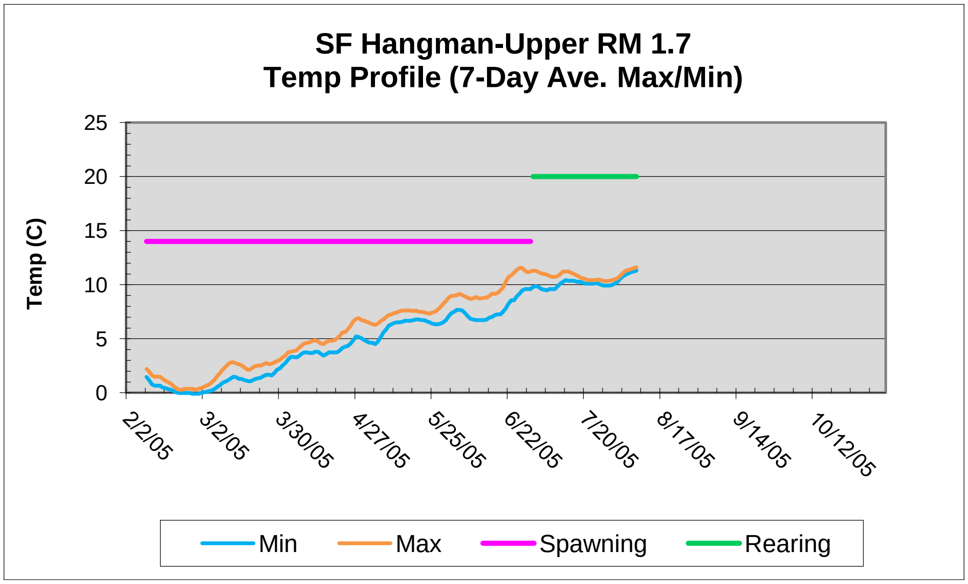


Figure C-100. Average weekly maximum/minimum temperature profiles of Upper SF Hangman Cr. in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

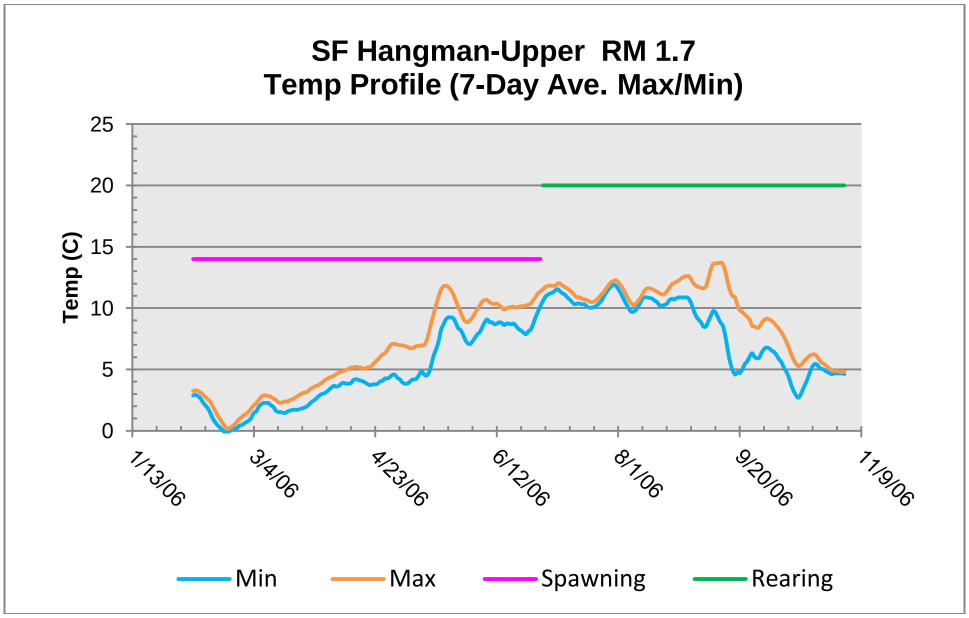


Figure C-101. Average weekly maximum/minimum temperature profiles of Upper SF Hangman Cr. in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

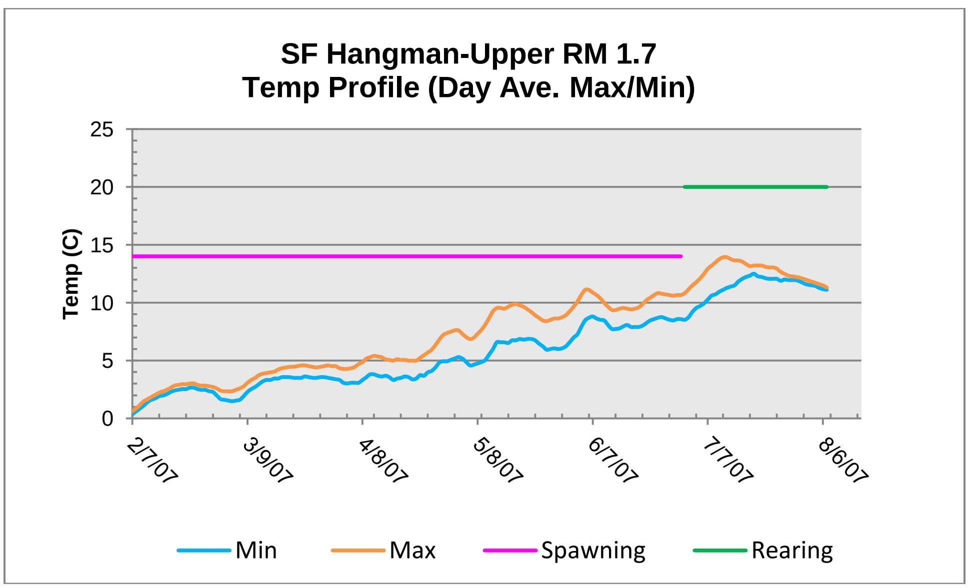


Figure C-102. Average weekly maximum/minimum temperature profiles of Upper SF Hangman Cr. in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

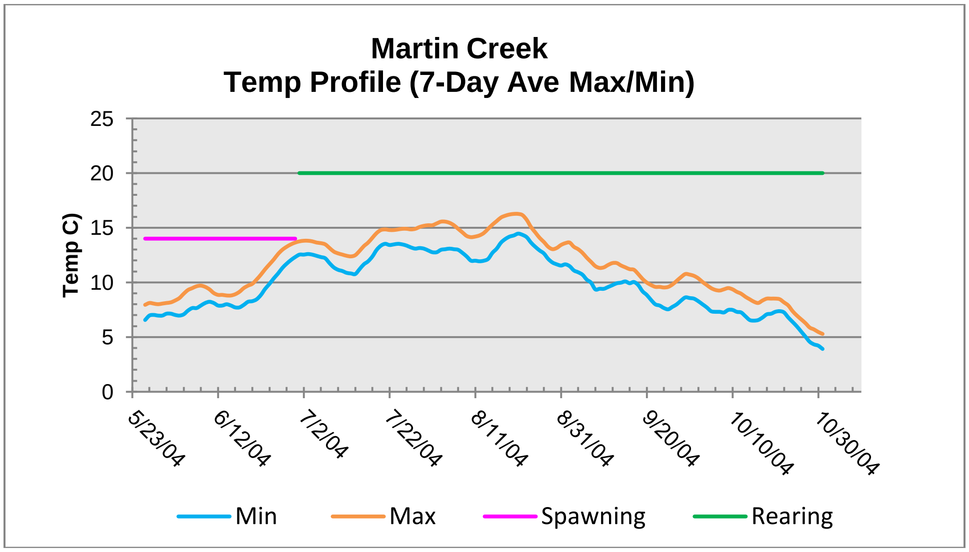


Figure C-103. Average weekly maximum/minimum temperature profiles for Martin Cr. in 2004 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

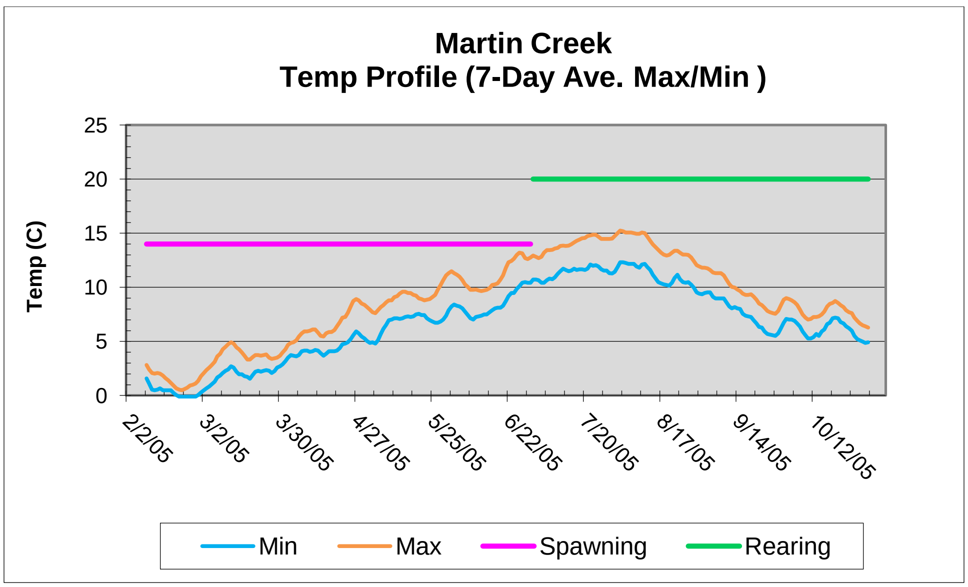


Figure C-104 Average weekly maximum/minimum temperature profiles for Martin Cr. in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

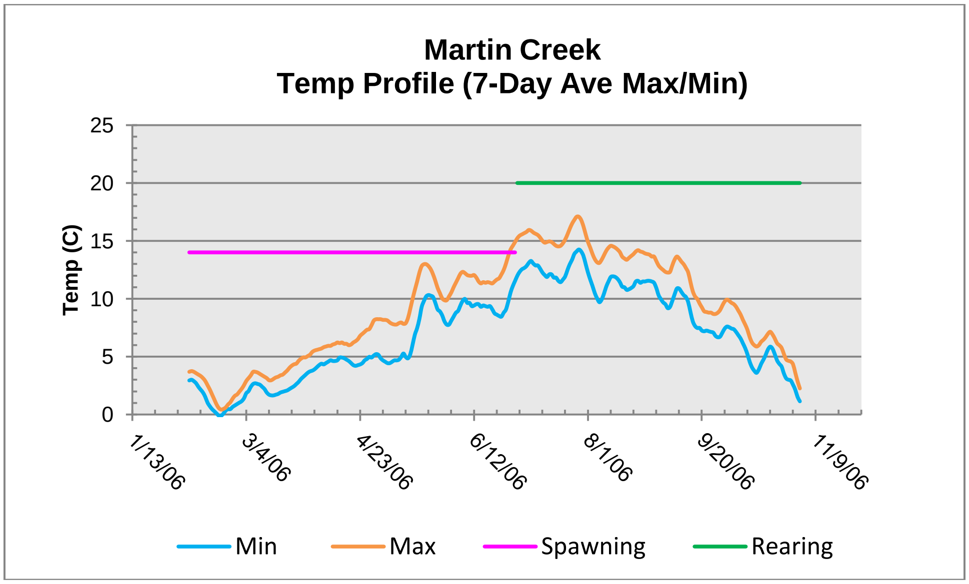


Figure C-105. Average weekly maximum/minimum temperature profiles for Martin Cr. in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

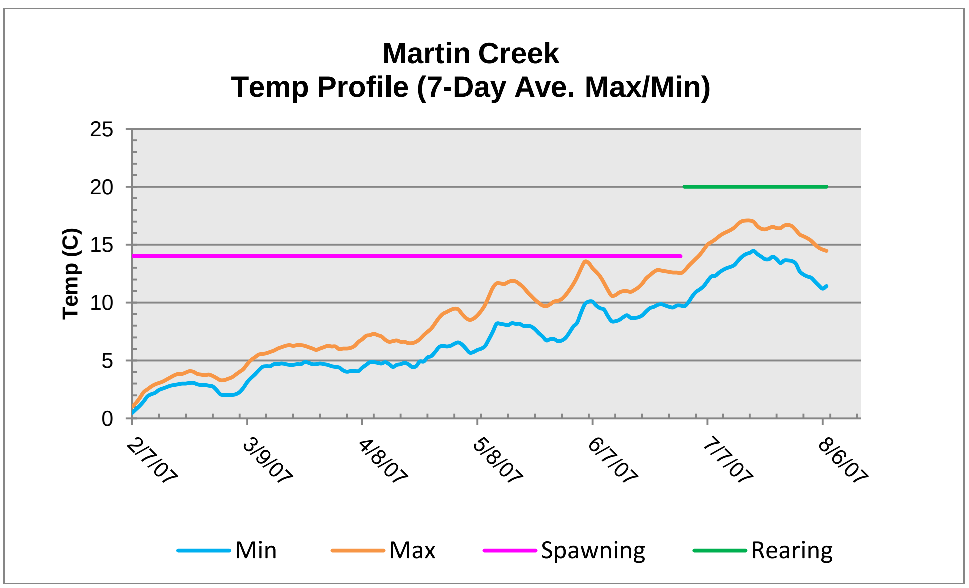


Figure C-106. Average weekly maximum/minimum temperature profiles for Martin Cr. in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

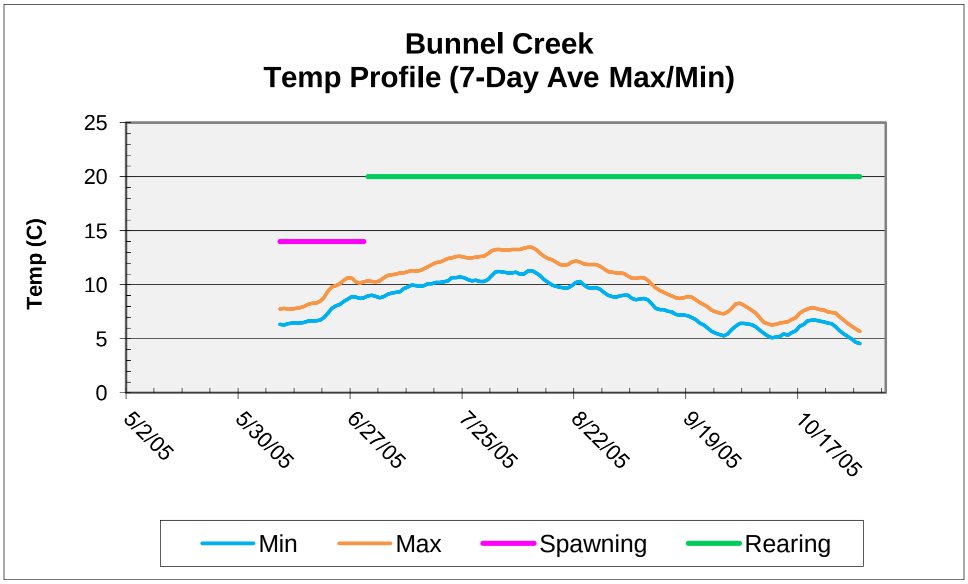


Figure C-107. Average weekly maximum/minimum temperature profiles for Bunnel Cr. in 2005 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

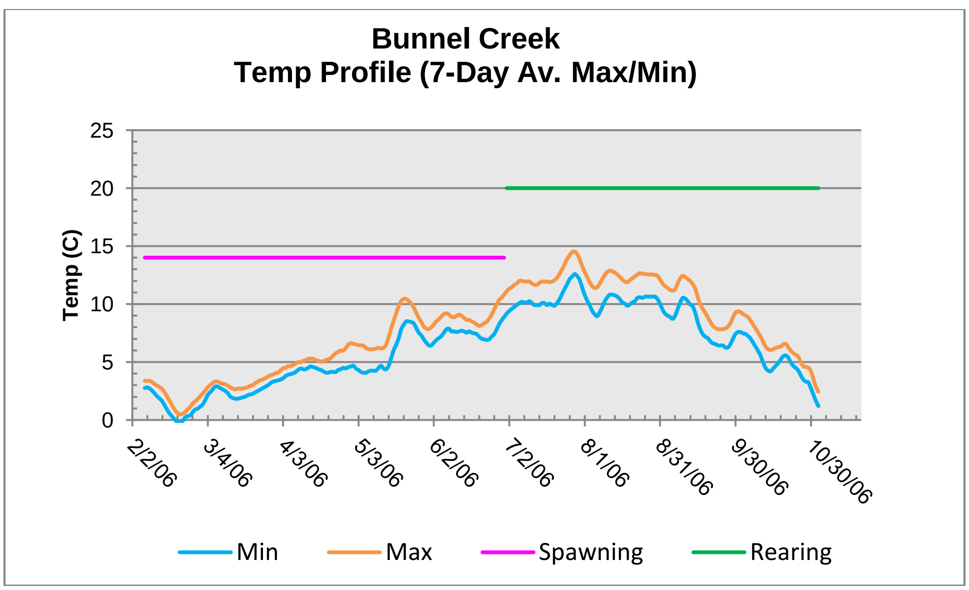


Figure C-108. Average weekly maximum/minimum temperature profiles for Bunnel Cr. in 2006 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

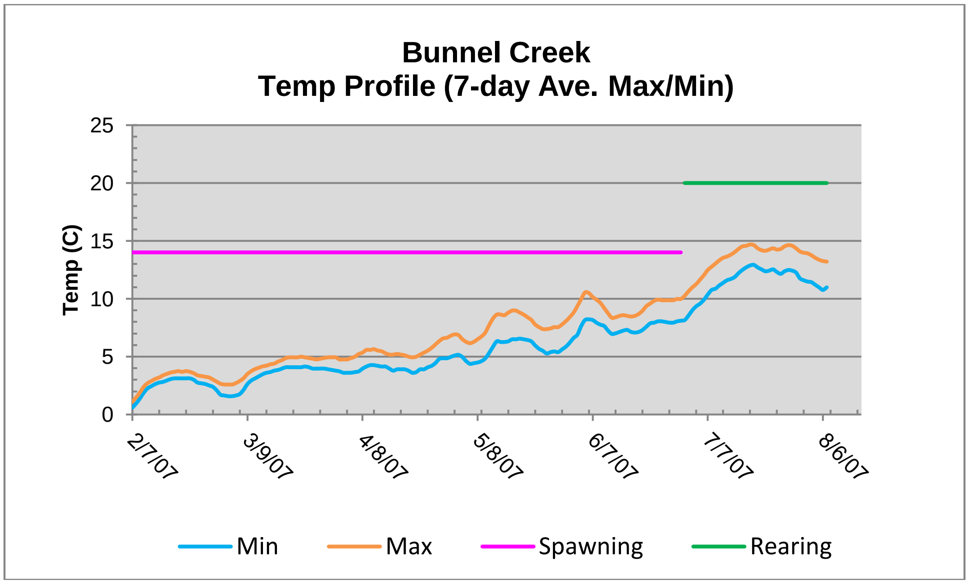


Figure C-109. Average weekly maximum/minimum temperature profiles for Bunnel Cr. in 2007 marked with optimum/critical ranges for salmonids. Green line estimates rearing limit temperature, and the pink is the beneficial uses limit set by IDDEQ for salmonid spawning.

9.5 Appendix D: Watershed Scale Maps of Electroshocking Sample Sites and Raw Data.

Watershed specific maps of sample sites for summer electroshocking is shown in Figures D-1 thru D-8 for Mission, Sheep, Nehchen, and Indian.

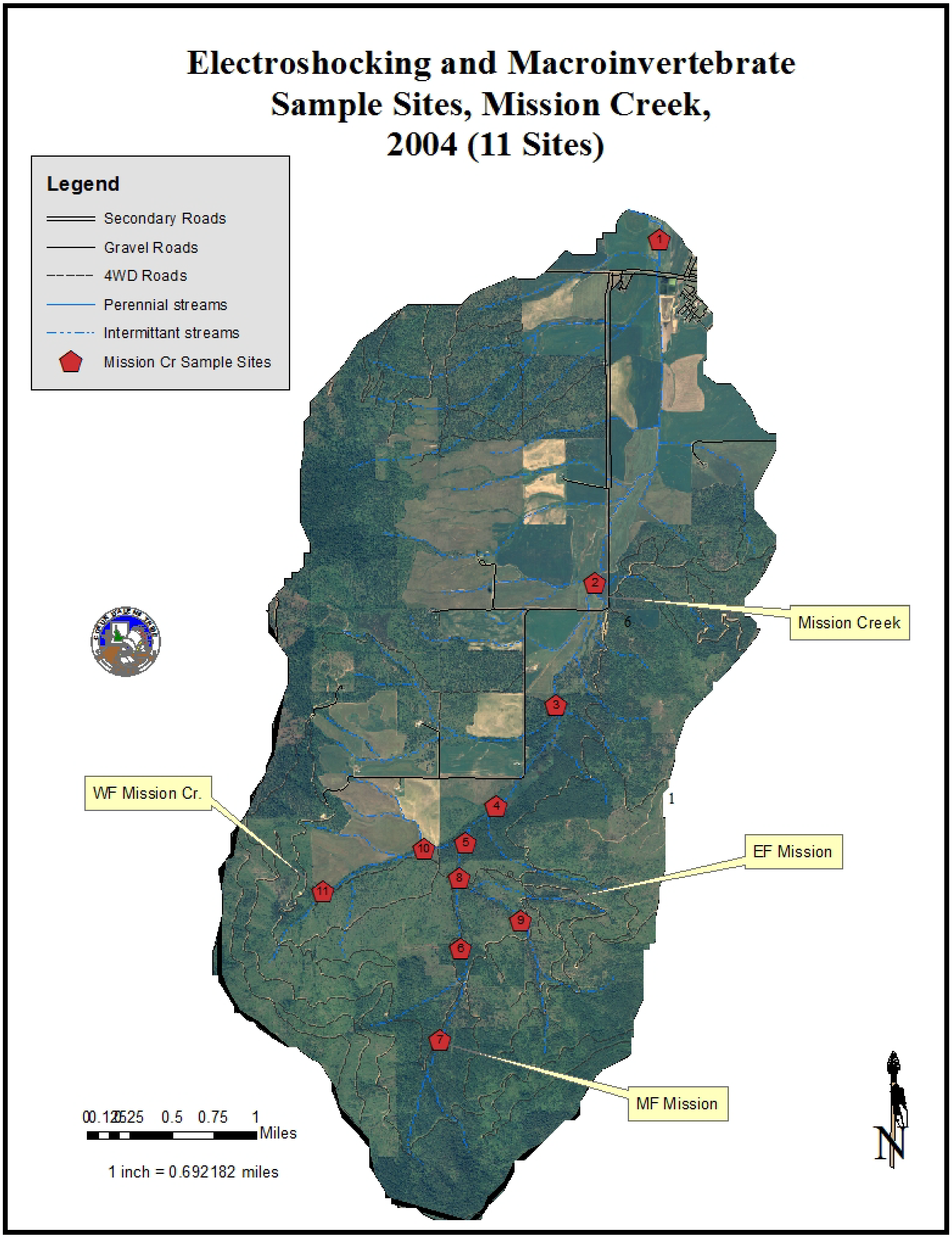


Figure D-1. Sample locations for electro-shocking and macro-invertebrates in the Mission Creek watershed during 2004.

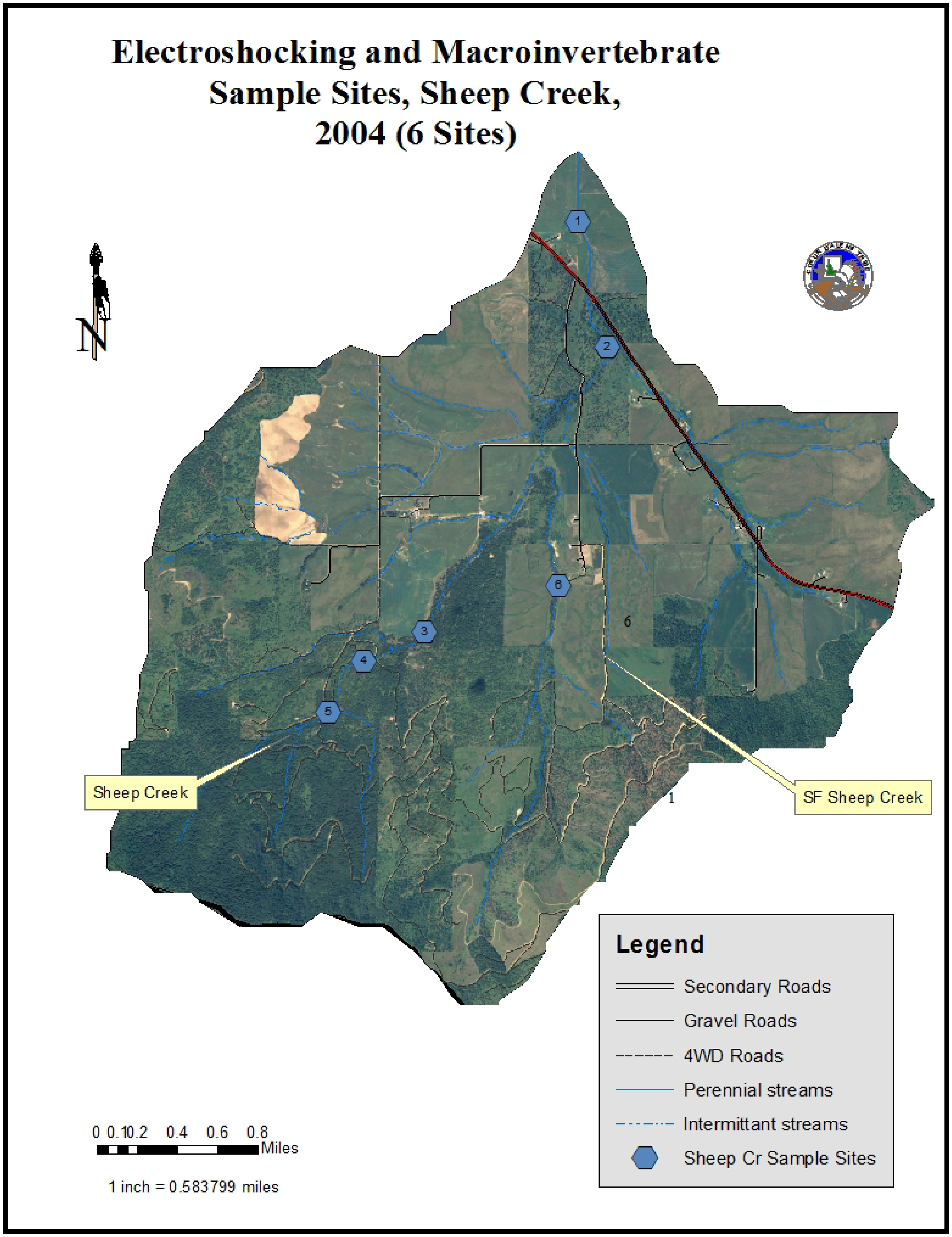


Figure D-2. Sample locations for electro-shocking and macro-invertebrates in the Sheep Creek watershed during 2004.

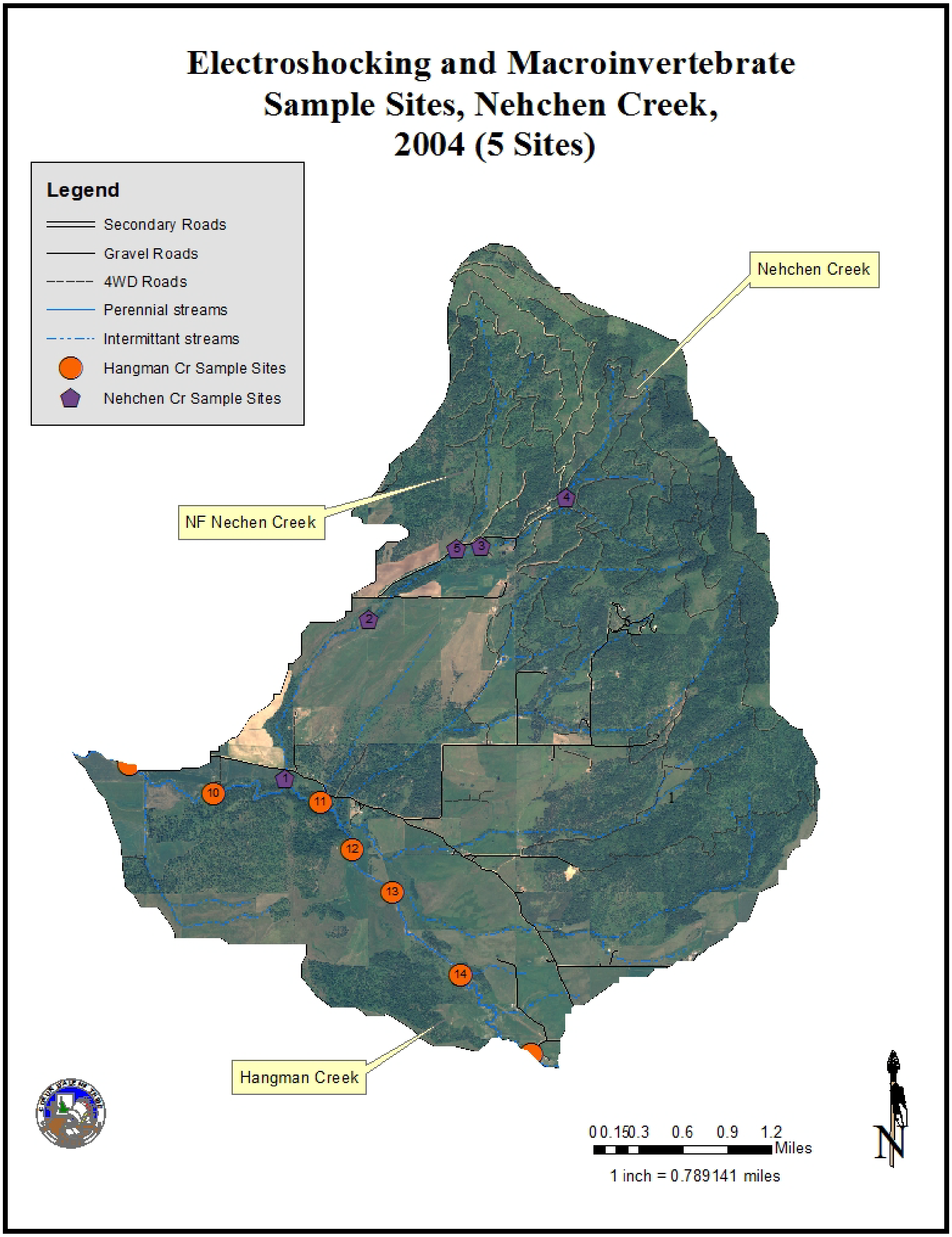


Figure D-3. Sample locations for electro-shocking and macroinvertebrates in the Nehchen Creek watershed during 2004.

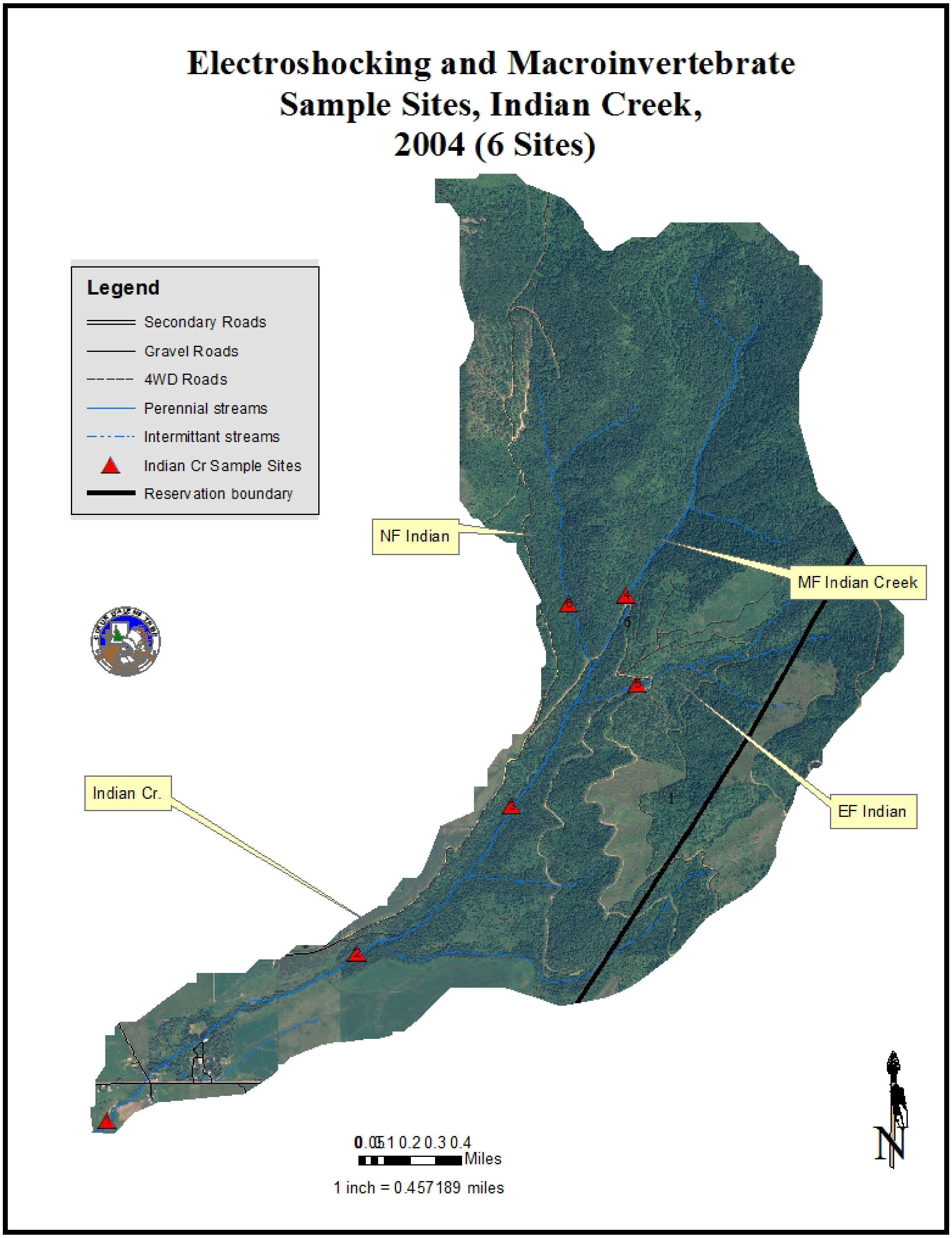


Figure D-4. Sample locations for electro-shocking and macro-invertebrates in the Indian Creek watershed during 2004.

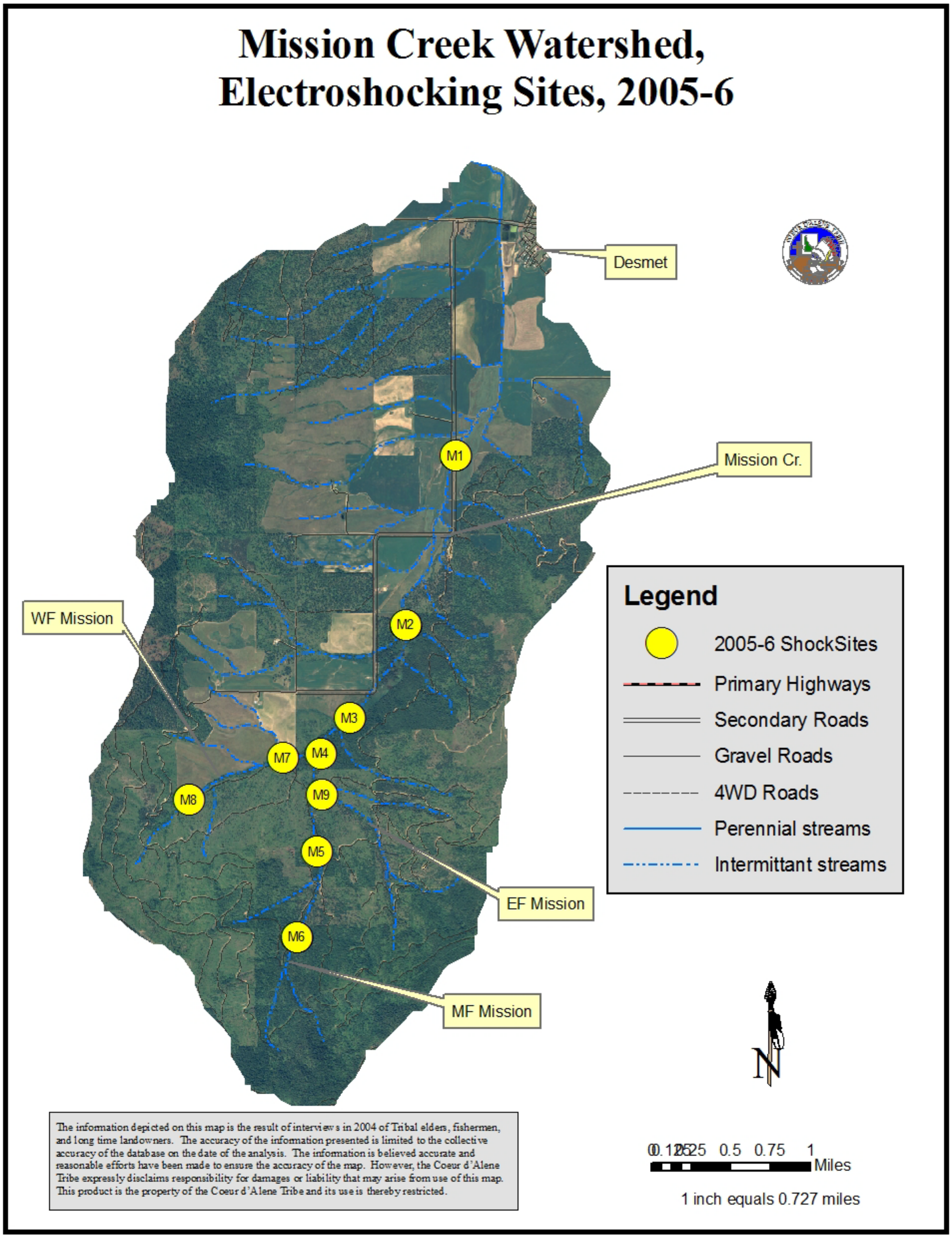


Figure D-5. Sample locations for electro-shocking in the Mission Creek watershed during 2005-6

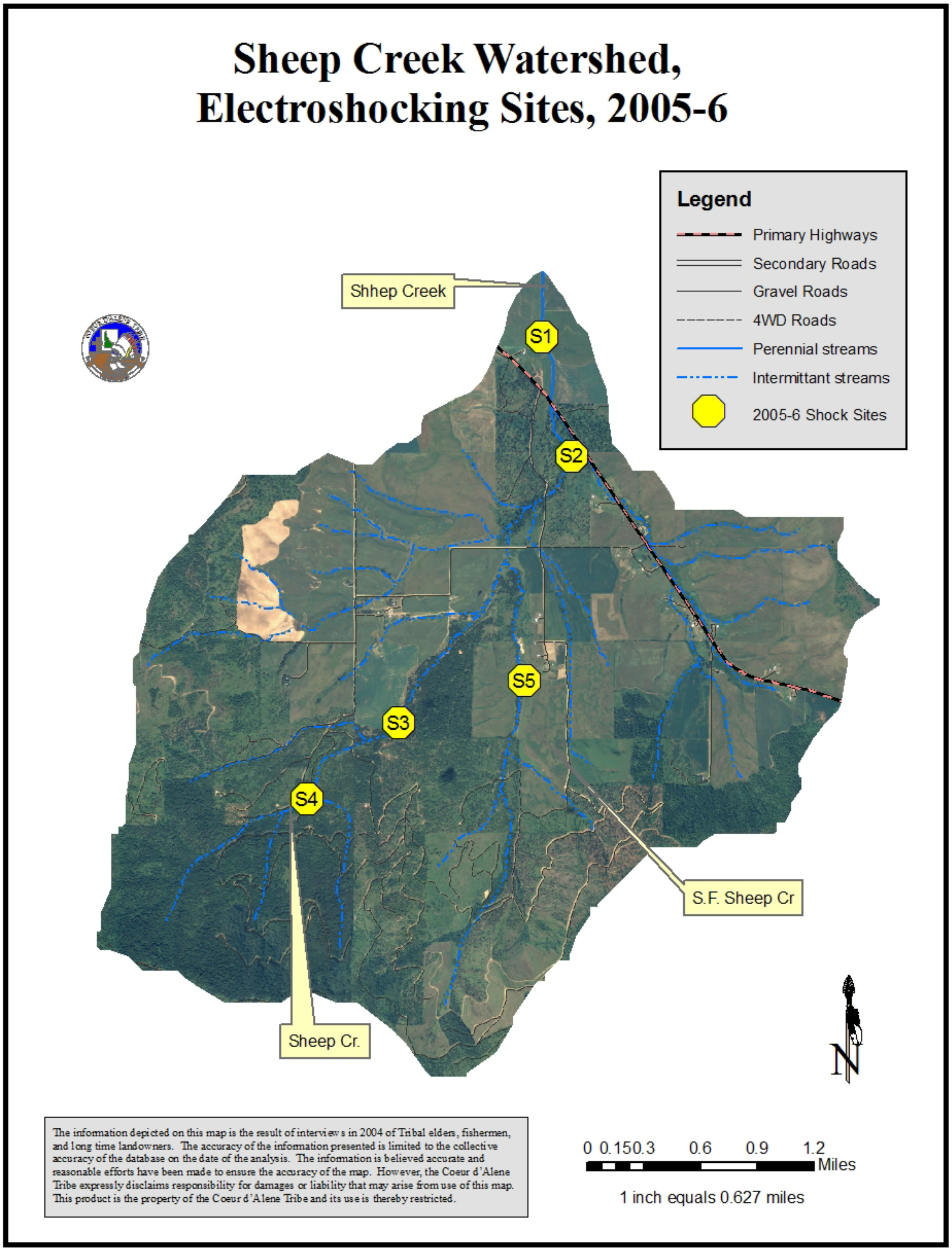


Figure D-6. Sample locations for electro-shocking in the Sheep Creek watershed during 2005-6.

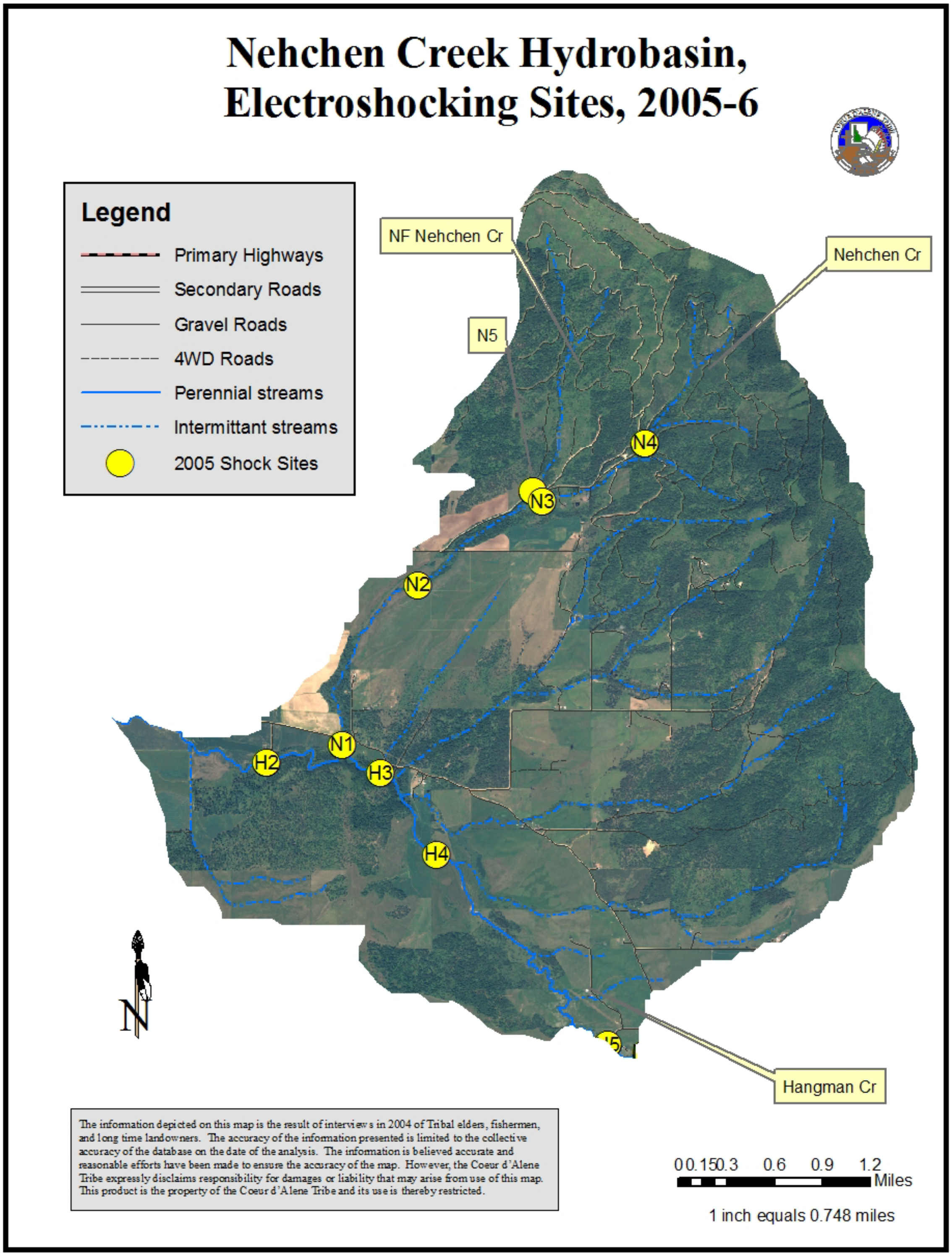


Figure D-7. Sample locations for electro-shocking in the Nehchen Creek watershed during 2005-6.

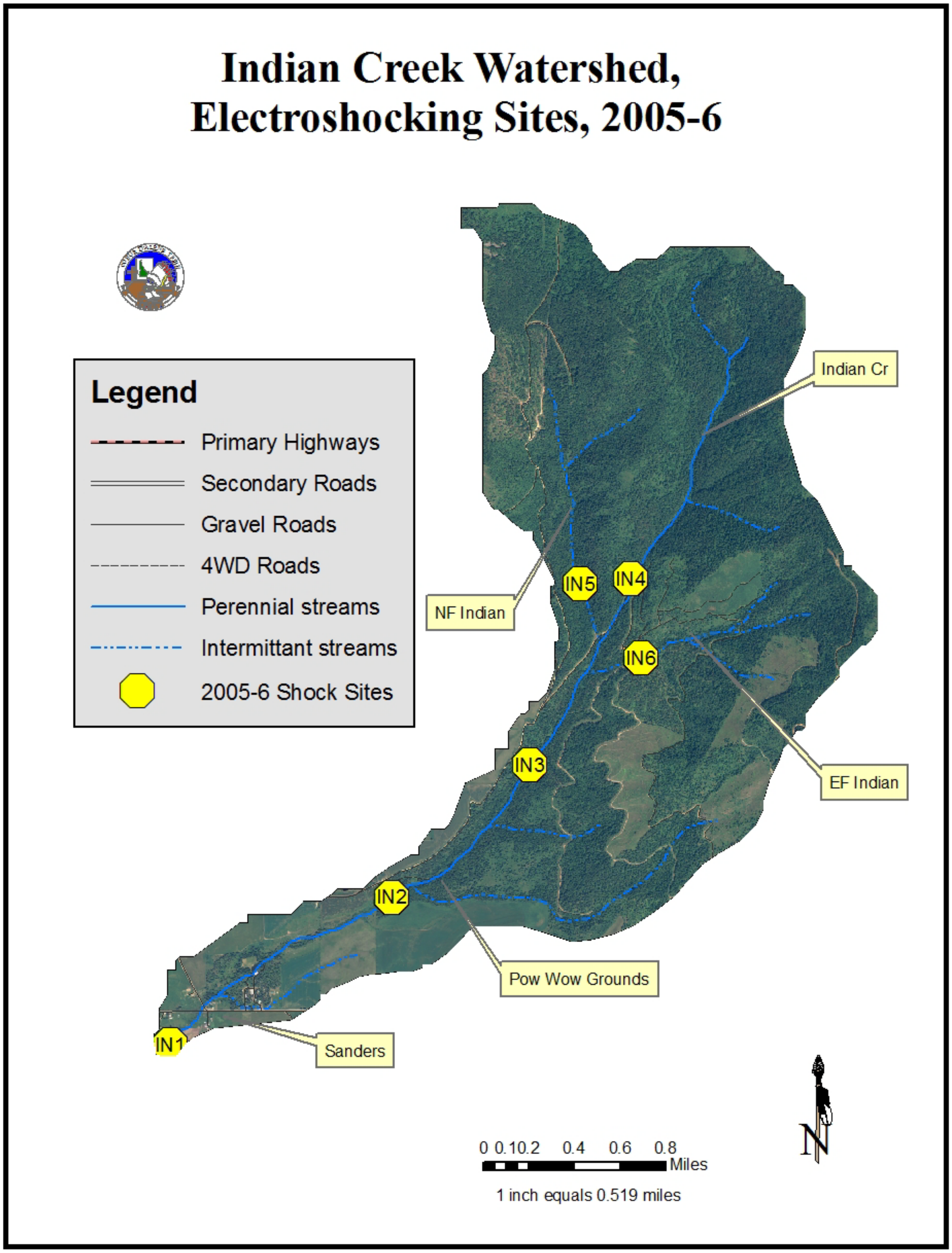


Figure D-8. Sample locations for electro-shocking in the Indian Creek watershed during 2005-6

9.6 Appendix E. Raw data for electroshock sampling

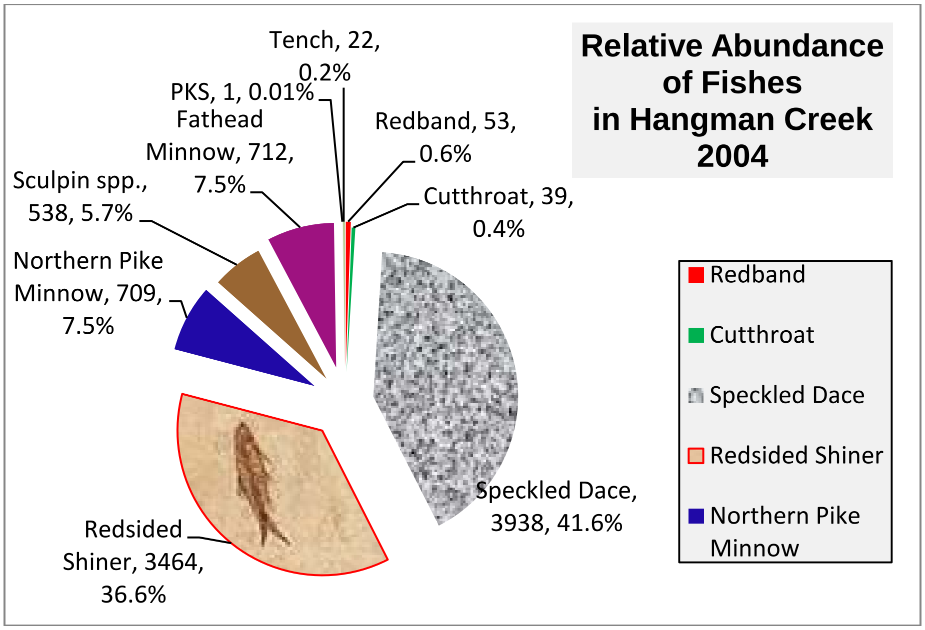


Figure E-1: Relative abundance of fishes sampled in Hangman Creek in 2004.

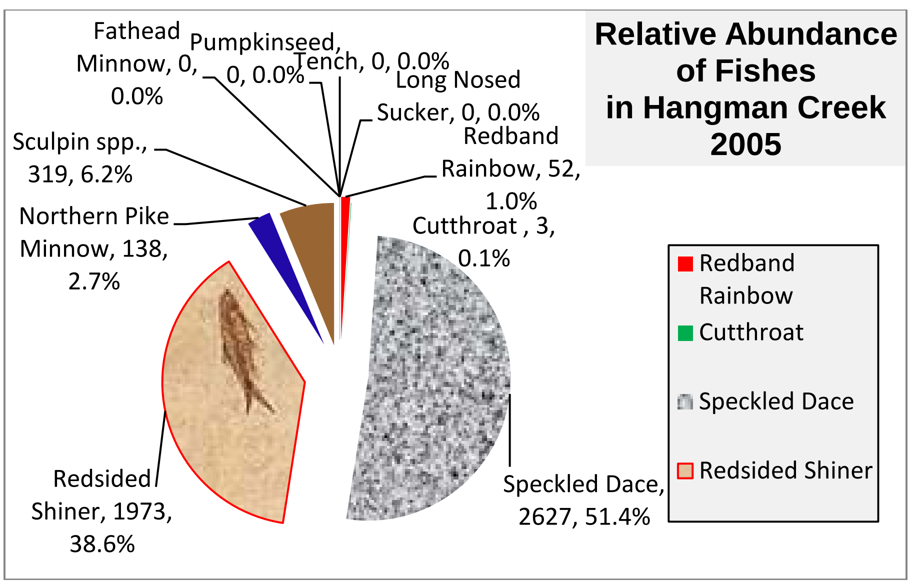


Figure E-2: Relative abundance of fishes sampled in Hangman Creek in 2005.

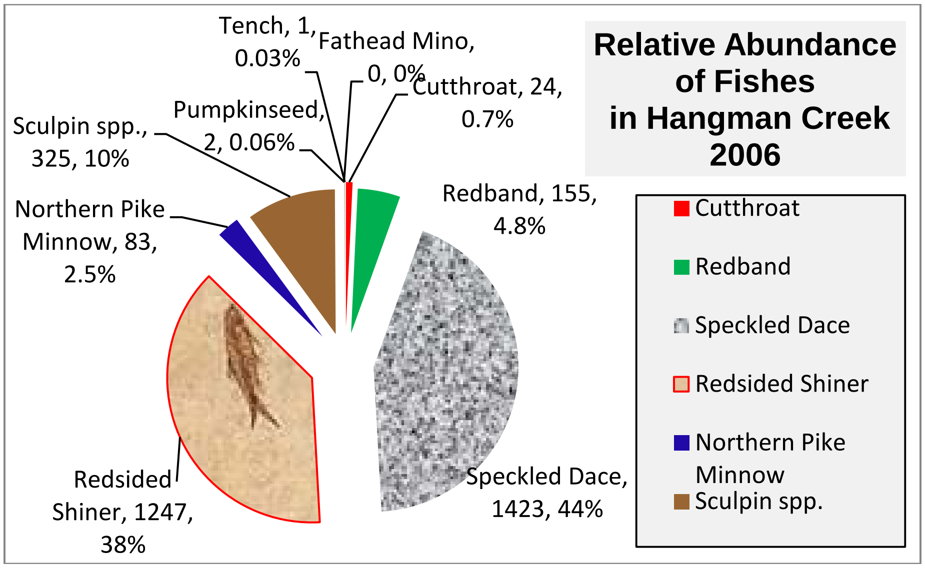


Figure E-3: Relative abundance of fishes sampled in Hangman Creek in 2006.

Table E-1: Summary of fish sampled using multiply-pass electro-shocking techniques in Hangman Creek during 2004 (1 of 3).

			Salmonids		**Age**			**Non Salmonids**								
Stream	**Site #**	**Spp.**	**Total**	**0+**	**1+**	**2+**	**3+**	**Total**	**SD**	**RSS**	**NPM**	**SCP**	**LNS**	**FHM**	**PKS**	**TCH**
Hangman	1		**0**	0	0	0	0	**511**	189	105	14	0	0	203	0	1
Hangman	2		**0**	0	0	0	0	**428**	150	140	6	0	0	130	0	2
Hangman	3		**0**	0	0	0	0	**565**	253	211	5	0	0	93	0	3
Hangman	4		**0**	0	0	0	0	**687**	261	203	11	0	0	207	0	5
Hangman	5		**0**	0	0	0	0	**436**	241	99	17	0	0	79	0	0
Hangman	6		**0**	0	0	0	0	**174**	51	113	6	0	0	0	1	3
Hangman	7		**0**	0	0	0	0	**209**	79	123	2	0	0	0	0	5
Hangman	8		**0**	0	0	0	0	**387**	231	152	1	0	0	0	0	3
Hangman	9		**0**	0	0	0	0	**257**	107	131	19	0	0	0	0	0
Hangman	10		**0**	0	0	0	0	**498**	265	171	33	29	0	0	0	0
Hangman	11		**0**	0	0	0	0	**145**	19	82	26	38	0	0	0	0
Hangman	12		**0**	0	0	0	0	**309**	147	162	0	0	0	0	0	0
Hangman	13		**0**	0	0	0	0	**34**	13	21	0	0	0	0	0	0
Hangman	*14*												0			
Hangman	15	RBT	**3**	0	0	2	1	**472**	200	161	0	111	0	0	0	0
Hangman	16	RBT	**2**	0	0	1	1	**364**	125	152	0	87	0	0	0	0
Hangman	17	RBT	**9**	0	6	2	1	**108**	55	35	0	18	0	0	0	0
Mission	1		**0**	0	0	0	0	**286**	93	189	4	0	0	0	0	0
Mission	2		**0**	0	0	0	0	**170**	72	96	2	0	0	0	0	0
Mission	3		**0**	0	0	0	0	**16**	11	5	0	0	0	0	0	0
Mission	4	RBT	**5**	0	3	1	1	**0**	0	0	0	0	0	0	0	0
Mission	5		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Mission	6		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Mission	7		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
E.F. Mission	8		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
E.F. Mission	9		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0

RBT= Rainbow Trout CTT= Cutthroat Trout RSS= Redsided Shinner SD= Speckled Dace *site 14 not completed
SCP= Sculpin spp. PKS=Pumpkinseed NPM= Northern Pike Minnow TCH= Tench LNS=Long Nosed Sucker

Table E-1: Summary of fish sampled using multiply-pass electro-shocking techniques in Hangman Creek during 2004 (2 of 3).

			Salmonids			Age		Non Salmonids								
Stream	**Site #**	**Spp.**	**Total**	**0+**	**1+**	**2+**	**3+**	**Total**	**SD**	**RSS**	**NPM**	**SCP**	**LNS**	**FHM**	**PKS**	**TCH**
W.F. Mission	10	RBT	**8**	0	3	2	3	**0**	0	0	0	0		0	0	0
W.F. Mission	11		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Indian	1	RBT	**5**	0	1	2	2	**252**	57	63	0	131		0	0	0
Indian	2	RBT	**9**	0	5	4	0	**57**	0	0	0	57		0	0	0
Indian	3	RBT	**7**	0	6	1	0	**67**	0	0	0	67		0	0	0
Indian	4		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
N.F. Indian	5		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
E.F. Indian	6		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Tensed	1		**0**	0	0	0	0	**57**	31	26	0	0		0	0	0
Tensed	2		**0**	0	0	0	0	**37**	21	16	0	0		0	0	0
Tensed	3		**0**	0	0	0	0	**3**	3	0	0	0		0	0	0
Tensed	4		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Tensed W.F.	5		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Tensed W.F.	6		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Sheep	1		**0**	0	0	0	0	**19**	19	0	0	0		0	0	0
Sheep	2		**0**	0	0	0	0	**183**	62	121	0	0		0	0	0
Sheep	3		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Sheep	4	RBT	**2**	0	1	1	0	**0**	0	0	0	0		0	0	0
Sheep	5	RBT	**3**	0	2	1	0	**0**	0	0	0	0		0	0	0
Sheep/Lar.	6		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Nechen	1		**0**	0	0	0	0	**2**	2	0	0	0		0	0	0
Nechen	2	CTT	**20**	0	7	13	0	**0**	0	0	0	0		0	0	0
Nechen	3	CTT	**12**	0	7	5	0	**0**	0	0	0	0		0	0	0
Nechen	4	CTT	**7**	0	0	7	0	**0**	0	0	0	0		0	0	0
N.F. Nechen	5		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Rose	1		**0**	0	0	0	0	**160**	79	81	0	0		0	0	0

RBT = Rainbow Trout CTT= Cutthroat Trout RSS= Redsided Shiner SD=Speckled Dace PKS=Pumpkinseed

SCP=Sculpin spp. FHM=Fathead Mino NPM=Northern Pike Minnow TCH=Tench LNS=Long Nosed Sucker

Table E-1: Summary of fish sampled using multiply-pass electro-shocking techniques in Hangman Creek during 2004 (3 of 3).

			Salmonids		Age			Non Salmonids								
Stream	**Site #**	**Spp.**	**Total**	**0+**	**1+**	**2+**	**3+**	**Total**	**SD**	**RSS**	**NPM**	**SCP**	**LNS**	**FHM**	**PKS**	**TCH**
Rose	2		**0**	0	0	0	0	**58**	31	27	0	0		0	0	0
Rose	3		**0**	0	0	0	0	**12**	12	0	0	0		0	0	0
N.F. Rock	1		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
N.F. Rock	2		**0**	0	0	0	0	**8**	3	5	0	0		0	0	0
N.F. Rock	3		**0**	0	0	0	0	**564**	83	72	409	0		0	0	0
Moctileme	1		**0**	0	0	0	0	**221**	77	144	0	0		0	0	0
Moctileme	2		**0**	0	0	0	0	**204**	197	7	0	0		0	0	0
Moctileme	3		**0**	0	0	0	0	**94**	89	0	5	0		0	0	0
Moctileme	4		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Lolo	1		**0**	0	0	0	0	**284**	157	123	4	0		0	0	0
Lolo	2		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Lolo	3		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Little Hangman	1		**0**	0	0	0	0	**350**	101	179	70	0		0	0	0
Little Hangman	2		**0**	0	0	0	0	**302**	72	155	75	0		0	0	0
Little Hangman	3		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Andrew Springs	1		**0**	0	0	0	0	**180**	111	69	0	0		0	0	0
Smith	1		**0**	0	0	0	0	**114**	89	25	**0**	**0**		**0**	**0**	0
Smith	2		**0**	0	0	0	0	**27**	27	0	**0**	**0**		**0**	**0**	0
Smith	3		**0**	0	0	0	0	**53**	53	0	**0**	**0**		**0**	**0**	0
Smith	4		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Mineral	1		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Mineral	2		**0**	0	0	0	0	**0**	0	0	0	0		0	0	0
Watershed Totals			**92**	**0**	**41**	**42**	**9**	**9364**	**3938**	**3464**	**709**	**538**	**0**	**712**	**1**	**22**

RBT= Rainbow Trout; CTT= Cutthroat Trout; RSS= Redsided Shinner; SD= Speckled Dace; FHM=Fathead Mino
SCP= Sculpin spp.; PKS=Pumpkinseed; NPM= Northern Pike Minnow; TCH= Tench; LNS=Long Nosed Sucker

Table E-2: Summary of fish sampled using multiply-pass electro-shocking techniques in Hangman Creek during 2005 (1 of 2).

			Salmonids		Age			Non Salmonids								
Stream	**Site #**	**Spp.**	**Total**	**0+**	**1+**	**2+**	**3+**	**Total**	**SD**	**RSS**	**NPM**	**SCP**	**LNS**	**FHM**	**PKS**	**TCH**
Hangman	1		**0**	0	0	0	0	**590**	255	312	23	0	0	0	0	0
Hangman	2		**0**	0	0	0	0	**703**	411	245	14	33	0	0	0	0
Hangman	3		**0**	0	0	0	0	**443**	300	93	5	45	0	0	0	0
Hangman	4		**0**	0	0	0	0	**622**	455	130	37	0	0	0	0	0
Hangman	5	RBT	**1**	0	0	0	1	**694**	320	260	17	97	0	0	0	0
Hangman	6		**0**	0	0	0	0	**354**	165	144	5	40	0	0	0	0
Tensed	1		**0**	0	0	0	0	**70**	38	32	0	0	0	0	0	0
Mission	1		**0**	0	0	0	0	**185**	50	122	13	0	0	0	0	0
Mission	2		**0**	0	0	0	0	**10**	10	0	0	0	0	0	0	0
Mission	3	RBT	**3**	0	3	0	0	**0**	0	0	0	0	0	0	0	0
Mission	4	RBT	**7**	0	2	2	3	**0**	0	0	0	0	0	0	0	0
Mission	5		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Mission	6		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
W.F. Mission	7	RBT	**10**	0	5	2	3	**0**	0	0	0	0	0	0	0	0
W.F. Mission	8		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
E.F. Mission	9		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Sheep	1		**0**	0	0	0	0	**420**	233	176	11	0	0	0	0	0
Sheep	2		**0**	0	0	0	0	**359**	151	203	5	0	0	0	0	0
Sheep	3		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Sheep	4	RBT	**4**	0	4	0	0	**0**	0	0	0	0	0	0	0	0
Sheep/Lar.	5		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Smith	1		**0**	0	0	0	0	**405**	159	238	8	0	0	0	0	0
Smith	2		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Mineral	1		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0

RBT= Rainbow Trout; CTT= Cutthroat Trout; RSS= Redsided Shinner; SD= Speckled Dace; PKS=Pumpkinseed
SCP= Sculpin spp.; PKS=Pumpkinseed; NPM= Northern Pike Minnow; TCH= Tench; LNS= Long Nosed Sucker

Table E-2: Summary of fish sampled using multiply-pass electro-shocking techniques in Hangman Creek during 2005 (2 of 2).

			Salmonids		Age			Non Salmonids								
Stream	**Site #**	**Spp.**	**Total**	**0+**	**1+**	**2+**	**3+**	**Total**	**SD**	**RSS**	**NPM**	**SCP**	**LNS**	**FHM**	**PKS**	**TCH**
Nechen	1		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Nechen	2		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Nechen	3	RBT	**1**	0	0	0	1	**0**	0	0	0	0	0	0	0	0
Nechen	4	CTT	**3**	0	2	0	3	**0**	0	0	0	0	0	0	0	0
N.F. Nechen	5		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
Indian	1	RBT	**2**	0	0	1	1	**157**	80	18	0	59	0	0	0	0
Indian	2	RBT	**5**	0	1	2	2	**20**	0	0	0	20	0	0	0	0
Indian	3	RBT	**13**	0	6	3	4	**25**	0	0	0	25	0	0	0	0
Indian	4	RBT	**2**	0	0	2	0	**0**	0	0	0	0	0	0	0	0
N.F. Indian	5	RBT	**4**	0	1	3	0	**0**	0	0	0	0	0	0	0	0
E.F. Indian	6		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0	0
			55	**0**	**24**	**15**	**18**	**5057**	**2627**	**1973**	**138**	**319**	**0**	**0**	**0**	**0**

RBT = Rainbow Trout | CTT= Cutthroat Trout | RSS= Redsided Shiner | SD=Speckled Dace | PKS=Pumpkinseed

SCP=Sculpin spp. | FHM=Fathead Mino | NPM=Northern Pike Minnow | TCH=Tench | LNS= Long Nosed Sucker

Table E-3: Summary of fish sampled using multiply-pass electro-shocking techniques in Hangman Creek during 2006 (1 of 2).

			Salmonids			**Age**		**Non Salmonids**							
Stream	**Site #**	**Spp.**	**Total**	**0+**	**1+**	**2+**	**3+**	**Total**	**SD**	**RSS**	**NPM**	**SCP**	**FHM**	**PKS**	**TCH**
Hangman	1		**0**	0	0	0	0	**496**	260	211	25	0	0	0	0
Hangman	2		**0**	0	0	0	0	**561**	311	218	18	14	0	0	0
Hangman	3		**0**	0	0	0	0	**235**	33	110	7	84	0	0	1
Hangman	4		**0**	0	0	0	0	**98**	10	13	1	74	0	0	0
Hangman	5	RBT	**2**	0	0	1	1	**0**	0	0	0	0	0	0	0
Hangman	6		**0**	0	0	0	0	**201**	147	25	0	29	0	0	0
Hangman	7		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0
Hangman	8	RBT	**54**	3	18	15	18	**17**	0	0	0	17	0	0	0
Tensed	1		**0**	0	0	0	0	**114**	63	47	4	0	0	0	0
Mission	1		**0**	0	0	0	0	**144**	84	52	6	0	0	2	0
Mission	2		**0**	0	0	0	0	**14**	14	0	0	0	0	0	0
Mission	3		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0
Mission	4	RBT	**3**	0	0	2	1	**0**	0	0	0	0	0	0	0
Mission	5		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0
Mission	6		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0
W.F. Mission	7		**13**	0	7	4	2	**0**	0	0	0	0	0	0	0
W.F. Mission	8		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0
E.F. Mission	9		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0
Sheep	1		**0**	0	0	0	0	**333**	165	150	18	0	0	0	0
Sheep	2		**0**	0	0	0	0	**297**	95	200	2	0	0	0	0
Sheep	3	RBT	**7**	0	5	1	1	**0**	0	0	0	0	0	0	0
Sheep	4	RBT	**5**	0	5	0	0	**0**	0	0	0	0	0	0	0
Sheep/Lar.	5		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0

RBT= Rainbow Trout   CTT= Cutthroat Trout   RSS= Redsided Shinner   SD= Speckled Dace   LNS-Long Nosed Sucker
SCP= Sculpin spp.   PKS=Pumpkinseed   NPM= Northern Pike Minnow   TCH= Tench

Table E-3: Summary of fish sampled using multiply-pass electro-shocking techniques in Hangman Creek during 2006 (2 of 2).

			Salmonids			Age		Non Salmonids							
Stream	**Site #**	**Spp.**	**Total**	**0+**	**1+**	**2+**	**3+**	**Total**	**SD**	**RSS**	**NPM**	**SCP**	**FHM**	**PKS**	**TCH**
Indian	1	RBT	**2**	0	0	2	0	**70**	27	0	0	43	0	0	0
Indian	2	RBT	**4**	0	3	1	0	**14**	0	0	0	14	0	0	0
Indian	3	RBT	**16**	4	6	5	1	**50**	0	0	0	50	0	0	0
Indian	4	RBT	**0**	0	0	0	0	**0**	0	0	0	0	0	0	0
E.F. Indian	5	RBT	**0**	0	0	0	0	**0**	0	0	0	0	0	0	0
N.F. Indian	6	RBT	**13**	5	5	3	0	**0**	0	0	0	0	0	0	0
S.F. Hangman	1		**0**	0	0	0	0	**113**	113	0	0	0	0	0	0
Martin	1	RBT	**36**	20	14	2	0	**0**	0	0	0	0	0	0	0
Nehchen	1	CTTBO	**10**	10	0	0	0	**0**	0	0	0	0	0	0	0
Nehchen	2		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0
Nehchen	3		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0
Nehchen	4	CTTBO	**14**	1	11	2	0	**0**	0	0	0	0	0	0	0
N.F. Nehchen	5		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0
Smith	1		**0**	0	0	0	0	**324**	101	221	2	0	0	0	0
Smith	2		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0
Mineral	1		**0**	0	0	0	0	**0**	0	0	0	0	0	0	0
Watershed Totals			**179**	**43**	**74**	**38**	**24**	**3081**	**1423**	**1247**	**83**	**325**	**0**	**2**	**1**

RBT = Rainbow Trout; CTT= Cutthroat Trout; RSS= Redsided Shiner; SD=Speckled Dace; PKS=Pumpkinseed
SCP=Sculpin spp.; FHM=Fathead Mino; NPM=Northern Pike Minnow; TCH=Tench

Table E-4: Summary of weights and lengths for salmonids in Hangman Creek in 2004.

Age Class	# individuals	Mean L (mm)	Range L (mm)	St.Dev	Mean Wt (g)	Range Wt. (g)	St.Dev
CTT/Hybrid 0+	0						
CTT/Hybrid 1+	14	96.9	77 - 118	12.5	6.6	2.60 - 11.20	2.5
CTT/Hybrid 2+	25	146	122 - 164	12.3	22.3	15.00 - 33.00	5.6
CTT/Hybrid 3+	0						
RBT 0+	0						
RBT 1+	22	91.8	52 - 122	21.8	7.3	4.20 - 13.55	2,4
RBT 2+	17	148.3	120 - 188	20.7	22.5	12.01 - 43.00	9.6
RBT 3+	9	185.4	170 - 225	16.4	41.7	25.70 - 68.30	11.4

:

9.7 Appendix F: Protocols for Collecting DNA Samples

Appendix F-1: Summary of Methds used for DAN Sampling

Appendix F-1 was provided by Washington Dept of Fish & Wildlife

[DNA sampling summary.wpd] rev 14 Mar 02

Tissue Sampling for DNA Analysis

Background:

As with any form of data collection, the statistical validity, quality, and documentation of the samples are of critical importance to the overall study. We will do our best to generate quality data in the laboratory analysis, but the overall success of each project is also dependent on the quality of the samples and the sampling design. For most of the work we do, the study designs require that we sample **unrelated individuals**. Thus, field sampling activities should minimize the chances for sampling family groups (e.g., fry from a single redd or one hatchery raceway or one production lot). In the case of non-lethal sampling, avoid repeated sampling of the same individuals at different times.

Our general procedure for DNA studies, is to collect fresh tissue directly into a special ethanol preservative. This preservative, which is a ***poison*** and is ***flammable***, should be obtained from the WDFW Genetics Lab. Once in this preservative, tissue samples can be stored at room temperature. The solution preserves the DNA by desiccating the tissue. Thus, **it is critical that the volume ratio of tissue:preservative not exceed 1:4 (20% tissue: 80% preservative)**. Note, an excess of preservative is okay. Sampling instruments, dissecting areas, and your hands should be kept clean (rinsed between specimens or as frequently as necessary) to avoid sample-to-sample contamination. Because all our DNA analyses involve PCR amplification of the DNA extracted from the tissue samples, sample-to-sample contamination can be a problem and must be avoided. Nevertheless, it is not necessary to wear gloves during the dissection process to avoid contamination of the samples -- just keep your hands, the sampling instruments, and the work area clean.

Tissue Sample Quality: *tissue samples should be obtained from live or freshly dead specimens; decomposed carcasses should not be sampled!*

Individuals separately IDed (to retain association of individual-specific genetic & biological data):

Wherever possible, samples should consist of a piece of fin or opercle tissue from each fish approximately 1 cm^2 if possible). *[Note that the tissue sample can either be a fin clip sample obtained with scissors or a series of 2-4 punches obtained using a standard 1/4" diameter paper punch]*. Because the DNA will actually be extracted primarily from the epithelial cells covering the fin or opercle, it is imperative that there is a reasonably intact layer of skin covering the tissue sample -- it should not be significantly abraded. If fin will be sampled and survival of the fish is not an issue, we recommend sampling the distal end of the caudal, dorsal, or pectoral fin. When it is not feasible to obtain samples as large as 1-2 cm^2 (e.g., non-lethal sampling of fry or pre-smolts), a smaller piece of fin (perhaps as small as 0.5 cm x 0.5cm) should be adequate. Because partial fin clips regenerate, whereas total fin amputations typically do not, we recommend obtaining partial fin clips from both pelvic fins (if necessary to get the desired amount of tissue) rather than complete removal of one fin, for non-lethal sampling of small fish.

The tissue sample from each specimen should be placed in a 2 mL screw-cap cryovial (filled with DNA preservative solution) immediately after dissection. Caps should be securely tightened on the vials (but not over tightened) and the sample vials should be stored upright at room temperature (do not freeze).

Each cryovial should contain a small laser-printed label on **write-in-the-rain paper** that gives the 4-digit WDFW collection code (e.g., "01CY") and the individual fish number [or, in an emergency, a pencil label identifying the sample]. Printed labels are provided by the WDFW Genetics Lab. **NOTE: DO NOT USE INK ON ANY LABELS; the preservative solution will dissolve the ink**.

Each set of tissue samples from a single locality/date should be accompanied by collection data (completed WDFW scale cards, WDFW Genetic Sampling Field Data Sheets, or another suitable form). Sampling data should be cross-referenced either to a map annotated with sampling locations or to GPS coordinates (for the site of collection of each fish, if possible) wherever possible.

Please store all vials containing DNA samples in the plastic sample storage boxes provided. Before placing vials containing tissue samples in the storage boxes, please verify that the vials are filled with
DNA preservative solution and that the caps are securely tightened; but do not over tighten.

Begin loading vials in the storage boxes in the back left corner cell (A1) and proceed from left to right and back to front to the front right corner cell (J10). Thus, for a collection of 100 fish, consecutively numbered from 1-100: sample #1 should be placed in cell A1, sample #2 should be in cell A2, ... sample #10 should be in cell A10, sample #11 should be in cell B1, ... sample #20 should be in cell B10 .... sample #91 should be in cell J1, ... sample #100 should be in cell J10). Note that one collection of up to 100 samples or two collections of up to 50 samples each (or several smaller collections) can be stored in a single box. The storage boxes should always be stored upright at room temperature until they are returned to the Genetics Lab in Olympia (as per instructions). Do not put tape on the boxes or on the individual vials or write on them. If you need to add a label, write it (in pencil) on a piece of paper and put it inside the top of the storage *box*.

Individuals treated as an aggregate group (when it is not necessary to retain the association of individual-specific genetic & biological data):

Opercle or fin samples from multiple individuals can be stored together in a single container provided: 1) only one tissue sample is taken from each individual

2) the tissue samples have enough structural integrity that they will remain intact during storage (*note: if even one sample falls apart, we won't know which fragments represent different individuals*)

3) the volume of preservative solution makes up at least 80% of the total final volume (preservative + tissue samples)

4) the tissues are dissected and handled in such a way as to minimize any cross-contamination of samples among individuals prior to, or during, immersion in the preservative

BEFORE BEGINNING SAMPLING, Please talk to:

Sewall Young (office phone: 360-902-2773; email: <youngsfy@dfw.wa.gov>)
Jim Shaklee (office phone: 360-902-2752; email: <shakljbs@dfw.wa.gov>)

Sewall and Jim can also be reached by phone in the lab at 360-902-2774 and by FAX at 360-902-2943.

Obtaining Sampling Supplies & Sampling Kits:

Supplies such as cryovials & screw-caps, sample boxes, paper punches, DNA preservative solution, labels, WDFW genetics style scale cards and/or WDFW Genetic Field Collection Data Sheets, and complete sampling kits can be obtained from the WDFW Genetics Laboratory (see below) by contacting Nathan Hyde. **Never use labels for a collection/stock different from the one the labels were originally assigned to. Do not retain labels for use in future years. Unused labels should be destroyed or returned to the Genetics Lab.**

Delivery of Samples to the WDFW Genetics Laboratory:

Whenever possible, it is best to hand deliver samples rather than ship them, both because this eliminates the possibility of loss of the samples and because there are restrictions on shipping the preservative solution. As collections are completed, or at the end of the sampling season, samples including accompanying scale cards, field collection data sheets, locality information appropriate to the samples, and **all unused sampling supplies** should be delivered or shipped to the lab at:

WDFW Genetics Laboratory
Natural Resources Building, Rm 665
1111 Washington Street SE
Olympia, WA 98504
attn. N. Hyde / J. Shaklee

Before shipping any samples to the lab, please contact Nathan or Jim so that they will expect the shipment and can initiate a search with the shipper if the samples do not arrive when expected.

Appendix F-2: Methods for Field Sampling

Guidlines for Non-Lethal Fry and Smolt Sampling for DNA Analysis

The goal is to take a small enough piece of a non-critical tissue (e.g., fin) to have little or no impact on the subsequent survival of the fish but that is adequate to allow genetic analysis. DNA analysis is ideal for this for two reasons: 1) all living cells of an organism have essentially the same DNA composition (unlike the tissue specific expression characteristic of allozymes and other proteins), so that tissues such as fin and opercle can provide adequate samples, and 2) amplification of the resulting DNA from such samples via the PCR (polymerase chain reaction) provides the sensitivity of detection to enable working with very small pieces of tissue and small amounts of DNA. *[For mammals, this approach has be used successfully to characterize animals by analyzing DNA extracted from hair follicles, blot spatters, and scat samples.]*

The **minimum amount of tissue** that is needed is approximately the size of this circle: • (a piece of tissue with the same approximate surface area as a 1.5mm diameter disc). The recommended sources of such a tissue sample are any of the following:

1) A distal portion of the dorsal lobe of the caudal fin
2) A distal portion of one of the pelvic fins
3) Smaller distal portions of both pelvic fins
4) One entire pelvic fin

By sampling only the distal portion of a fin, we expect that the fish will successfully regenerate the entire fin over time. In contrast, removing an entire fin often results in little or no fin regeneration, presumably leaving the fish at a selective disadvantage.

When sampling larger fish, a larger sample is preferred (e.g., a piece of tissue approximately the size of one of these circles: □[approx. 3mm diameter] or □[approx. 4.5mm diameter]), because this will provide more material (DNA). The "extra" tissue provides a reserve that can be used to overcome some types of analytical problems in the lab by repeated analysis and/or it provides material that can be used for subsequent analyses (for example to examine additional loci at a future date) or can be shared with other laboratories/agencies.

Live fish should be handled appropriately before, during, and after sampling. This will probably involve: a) anesthetization prior to handling for tissue sampling (and taking of measurements or other biological samples such as scales), b) careful handling during sampling to avoid injury and scale/mucous loss, and c) holding fish in a recovery vessel after sampling (until the anesthetic has worn off) before releasing them in a way that minimizes immediate mortality due to predation of other effects.

Each tissue sample should be placed in a vial that contains DNA preservative solution (and an appropriate label -- preprinted by WDFW [preferred] or written in *pencil*) immediately after it is taken. We recommend using vials that are approximately 3/4 full of preservative solution and never adding more than 1/5 of this volume of tissue (to ensure adequate preservation). Please rinse forceps, scissors, etc. (with fresh water) and dry them between fish to minimize the chance of cross- contamination of samples. Such preserved samples should be stored at ambient temperatures (20-80^{o}F) until they are returned to the WDFW Genetics Laboratory in Olympia.

If you have questions or need additional information, please telephone Jim Shaklee (360-902-2752), Sewall Young (360-902-2773), or the Genetics Lab at 360-902-2775).

Appendix F-3: Laboratory Methods

Details regarding the proposed analysis of Hangman (Latah) Creek rainbow trout 3-Jan-03

Genetic markers to be screened:

Approximately 16 microsatellite DNA loci will be screened as the primary genetic markers in this investigation. Microsatellite DNA loci have high levels of variation (high allelic diversities and heterozygosities) that make them informative markers of populations. They exhibit Mendelian inheritance and are considered selectively neutral. If necessary, we may also screen some PINE markers to look for evidence of interspecific hybridization.

Proposed DNA extraction methods:

DNA will be extracted from fin tissues using a simple Chelex extraction protocol. A small fragment of fin will be incubated overnight at 70°C in 180uL chelex solution (5% Chelex-100 [BioRad] in distilled water with 1.4 mg/mL proteinase-K [Sigma]). The extract will then be incubated at 95°C for 5 min to inactivate proteins and then stored refrigerated or frozen until polymerase chain reaction (PCR) amplification is done.

Proposed PCR conditions:

Multiplex	Buffer	dNTP	$MgCl_2$ [mM]	Initial Denature	Cycle temps	# Cycles	Final Extension
OmyB	1X Promega PCR Buffer A	0.2mM each	1.5	92° 2min	92° 15s, 55° 30s, 72° 60s	32	72° 30min
OmyC	1X Promega PCR Buffer A	0.2mM each	1.5	92° 2min	92° 15s, 55° 30s, 72° 60s	32	72° 30min
OmyD	1X Promega PCR Buffer A	0.2mM each	1.5	92° 2min	92° 15s, 49° 30s, 72° 60s	42	72° 30min
OmyE	1X Promega PCR Buffer A	0.2mM each	1.5	92° 2min	92° 15s, 62° 30s, 72° 60s	35	72° 30min
OmyF	1X Promega PCR Buffer A	0.2mM each	1.5	92° 2min	92° 15s, 52° 30s, 72° 60s	35	72° 30min

Multiplex	Locus 1	conc 1 [uM]	Dye 1	Locus 2	conc 2 [uM]	Dye 2	Locus 3	conc 3 [uM]	Dye 3	Anneal T	Taq [units/rxn]
OmyB	One-102	0.12	6fam	One-114	0.20	hex	Ots-100	0.08	ned	55	0.05
OmyC	One-108	0.03	6fam	Ots-103	0.03	hex	One-101	0.04	ned	55	0.05
OmyD	Ots-1	0.07	6fam	Omy-77	0.08	hex	Ots-3M	0.04	ned	49	0.05
OmyE	Omm-1130	0.10	6fam	Omm-1070	0.07	hex	Omy-1011	0.06	ned	62	0.05
OmyF	Omy-1001	0.06	6fam	Omm-1128	0.08	hex	One-18	0.09	ned	52	0.05
OmyF				Oki-10	0.08	hex					

9.8 Appendix G Washington F&W Genetics Report

The following is a complete report supplied to the Coeur d'Alene Tribe in 2005.

<u>Microsatellite DNA analysis of rainbow trout population structure in the Hangman Creek drainage with comparison to populations in the greater Spokane River drainage and hatchery rainbow trout collections</u>

Final Draft, Oct. 25, 2005

Maureen P. Small and Jennifer Von Bargen
Washington State Department of Fish and Wildlife, Science Division, Conservation, Genetics Lab

Abstract:
We examined population structure in rainbow trout (*Oncorhynchus mykiss)* collected from 5 tributaries and the mainstem of upper Hangman Cr. using 16 microsatellite loci. Average expected heterozygosity per collection over all loci was 0.69. Populations displayed some excess homozygosity, likely the result of small effective population sizes. Nehchen Cr. fish were cutthroat trout (*Oncorhynchus clarkii*), rather than rainbow trout, introduced by a landowner 20 years ago. Comparisons to cutthroat trout and hatchery steelhead, coastal, and interior trout indicated little introgression by hatchery trout into upper Hangman Cr. populations and little hybridization with cutthroat trout.

Introduction:
Effective fisheries management is based upon an understanding of population structure. Since salmonids home to their natal stream for breeding, population structure is generally organized upon geographic structure of drainages. As some amount of straying naturally occurs within drainages and to a lesser extent among drainages within the same region, population structure follows a hierarchy of regional structure with populations more closely related in nearby drainages. In addition to natural movement among drainages, fisheries managers (and zealous fishermen) have sometimes moved trout among drainages and among regions. Hatchery introductions have mixed impacts upon natural populations: salmonids are regionally adapted (Taylor 1991) and hatchery fish often are of non-local origin and may lack characteristics allowing them to succeed in regions different from their origins or to succeed under natural conditions. Further, population structure is impacted by barriers to fish movement. Dams, culverts, periodic loss of flow within a waterway, heavy sediment loads and other impediments may prevent fish from moving throughout a drainage and lead to smaller effective population sizes.

Movement of fish among tributaries within the greater Spokane drainage, in Northeastern Washington State, is restricted by availability of water: in most creeks, some portion is dry for at least part of the year. Water availability in some drainages (and potential for fish passage) has declined dramatically in the past 20 years as riparian plants were removed and roads, timber harvest and agriculture increased (Bruce Kinkead, tribal biologist, Coeur d'Alene Tribe, pers. comm.). Fish movement is further inhibited by dams and other barriers, natural and human-made (culverts etc.). Nehchen Cr. had a culvert (removed in 2004) between the upper and lower portions, preventing upward movement. In Indian Cr., a barrier erected 20 years ago prevented upward movement. Poor habitat quality may also serve as a barrier. For instance, seasonal heavy sediment loads in the mainstem Hangman Cr. may prevent movement between upper and lower tributaries (Bruce Kinkead, pers. comm.).

In this study, we used microsatellite DNA to investigate population genetic structure in rainbow trout occupying tributaries in the upper reaches of Hangman Creek in the Spokane drainage. Interior "Redband" rainbow trout, both anadromous and resident forms, were native to the area. Dam construction on the Spokane River eliminated the anadromous form but the native resident populations could persist. Hatchery rainbow (coastal origin) and cutthroat trout were stocked throughout the Spokane drainage starting in the early 1900s, and hatchery-origin fish introduced into other portions of the Spokane drainage may have moved into upper reaches of Hangman Creek. In addition to managed stocking, a landowner conducted an unsanctioned introduction of cutthroat in Nehchen Cr. using stock from Benewah Cr. in adjacent Coeur d'Alene drainage. In this study we examine natural-spawning rainbow trout and cutthroat trout from tributaries in the upper reaches of Hangman Cr. and compare them to Spokane Hatchery rainbow and Pend Oreille cutthroat to assess hatchery introgression and hybridization with cutthroat trout. In a cluster analysis, Hangman tributary collections were compared to collections from the lower Hangman, Spokane mainstem, the Little Spokane drainage, Kettle River drainage, hatchery rainbow, steelhead and Redband collections, natural spawning coastal rainbow from the Olympic Peninsula and interior rainbow from Packwood Lake as well as Pend Oreille cutthroat to examine introgression and hybridization and assess genetic relationships to other interior trout and natural spawning trout from other regions.

Materials, Methods and Results:

Samples of adult fish fin tissue were obtained non-lethally by backpack electrofishing. Genotypes were assessed at 14 microsatellite loci for 209 rainbow trout and cutthroat trout collected in 2003 and 2004 from five tributaries and the mainstem of Hangman Creek (Figure 1, Table 1). Collections from Sheep and Mission creeks were combined (see Table 1) for all analyses since individual collections were too small for statistical tests. The 2003 and 2004 Indian Cr. collections and Hangman Cr. collection were also combined in the cluster analysis since another analysis (ancestry test) indicated that they were not significantly different from each other.

DNA was extracted using a chelex protocol (Small *et al.* 1998). Microsatellite alleles at 14 loci were PCR-amplified using fluorescently labeled primers (see Table 2 for detailed PCR information). PCR's were conducted on a MJResearch PTC-200 thermocycler in 96 well plates in 5 µl volumes employing 1 µl template with final concentrations of 1.5 mM $MgCl_2$, 200µM of each dNTP, and 1X Promega PCR buffer. After initial three minute denature at 92°, 33 cycles consisting of 92° for 15 seconds, annealing (temp in Table 2) for 30 seconds, extension at 72° for 60 seconds were followed by a 30 minute extension at 72°. Samples were run on ABI 3730 automated sequencer and alleles were sized (to base pairs, bp) and binned using an internal lane size standard (GS500Liz from Applied Biosystems) and Genemapper software (Applied

Biosystems). Individual multilocus genotypes were composed of alleles at 14 loci and populations were identified by frequencies of alleles at each locus.

Since the early 1900s hatchery rainbow and cutthroat trout, have been planted extensively in the Spokane drainage (Jason McLellan, WDFW biologist, pers. comm.). Stock origin records were unavailable prior to 1980. After 1980, documentation indicated that the predominant hatchery rainbow stock was from the Spokane Hatchery. The broodstock is a coastal variety that originated in the McCloud River in California. Since this was the most widely used hatchery stock, we compare a Spokane Hatchery collection to Hangman Cr. collections to look at hatchery introgression. Two other hatchery stocks were also planted lower in the system over the past 25 years from Phalon Lake (interior Redband origin) and Trout Lodge (coastal origin) hatcheries. These two stocks were included in a cluster analysis to further examine hatchery introgression. Since it was unclear if native stocks (interior Redband) have been replaced by hatchery stocks, Redband trout from two tributaries of the Kettle River were included in the cluster analysis to provide potentially pure Redband collections for comparison (Table 1, Kettle River is the next drainage to the north of the Spokane drainage, not shown in Figure 1). With the exception of the sample from Nehchen Cr., all Spokane drainage collections were natural-origin, adult rainbow trout. The Nehchen Cr. collection was natural-origin adults, but genetic analysis (see below) indicated that they were cutthroat trout rather than rainbow trout. Although anadromous fish passage ceased with the construction of dams on the Spokane River in the early 1900's, hatchery steelhead have been planted in the greater Spokane drainage within the past 20 years, so the cluster analysis included a collection of summer steelhead from Lyons Ferry Hatchery on the Snake River. Cutthroat samples from Pend Oreille were included to estimate hybridization. Native coastal rainbow from the Dosewallips River on the Olympic Peninsula and interior rainbow from Packwood Lake were also included to provide comparisons to native rainbow from different geographic areas. All samples from different drainages and hatcheries included in cluster analyses are listed in Table 1. However, this study mainly focused upon fish from the upper Hangman drainage.

Statistical tests were applied to determine characteristics of individual collections, to estimate relatedness among collections from different tributaries, and to assess relationships between natural-origin and hatchery-origin rainbow. To estimate inbreeding, population mixing, and population fragmentation, departures from Hardy-Weinberg equilibrium (HWE) expectations (departure from heterozygosity expected when collection is a set of randomly mating individuals) were tested in collections using FSTAT2.9.3 (Goudet 2001) with 322,000 randomizations for HWE tests at each locus, and GENEPOP3.3 (Raymond and Rousset 1995) for HWE tests globally across loci with 100 batches and 2000 iterations. In individual locus tests in Hangman drainage collections (Table 3), 22 tests out of 112 total F_{IS} tests were significant before Bonferroni corrections for multiple simultaneous tests and 4 were significant after corrections (Table 3, adjusted alpha, 0.05/112 = 0.00045). In global tests, Martin and Hangman creeks collections were too small for testing, and the other collections were out of HWE with homozygote excess (Table 1). In global tests across populations (Table 2), most loci were out of HWE. Population sizes in the streams have been small for several years (Bruce Kinkead, pers. comm.) and disequilibrium suggested that collections have experienced inbreeding from small effective population sizes.

In other examinations, loci were tested for linkage (are alleles at different loci associated?) in pairwise genotypic disequilibrium tests across all collections using GENEPOP3.3 with 300 batches and 3000 iterations. Before and after corrections for multiple tests, 8/120 and 1/120 locus pairs were in disequilibrium, respectively, when summed over all populations. This non-independence could arise from the following sources. If loci are in close proximity on the same chromosome then alleles at different loci transmit as a set rather than independently. If individuals mate non-randomly, then individuals with particular genotypes mate with each other. Mating may also appear non-random if the population has a small effective size or has experienced a recent bottleneck such that related individuals mate with each other. Finally, loci appear linked if there is an admixture of breeding or sibling groups in the collection. Since different locus pairs were out of equilibrium in different collections, (and the same suite of loci transmit independently in other rainbow populations, M. Small, unpublished data) physical linkage is unlikely and linkage is more likely due to small population sizes. Admixture is unlikely since F_{IS} values were positive. In sum, the HWE, F_{IS} and linkage results suggest small effective population sizes or population fragmentation and tendencies towards inbreeding in most collections as well as some non-random collecting: Indian Cr. collection appeared to include some family groups (data not shown), which could also lead to significant positive F_{IS} values.

Allelic richness (number of alleles per collection corrected for sample size and for groups of samples) was estimated using rarefaction (8 genes per collection since 8 was the smallest number of genes in an individual collection) implemented in HP-Rare (Kalinowski 2005). In the Hangman drainage, the Sheep/Mission combined collection had the lowest allelic richness of the rainbow collections and rainbow trout had higher allelic richness than cutthroat and Spokane hatchery rainbow (Table 1). Gene diversity (expected heterozygosity, corrected for sample size) was estimated using FSTAT2.9.3 (Table 1). Gene diversity generally concurred with other diversity measures: collections with higher allelic richness had higher gene diversity. However, Nehchen Cr. had one of the lowest values for gene diversity among Hangman tributaries and among other collections studied (Table 1). Since the population in this small creek was recently founded (probably) with a limited number of trout and remains isolated by a barrier (Bruce Kinkead, personal communication), the effective population is small with low diversity.

Since most collections were out of HWE and samples were sometimes quite small (Table 1), pairwise tests investigating relationships among collections should be interpreted cautiously. Only upper Hangman collections were tested in pairwise tests since earlier tests (Small *et al.* unpublished data) had indicated that Hangman collections were significantly different from collections from the greater Spokane drainage. Pairwise F_{ST} analyses test for departures from the heterozygosity that would be expected if the paired collections were part of the same breeding group (FSTAT2.9.3 with 300,000 permutations). Collections were also tested for significant differences in genotypic distributions with pairwise genotypic tests using GENEPOP3.6 (with 300 batches and 3000 iterations). Pairwise F_{ST} and genotypic test results were congruent (Table 4). The Nehchen collections were significantly different from all rainbow collections. The combined Sheep/Mission collection was significantly different from Indian Creek rainbow collections but had comparatively low pairwise F_{ST} values (Table 4). Temporal samples from Indian and Nehchen creeks were not differentiated. The Martin and Hangman creeks collections were too small to include in the pairwise tests. Since the data suggest small effective population sizes in some collections (Hardy-Weinberg disequilibrium, lower allelic richness), differentiation between the rainbow collections may be due to enhanced drift as well as reproductive isolation. Bottleneck tests (Cornuet and Luikart 1996) conducted under the infinite allele model indicated recent reduction in population sizes in several collections (Table 1).

Cavalli-Sforza and Edwards chord distances (1967) among the full group of collections (Table 1) were generated and displayed in a dendrogram (genetic distance tree) using PHYLIP (Felsenstein 1993). Distances were based upon allele frequencies at 14 loci and plotted in a neighbor-joining (NJ) tree (Figure 2). The analysis was bootstrapped 1000 times to give an indication of confidence for groupings in the dendrogram: to simulate variability in the data set encountered if populations were resampled 1000 times, the allele frequency matrix was resampled 1000 times, a distance matrix was calculated for each data set, and a NJ dendrogram was constructed from each distance matrix. The 1000 dendrograms were combined in a consensus tree and values at the nodes of the tree indicate the percentage (above 60%) of 1000 trees in which collections beyond the node occurred together.

The consensus tree (Figure 2) showed associations among collections within tributaries: collections from the upper Hangman Cr. formed a branch with 99% bootstrap support and were joined by California Cr. (lower Hangman) with 65% bootstrap support, Spokane River mainstem, Deep Cr., Little Deep Cr., Dartford Cr., Dragoon Cr. and Deer Cr. drainages each formed a branch with at least 99% bootstrap support. Cutthroat collections and Nehchen Cr. collections from the Hangman drainage formed a branch with 100% bootstrap support, supporting a hypothesis that the Nehchen Cr. fish were actually cutthroat trout. Putative Redband collections from tributaries of the Kettle River (SF Boulder and WF Trout creeks) were genetically distant from each other (Figure 2). However, WF Trout Cr. is an isolated tributary (Jason McLellan, WDFW, pers. comm.). The branch with all the hatchery collections (Figure 2) also included several wild collections: Marshall, SF Boulder (from the Kettle drainage) and Deep creeks, suggesting some hatchery influence in these wild collections. The hatchery branch included Marshall Cr. with a bootstrap value of 64% when the analysis was conducted without cutthroat collections (data not shown).

STRUCTURE 2.1 (Pritchard *et al.* 2000) was used to estimate the proportion of ancestry shared among collections, to examine hybridization between *O. clarki* and *O. mykiss*, and to estimate introgression by hatchery fish. In this program, collections are tested for membership in a series of user-specified number of clusters. The program sorts individuals in order to achieve Hardy-Weinberg equilibrium and linkage equilibrium in the hypothetical clusters or populations. The Ln of the data indicates the likelihood of the number of clusters, with higher Ln values indicating greater likelihood. Thus, to test if *O. clarki* and *O. mykiss* are reproductively isolated, two clusters (the two species) are hypothesized among the collection data and the percentage of membership in either cluster calculated for an individual (and population) gives an estimate of the individual's (and population's) ancestry. If the individual were purely *O. clarki* or *O. mykiss*, they would be included in clusters with their conspecifics. A hybrid individual would show ancestry in both clusters, with percentage of ancestry varying by generation of hybridization event (1st generation 50:50). Migrants could be detected as individuals with high membership in another collection. Distinct and strongly divergent populations would share little ancestry with other collections. Collections with a history of introgression or hatchery influence might display mixed ancestry or mixed membership in individuals, with some ancestry shared with the hatchery collections. Membership is calculated per individual and over collections. However, analysis can be problematic and misleading with so many collections since the program will force individuals or collections into a group even if they don't truly share recent common ancestry with other members of the group: the program has to assign individuals among the number of groups hypothesized. Yet, when more groups are hypothesized, individuals and groups may be partitioned among several clusters. Further, the amount of Hardy-Weinberg and linkage disequilibrium in this data set makes the results from STRUCTURE less definitive.

Several tests were conducted using STRUCTURE with the number of hypothetical populations (K) set from 2 to 8 and with cutthroat trout collection Sullivan Cr. from the Pend Oreille system and Spokane Hatchery included. With K = 2, the cutthroat, Nehchen Cr. and coastal hatchery rainbow trout formed one group (an association likely due to forcing fish into 2 groups), and Hangman rainbow trout collections formed the other group (Table 5). (Note: when STRUCTURE was run without Sullivan Cr., Spokane Hatchery grouped with the rainbow collections with K = 2). With K = 3, one cluster was occupied by cutthroat and Nehchen Cr, another by coastal hatchery trout from Spokane Hatchery, and the third by Hangman rainbow trout. With K = 4, the Sullivan Cr. cutthroat collection occupied its own cluster and the other Hangman, Nehchen Cr. and Spokane hatchery collections each occupied their own clusters. With K = 5, Sheep/Mission separated from the other Hangman collections into its own cluster. With K > 5, Martin, Indian and Hangman collections were subdivided among clusters and did not occupy their own single clusters. In analyses beyond K = 2, Hangman rainbow trout collections shared less than 1% ancestry with the coastal hatchery collection, indicating little to no hatchery introgression. One individual in 03Nehchen Cr. had high ancestry and another had about 20% ancestry to rainbow clusters, suggesting one rainbow trout and one cutthroat of hybrid ancestry were present in the Nehchen Cr. collection.

The program WHICHRUN 4.1 (Banks and Eichert 2000) was used to perform maximum likelihood assignments of each fish to a collection (Table 6). The program implements a jackknife procedure, each fish in turn is removed from the dataset, allele frequencies of the baseline (all the collections in the study) are recalculated and the fish is assigned to the most likely group based upon its genotype and the allele frequencies of the collections. Small collections act as attractors since their allele frequencies are overrepresented – microsatellites are highly polymorphic and large sample sizes are required to adequately represent a population's allelic diversity. High assignments back to collection of origin suggest that the collection is genetically distinct from other collections (assignments back to origin are termed "correct assignments" and assignments to other collections are termed "misassignments" although fish may have originated outside of collection location). For all collections, the most common assignment of individuals was back to collection of origin (Table 6). Lowest correct assignment was in 04Indian: misassigned fish went mostly to Hangman Cr., likely an artifact of the small size of the Hangman Cr. collection. Highest correct assignment among Hangman collections was in the Sheep/Mission collection. One Nehchen Cr. fish was assigned to Martin Cr. (the same one with the rainbow ancestry in the STRUCTURE analysis), and no fish were assigned to the hatchery collection.

Discussion:

This study explored the population structure of natural rainbow trout populations in the upper Hangman drainage and assessed if hatchery fish had introgressed into native populations. Since we lack genetic data for natural populations prior to hatchery supplementation (early 1900's) throughout the Spokane drainage, we compared gene pools of natural spawning populations to a coastal gene pool maintained in Spokane Hatchery and introduced into the system within the past 20 years. A coastal strain of rainbow trout, originally from the McCloud River in California and maintained in Spokane Hatchery, was the most extensively planted hatchery fish in the greater Spokane system. While hatchery fish were not planted in upper Hangman creeks, hatchery fish may have moved up the mainstem into spawning areas. However, the data show that gene pools of natural spawning rainbow in the upper Hangman remain distinct from the coastal rainbow gene pool. This indicates that this coastal-origin hatchery stock has not replaced or substantially introgressed into natural populations. Given that salmonids are regionally adapted and that adaptations have a genetic basis (Taylor 1991), if hatchery rainbow (originally from coastal California) moved up the drainage, they were not likely adapted for physical conditions prevailing in the upper reaches of the Hangman drainage.

A cutthroat introduction in Nehchen Cr. appeared successful in establishing a cutthroat population. However, we have no genetic history of this creek or a cutthroat sample from Benewah Cr. (likely origin of introduced cutthroat) for comparison. We are unable to confirm whether the tributary lacked trout and Benewah Cr.–origin trout became established after transplanting, or if a native cutthroat population was supplemented or a native rainbow trout population was replaced by the introduction. The low gene diversity and allelic richness in comparison to other upper Hangman collections would support that these cutthroat were introduced using a small number of founding fish. Further, the creek suffered dewatering prior to the stocking (Bruce Kinkead, pers. comm.), which may have eliminated native fish, also supporting the introduction. The single fish identified as a rainbow trout indicated that small numbers of rainbow trout are found in Nehchen Cr. The second or third generation hybrid individual suggested that minimal hybridization has occurred.

The upper Hangman collections formed a cohesive group in the dendrogram indicating that following colonization by common ancestors, populations remained connected through gene flow as fish moved among tributaries when habitat was pristine throughout the drainage. California Cr. in the lower Hangman was the most closely associated collection to the upper Hangman collections. This suggested that prior to habitat deterioration, rainbow moved throughout the entire drainage via the mainstem of Hangman Cr., or that common ancestors colonized the upper and lower tributaries. The association of Marshall Cr. with the coastal hatcheries and its distance from other Hangman Cr. collections suggests that repeated hatchery supplementation in this creek (Jason McClellan pers. comm.) had an impact on the population.

Although our data support that trout in upper Hangman tributaries may be native populations of interior Redband trout, not naturalized hatchery fish, known or suspected Redband rainbow trout collections (see Table 1) from other drainages did not group with upper Hangman collections in the dendrogram. This may be a result of the polyphyletic origins of Redband trout, or may reflect a lack of movement and subsequent genetic divergence among populations as habitat conditions declined in the greater Spokane drainage.

Acknowledgements:
Fish from the upper Hangman tributaries were collected by Bruce Kinkead (Tribal Biologist, Coeur d'Alene Tribe). Fish from the greater Spokane drainage were collected by Jason McLellan (WDFW), hatchery fish were collected by WDFW personnel. Funding for upper Hangman collection analyses was provided by the Coeur d'Alene Tribe. Denise Hawkins and Ken Warheit provided valuable comments.

References:
Banks, M.A., M.S. Blouin, B.A. Baldwin, V.K. Rashbrook, H.A. Fitzgerald, S.M. Blankenship, and D. Hedgecock. 1999. Isolation and inheritance of novel microsatellites in chinook salmon (*Oncorhynchus tschawytscha*). J. Heredity 90:281-288

Banks, M.A. and Eichert W. 2000. WHICHRUN (Version 3.2) a computer program for population assignment of individuals based on multilocus genotype data. Journal of Heredity. 91:87-89.

Cavalli-Sforza L.L. and Edwards A.W.F. 1967. Phylogenetic analysis: models and estimation procedures. American Journal of Human Genetics, 19, 233-257.

Felsenstein J. 1993. Phylogeny inference package (PHYLIP) Version 3.5c. University of Washington, Seattle.

Goudet J. 2001. FSTAT, a program to estimate and test gene diversities and fixation indices (version 2.9.3). Updated from Goudet (1995) Available from http://www.unilch/izea/softwares/fstat.html

Kalinowski, S. K. 2005. HP-RARE 1.0: a computer program for performing rarefaction on measures of allelic richness. Molecular Ecology Notes, 5(1) 287.

Morris, D.B., K.R. Richard, and J.M. Wright. 1996. Microsatellites from rainbow trout (*Oncorhynchus mykiss*) and their use for genetic study of salmonids. Can. J. Fish. Aquat. Sci. 53:120-126

Nelson, R.J., and T.D. Beacham. 1999. Isolation and cross species amplification of microsatellite loci useful for study of Pacific salmon. Animal Genetics 30:228-229

Olsen, J.B., S.L. Wilson, E.J. Kretschmer, K.C. Jones,and J.E. Seeb. 2000. Characterization of 14 tetranucleotide microsatellite loci derived from sockeye salmon. Molecular Ecology 9:2185-2187.

Piry, S, Luikart G., and Cornuet J. M. 1998. BOTTLENECK, a program for detecting recent population effective population size reductions from allele frequency data. Available from http://www.ensam.inra.fr.URLB.

Pritchard, J. K., Stephens, M. and P. Donnelly (2000) Inference of population structure using multilocus genotype data. *Genetics*, 155**,** 945-959.

Raymond M. and Rousset F. 1995. GENEPOP (Version 3.3): Population genetics software for exact tests and ecumenicism. Journal of Heredity, 86, 248-249.

Rexroad, C.E., III, R.L. Coleman, A.M. Martin, W.K. Hersshberger, and J. Killefer. 2001. Thirty-five polymorphic microsatellite markers for rainbow trout (Oncorhynchus mykiss). Anim. Genet. 32:317-319.

Rohlf F.J. 1993. Numerical taxonomy and multivariate analysis system. Version 2.02j. Applied Biostatistics Inc., Setauket, NY.

Small, M.P., T.D. Beacham, R.E. Withler, and R.J. Nelson. 1998. Discriminating coho salmon (*Oncorhynchus kisutch*) populations within the Fraser River, British Columbia. Mol. Ecol. 7:141-155.

Smith, C.T., B.F. Koop, and R.J. Nelson. 1998. Isolation and characterization of coho salmon (*Oncorhynchus kisutch*) microsatellites and their use in other salmonids. Mol. Ecol. 7:1613-1621.

Taylor, E.B. 1991. A review of local adaptation in Salmonidae, with particular reference to Pacific and Atlantic salmon. Aquaculture, 98, 185-207.

9.9 Appendix H. Summary of macro-invertebrate analyses, 2004

Table I-1. Summary of habitat metrics and selected macro-invertebrate metrics analyzed for 74 sites sampled in the upper Hangman watershed in 2004.

Rosgen Reach #	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
Stream	Hangman	Hangman	Hangman	Hangman	Hangman	Hangman	Hangman	Hangman	Hangman	Hangman	Hangman
Location in River Miles - RM	RM 0.0	RM 1.1	RM 3.2	RM 5.3	RM 6.0	RM 6.6	RM 8.4	RM 9.7	RM 10.4	RM 11.2	RM 12.1
Site Code	CDA04HAN01	CDA04HAN02	CDA04HAN03	CDA04HAN04	CDA04HAN05	CDA04HAN06	CDA04HAN07	CDA04HAN08	CDA04HAN09	CDA04HAN10	CDA04HAN11
Date	08-04-2004	08-04-2004	08-04-2004	08-04-2004	08-04-2004	08-04-2004	08-05-2004	08-05-2004	08-17-2004	08-05-2004	05-18-2004
Percent Subsampled	20.83	49.26	18.76	31.25	16.67	91.74	52.08	50.00	29.15	31.25	50.00
EcoAnalysts Sample ID	1	2	3	4	5	6	7	8	9	10	11
Rosgen Channel Type Level 1 (Map)	C	C	C	C	C	C	C	C	C	C	C
Percent Fines	65.7	63.4	85.5	79.0	83.8	83.3	81.2	51.9	50.5	38.0	44.3
Max 7-day running average Max	27.50	27.50	24.73	27.01	27.01	27.50	27.50	27.50	28.03	28.03	22.90
EPT Richness	5.00	9.00	5.00	11.00	8.00	5.00	8.00	4.00	6.00	9.00	8.00
Plecoptera Richness	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00
% Plecoptera	0.00	0.00	0.00	0.00	0.00	0.18	0.35	0.00	0.00	0.00	0.00
% EPT	13.72	35.57	48.88	15.70	14.48	2.12	20.87	33.71	5.96	12.76	77.60
% Diptera	63.36	41.30	28.07	64.94	79.84	77.43	36.00	48.76	79.30	69.42	21.86
% Chironomidae	61.55	41.30	27.14	63.87	79.65	77.25	32.70	45.90	77.72	68.48	2.00
% Perlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shannon-Weaver H' (log 10)	1.32	1.21	1.06	1.46	1.27	1.23	1.40	1.12	1.21	1.46	0.57
Shannon-Weaver H' (log e)	3.04	2.79	2.44	3.36	2.93	2.82	3.23	2.66	2.79	3.36	1.30
Fine Sediment Biotic Index	19.00	13.00	9.00	23.00	13.00	7.00	2.00	3.00	7.00	22.00	42.00
DEQ MBI	3.49	3.52	3.21	4.09	3.50	3.08	3.72	3.07	3.19	3.98	3.10
Long-Lived Taxa Richness	4.00	2.00	3.00	1.00	1.00	1.00	0.00	1.00	0.00	5.00	1.00
Intolerant Taxa Richness	1.00	2.00	1.00	1.00	1.00	2.00	2.00	1.00	1.00	4.00	5.00
% Tolerant taxa	2.51	3.50	2.26	3.22	0.21	11.75	19.71	6.25	3.53	3.08	0.00

Rosgen Reach #	R12	R13	R14	R15-Wise	R15-Crawford	R18-SF Rd.	R1	R2	R3	R4	R5
Stream	Hangman	Hangman	Hangman	Hangman	Hangman	Hangman	Mission	Mission	Mission	Mission	Mission
Location in River Miles - RM	RM 12.4	RM 13.2	RM 14.8	Rm 15.1	RM 15.4	RM 16.9	RM 0.2	RM 2.2	RM 3.0	RM 3.8	RM 4.1
Site Code	CDA04HAN12	CDA04HAN13	CDA04HAN15	CDA04HAN16	CDA04HAN17	CDA04HAN18	CDA04MIS01	CDA04MIS02	CDA04MIS03	CDA04MIS04	CDA04MIS05
Date	05-05-2004	05-05-2004	07-18-2004	07-16-2004	08-06-2004	07-16-2004	06-01-2004	06-01-2004	06-08-2004	06-08-2004	06-08-2004
Percent Subsampled	7.29	10.42	12.50	75.19	100.00	62.50	35.46	22.94	100.00	100.00	100.00
EcoAnalysts Sample ID	12	13	14	15	16	17	18	19	20	21	22
Rosgen Channel Type Level 1 (Map)	C	C	C	C	C	C	C	C	B	C	B
Percent Fines	50.0	39.3	45.0	45.5	44.7	15	59.3	51.3	54.0	64.7	45.6
Max 7-day running average Max	22.63	22.63	20.95	22.86	22.86	22.50	26.73	17.52	17.52	No data	17.52
EPT Richness	11.00	14.00	19.00	17.00	10.00	18.00	4.00	10.00	6.00	0.00	8.00
Plecoptera Richness	1.00	1.00	7.00	3.00	3.00	6.00	0.00	2.00	0.00	0.00	3.00
% Plecoptera	0.34	0.72	3.23	3.61	1.64	4.99	0.00	0.74	0.00	0.00	15.38
% EPT	46.39	77.66	23.48	54.56	6.81	60.78	1.35	37.75	35.90	0.00	38.46
% Diptera	41.58	15.66	55.20	14.11	51.17	26.92	75.24	60.41	37.61	33.33	34.62
% Chironomidae	15.29	8.47	42.65	12.22	39.20	24.96	71.57	14.18	27.35	33.33	34.62
% Perlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shannon-Weaver H' (log 10)	0.97	0.90	1.40	1.16	1.52	1.33	1.25	0.85	1.26	0.28	1.15
Shannon-Weaver H' (log e)	2.23	2.07	3.22	2.67	3.51	3.07	2.87	1.96	2.91	0.64	2.65
Fine Sediment Biotic Index	42.00	61.00	80.00	69.00	39.00	79.00	11.00	38.00	23.00	99.00	21.00
DEQ MBI	3.57	3.84	4.54	4.41	4.22	4.86	3.43	3.11	3.47	1.01	3.43
Long-Lived Taxa Richness	2.00	2.00	3.00	5.00	5.00	5.00	2.00	1.00	2.00	0.00	3.00
Intolerant Taxa Richness	8.00	7.00	15.00	13.00	7.00	14.00	3.00	6.00	3.00	0.00	6.00
% Tolerant taxa	0.65	0.49	0.54	13.38	13.23	1.70	5	0.26	22.32	0.00	0.00

Table H-1. Continued.

Rosgen Reach #	R6	R7	R1	R2	R1	R2	R1	R2	R3	R4	R5
Stream	Mission	Mission	Mission E.F.	Mission E.F.	Mission W.F.	Mission W.F.	Sheep	Sheep	Sheep	Sheep	Sheep
Location in River Miles - RM	RM 4.7	RM 5.2	RM 0.1	RM 0.4	RM 0.2	RM 1.0	RM 0.4	RM 0.8	RM 2.4	RM 2.8	RM 3.1
Site Code	CDA04MIS06	CDA04MIS07	CDA04MIS08	CDA04MIS09	CDA04MIS10	CDA04MIS11	CDA04SHP01	CDA04SHP02	CDA04SHP03	CDA04SHP04	CDA04SHP05
Date	06-01-2004	06-01-2004	06-07-2004	06-07-2004	06-07-2004	06-01-2004	06-09-2004	06-09-2004	06-10-2004	06-10-2004	06-10-2004
Percent Subsampled	100.00	100.00	100.00	100.00	100.00	100.00	29.15	85.47	100.00	97.09	100.00
EcoAnalysts Sample ID	23	24	25	26	27	28	29	30	31	32	33
Rosgen Channel Type Level 1 (Map)	B	A	A	A	B	A	C	C	C	B	A
Percent Fines	43.4	40.0	49.0	49.2	43.9	41.7	48	72	43	29	44
Max 7-day running average Max	17.52	17.52	17.52	No data	No data	Dry	21.60	23.50	16.76	16.76	16.76
EPT Richness	14.00	12.00	10.00	17.00	6.00	6.00	10.00	1.00	11.00	15.00	17.00
Plecoptera Richness	3.00	4.00	2.00	4.00	1.00	1.00	3.00	0.00	3.00	2.00	3.00
% Plecoptera	4.44	20.59	1.30	21.75	3.21	0.58	1.39	0.00	6.67	11.07	23.79
% EPT	26.83	30.00	28.57	45.48	13.37	7.78	14.29	0.35	40.00	28.85	43.55
% Diptera	49.81	49.41	37.66	24.86	18.72	13.54	83.73	71.80	35.00	55.93	39.72
% Chironomidae	42.86	25.88	34.24	24.01	16.04	7.49	54.76	69.70	29.17	51.58	36.29
% Perlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shannon-Weaver H' (log 10)	1.30	1.28	1.17	1.32	1.02	0.69	0.98	0.90	1.35	1.47	1.32
Shannon-Weaver H' (log e)	2.99	2.94	2.71	3.04	2.35	1.59	2.26	2.07	3.10	3.37	3.03
Fine Sediment Biotic Index	45.00	27.00	41.00	64.00	22.00	23.00	25.00	8.00	32.00	67.00	60.00
DEQ MBI	4.08	3.81	3.77	4.41	2.78	2.00	3.09	2.48	4.17	4.53	4.65
Long-Lived Taxa Richness	2.00	7.00	2.00	4.00	2.00	1.00	0.00	0.00	3.00	4.00	5.00
Intolerant Taxa Richness	10.00	12.00	6.00	10.00	4.00	4.00	6.00	1.00	8.00	12.00	13.00
% Tolerant taxa	5.50	11.43	5.96	14.99	25.82	68.53	0.18	22.24	2.56	2.97	3.49

Rosgen Reach #	R1	R1	R2	R3	R4	R1	R1	R3	R3	R1	R2
Stream	Sheep S.F.	Nehchen	Nehchen	Nehchen	Nehchen	Nehchen N.F.	Little Hangman	Little Hangman	Little Hangman	Moctilemme	Moctilemme
Location in River Miles - RM	RM 0.6	RM 0.1	RM 2.4	RM 2.8	RM 3.0	RM 0.2	RM 0.8	RM 1.0	RM 2.6	RM 0.1	RM 3.7
Site Code	CDA04SHP06	CDA04NEH01	CDA04NEH02	CDA04NEH03	CDA04NEH04	CDA04NEH05	CDA04LHA01	CDA04LHA02	CDA04LHA03	CDA04MOC01	CDA04MOC02
Date	06-11-2004	06-11-2004	06-14-2004	06-14-2004	06-15-2004	06-15-2004	07-09-2004	07-09-2004	07-09-2004	06-17-2004	06-17-2004
Percent Subsampled	45.87	66.67	91.74	75.19	76.92	64.94	4.17	10.94	10.42	31.25	22.94
EcoAnalysts Sample ID	34	35	36	37	38	39	40	41	42	43	44
Rosgen Channel Type Level 1 (Map)	B	B	A	A	A	A	C	C	C	C	C
Percent Fines	82	42	21	29	28	38	58	55	82	48	47
Max 7-day running average Max	Dry	Dry	Dry	16.76	16.76	Dry	25.17	No data	No data	23.00	No data
EPT Richness	6.00	10.00	24.00	24.00	22.00	8.00	3.00	3.00	3.00	4.00	6.00
Plecoptera Richness	1.00	2.00	6.00	8.00	8.00	2.00	0.00	0.00	0.00	0.00	2.00
% Plecoptera	0.74	0.57	16.32	18.41	37.04	8.81	0.00	0.00	0.00	0.00	0.91
% EPT	15.21	33.77	66.14	36.81	46.53	15.85	21.51	6.03	4.82	1.85	49.54
% Diptera	76.99	61.89	13.51	19.35	8.94	69.47	59.25	80.99	41.14	74.54	41.68
% Chironomidae	73.84	61.32	12.11	18.22	7.30	67.91	35.85	80.80	38.04	59.23	25.59
% Perlidae	0.00	0.00	0.35	0.57	1.28	0.00	0.00	0.00	0.00	0.00	0.00
Shannon-Weaver H' (log 10)	1.01	0.90	1.46	1.32	1.19	1.13	1.07	0.86	1.08	1.30	0.95
Shannon-Weaver H' (log e)	2.33	2.07	3.35	3.04	2.74	2.60	2.46	1.98	2.48	2.99	2.19
Fine Sediment Biotic Index	28.00	44.00	87.00	94.00	83.00	29.00	25.00	2.00	8.00	21.00	26.00
DEQ MBI	2.85	3.08	5.39	4.61	4.48	3.31	3.10	2.25	2.79	3.26	3.37
Long-Lived Taxa Richness	2.00	1.00	6.00	7.00	8.00	1.00	1.00	1.00	1.00	3.00	1.00
Intolerant Taxa Richness	4.00	8.00	19.00	17.00	17.00	5.00	1.00	0.00	0.00	3.00	2.00
% Tolerant taxa	2.38	0.75	6.36	1.30	6.65	5.34	0.35	0.77	5.83	3.36	0.30

Table H-1. Continued.

Rosgen Reach #	R3	R4	R1	R2	R3	R1	R2	R3	R4	R1	R1
Stream	**Moctilemme**	**Moctilemme**	**Lolo**	**Lolo**	**Lolo**	**Tensed**	**Tensed**	**Tensed**	**Tensed**	**Tensed W.F.**	**Rose**
Location in River Miles - RM	RM 4.9	RM 5.1	RM 0.1	RM 3.1	RM 4.1	RM 0.1	RM 1.6	RM 2.3	RM 3.4	RM 0.2	
Site Code	CDA04MOC03	CDA04MOC04	CDA04LOL01	CDA04LOL02	CDA04LOL03	CDA04TEN01	CDA04TEN02	CDA04TEN03	CDA04TEN04	CDA04TEN05	CDA04ROS01
Date	06-17-2004	06-17-2004	05-18-2004	05-14-2004	05-18-2004	05-18-2004	05-18-2004	05-18-2004	05-19-2004	05-19-2004	07-12-2004
Percent Subsampled	54.05	100.00	39.53	68.97	100.00	100.00	100.00	100.00	100.00	100.00	10.42
EcoAnalysts Sample ID	45	46	47	48	49	50	51	52	53	54	55
Rosgen Channel Type Level 1 (Map)	C	C	C	C	C	C	C	C	B	A	C
Percent Fines	50	44	41.9	65.3	55.0	100	74	19	43	36	40
Max 7-day running average Max	No data	No data	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	No data
EPT Richness	9.00	14.00	7.00	0.00	8.00	5.00	8.00	6.00	6.00	4.00	5.00
Plecoptera Richness	0.00	4.00	0.00	1.00	2.00	0.00	0.00	1.00	1.00	1.00	0.00
% Plecoptera	0.00	5.94	0.00	4.26	4.99	0.00	0.00	0.69	0.48	3.08	0.00
% EPT	44.85	60.67	2.39	31.38	31.54	2.54	65.61	19.91	3.86	20.21	4.96
% Diptera	38.42	21.15	74.63	47.34	42.71	31.64	28.77	46.99	4.83	22.60	52.16
% Chironomidae	36.58	17.25	73.71	44.68	41.12	30.72	26.67	40.05	2.42	5.48	50.88
% Perlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shannon-Weaver H' (log 10)	1.01	1.33	1.21	1.13	1.02	0.83	1.02	1.26	0.84	1.13	1.31
Shannon-Weaver H' (log e)	2.33	3.07	2.79	2.61	2.34	1.91	2.36	2.90	1.93	2.60	3.01
Fine Sediment Biotic Index	44.00	64.00	10.00	32.00	32.00	13.00	15.00	25.00	17.00	14.00	14.00
DEQ MBI	3.63	4.77	3.30	3.54	3.37	2.52	3.73	3.52	2.40	2.96	3.37
Long-Lived Taxa Richness	2.00	4.00	2.00	1.00	1.00	0.00	1.00	1.00	2.00	1.00	3.00
Intolerant Taxa Richness	4.00	12.00	2.00	5.00	7.00	4.00	5.00	4.00	5.00	4.00	1.00
% Tolerant taxa	4.34	5.09	0.81	6.81	17.52	40.30	7.14	18.51	47.04	56.35	3.61

Rosgen Reach #	R2	R3	R1	R2	R3	R4	R1	R2	R1	R2	R3
Stream	**Rose**	**Rose**	**Indian**	**Indian**	**Indian**	**Indian**	**Indian E.F.**	**Indian N.F.**	**NF Rock**	**NF Rock**	**NF Rock**
Location in River Miles - RM			RM 0.2	RM 1.3	RM 2.4	RM 3.4	RM 0.3	RM 0.2			
Site Code	CDA04ROS02	CDA04ROS03	CDA04IND01	CDA04IND02	CDA04ND03	CDA04ND04	CDA04IND05	CDA04IND06	CDA04NFR01	CDA04NFR02	CDA04NFR03
Date	07-18-2004	07-18-2004	08-06-2004	07-14-2004	07-14-2004	07-13-2004	07-13-2004	07-13-2004	07-08-2004	07-08-2004	07-08-2004
Percent Subsampled	6.25	18.76	16.67	14.58	66.67	89.29	12.50	16.67	100.00	31.25	16.67
EcoAnalysts Sample ID	56	57	58	59	60	61	62	63	64	65	66
Rosgen Channel Type Level 1 (Map)	C	C	C	B	B	A	A	A	C	C	C
Percent Fines	80	81	46	40	41	44	34	26	45	100	52
Max 7-day running average Max	No data	No data	21.71	18.00	14.85	14.85	No data	14.90	No data	No data	No data
EPT Richness	4.00	0.00	14.00	22.00	19.00	24.00	23.00	17.00	1.00	1.00	2.00
Plecoptera Richness	0.00	0.00	3.00	6.00	6.00	9.00	9.00	4.00	0.00	0.00	0.00
% Plecoptera	0.00	0.00	11.58	35.57	11.60	22.39	50.65	11.59	0.00	0.00	0.00
% EPT	3.15	0.00	36.50	62.54	47.39	42.39	62.90	23.19	4.55	0.19	1.73
% Diptera	76.12	42.14	41.96	28.01	38.08	22.57	15.32	47.46	22.73	35.26	32.58
% Chironomidae	72.97	37.93	39.87	25.60	18.82	20.92	13.23	45.11	18.18	35.26	31.37
% Perlidae	0.00	0.00	0.00	0.69	2.18	4.04	1.61	0.36	0.00	0.00	0.00
Shannon-Weaver H' (log 10)	1.20	1.19	1.33	1.22	1.33	1.36	1.28	1.16	0.97	0.95	1.30
Shannon-Weaver H' (log e)	2.76	2.75	3.06	2.82	3.06	3.13	2.94	2.66	2.22	2.18	2.99
Fine Sediment Biotic Index	18.00	5.00	57.00	110.00	94.00	106.00	86.00	70.00	1.00	3.00	7.00
DEQ MBI	3.05	2.94	4.50	4.76	4.65	4.80	5.01	4.01	2.28	2.17	3.44
Long-Lived Taxa Richness	3.00	2.00	4.00	8.00	10.00	11.00	11.00	11.00	2.00	1.00	3.00
Intolerant Taxa Richness	2.00	1.00	9.00	18.00	15.00	20.00	18.00	13.00	0.00	1.00	1.00
% Tolerant taxa	0.78	7.29	0.38	0.08	0.56	10.27	1.19	1.71	13.64	17.63	6.94

Table H-1. Continued.

Rosgen Reach #	R1	R1	R2	R3	R4	R1	R1	R2
Stream	SF Hangman	Smith	Smith	Smith	Smith	Andrew Spring	Mineral	Mineral
Location in River Miles - RM	RM 0.8	RM 0.5	RM 1.0	RM 2.7	RM 3.7	RM 0.1	RM 0.3	RM 1.8
Site Code	CDA04SFH01	CDA04SMI01	CDA04SMI02	CDA04SMI03	CDA04SMI04	CDA04ASP01	CDA04MIN01	CDA04MIN02
Date	07-16-2004	06-22-2004	06-24-2004	06-24-2004	06-24-2004	05-14-2004	06-21-2004	06-22-2004
Percent Subsampled	100.00	41.67	14.58	40.49	39.53	14.99	45.87	66.67
EcoAnalysts Sample ID	67	68	69	70	71	72	73	74
Rosgen Channel Type Level 1 (Map)	C	C	C	B	C	C	C	B
Percent Fines	14	82	50	56	32	55	100	38
Max 7-day running average Max	18.66	Dry	Dry	No data	No data	Dry	Dry	No data
EPT Richness	21.00	5.00	5.00	14.00	7.00	4.00	5.00	13.00
Plecoptera Richness	7.00	1.00	1.00	5.00	3.00	0.00	1.00	4.00
% Plecoptera	12.99	0.19	0.18	0.90	10.11	0.00	0.20	8.82
% EPT	54.33	5.64	5.05	23.62	28.34	1.10	23.87	63.89
% Diptera	32.47	76.26	72.56	43.35	48.38	86.84	51.48	24.13
% Chironomidae	29.00	73.35	60.11	32.88	5.60	73.49	50.49	20.30
% Perlidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shannon-Weaver H' (log 10)	1.45	1.25	1.20	1.25	0.91	1.12	1.00	1.12
Shannon-Weaver H' (log e)	3.33	2.88	2.75	2.88	2.10	2.57	2.30	2.58
Fine Sediment Biotic Index	81.00	10.00	16.00	35.00	22.00	8.00	5.00	50.00
DEQ MBI	5.08	3.31	3.15	3.92	3.02	3.03	3.18	4.59
Long-Lived Taxa Richness	6.00	0.00	1.00	4.00	1.00	2.00	0.00	5.00
Intolerant Taxa Richness	13.00	3.00	3.00	11.00	5.00	2.00	3.00	11.00
% Tolerant taxa	3.71	5.22	1.29	10.90	1.72	1.43	9.23	3.26

9.10 Appendix I. Instream Flow Incremental Methodology Report by Hardin-Davis

Physical Habitat and Temperature in Hangman

Creek, Idaho

FINAL REPORT

Prepared by

Hardin-Davis, Inc.

Corvallis, Oregon

For

The Coeur d'Alene Tribe

Plummer, Idaho

August 2005

PHYSICAL HABITAT AND TEMPERATURE IN HANGMAN CREEK, IDAHO

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

We would like to thank the Coeur d'Alene Tribe (CDAT) for the opportunity to carry out this study. Bruce Kinkead of the Tribal Fisheries Office provided valuable guidance in helping us select appropriate study sites. Bruce and his staff also collected most of hydrology data that we used in the SNTEMP model. Gerald Green of the Tribal Wildlife Office was instrumental in obtaining funding for the studies, and in asking the questions that led to an efficient and effective study plan. In addition, he helped obtain access to some of the sites. CDAT technicians Glenn Lambert and Ken Pluff, Jr. assisted our field crews.

We would also like to thank the Bonneville Power Administration for providing funding for this project.

EXECUTIVE SUMMARY

The Physical Habitat Simulation (PHABSIM) methodology was used in two mainstem sites and in Indian and Nehchen Creeks. In all sites, weighted usable area (WUA) for trout was a low percentage of total area; the percentage was highest in Indian Creek. WUA increased significantly with a small increase in flow in all sites; the increase was greatest in the tributary sites.

The Stream Network Temperature Model (SNTEMP) was used on mainstem Hangman Creek from the National Forest boundary to the State Line, a distance of 18 miles. Tributaries were not modeled, but inflow and temperature data from Indian, Nehchen, Sheep, and Mission Creeks were used as inputs to the mainstem model. Modeled weekly average temperatures for June-September showed good agreement with measured temperatures at sites downstream of Nehchen Creek; sites upstream showed more variability.

The SNTEMP model was used to simulate three restoration scenarios: increased base flow, increased shade, and a combination of increased flow and shade. Increased base flow (1 cfs added) reduced summer temperatures by an average of only about 0.2 C. Increased shade caused a reduction of about 2.0 C. The two factors combined reduced temperatures only slightly more than shade alone.

PHABSIM and SNTEMP were combined to evaluate restoration potential. Total habitat area (HA) was calculated by multiplying WUA by the length of stream with acceptable summer temperatures. The addition of 1 cfs caused a significant increase in HA in the tributaries, where existing water temperatures are low compared to the mainstem. Restored shade caused a significant increase in HA in the mainstem.

Priorities for habitat restoration include the following:

- Protection of the best existing habitat, notably Indian Creek
- Riparian restoration in the mainstem and tributaries. Shade in the mainstem could decrease temperatures below critical levels over significant lengths of the mainstem. Riparian restoration would also increase instream cover.
- Increased flow would provide immediate habitat benefits in Indian and Nehchen Creeks. The benefits in the mainstem would be minor unless the temperature problem was also addressed.

I. INTRODUCTION

Hangman Creek (also known as Latah Creek), a major tributary of the Spokane River, originates in Benewah and Kootenai Counties, Idaho and flows NW into Washington near the town of Tekoa. Hangman Creek is 58 miles long, and drains an area of 689 square miles. On the Idaho side, the creek is about 19 miles long and drains approximately 108 mi^2.

Historically, Hangman Creek supported a fishery of resident and anadromous salmonids (Edelen and Allen, 1998). Anadromous salmonids were present to the headwaters, but have had no access to Hangman Creek since 1910, when Little Falls Dam was closed. Resident salmonids, principally rainbow trout (*Oncorhynchus mykiss*) have also declined in Hangman Creek. The decline is likely due to agricultural and forest practices, which are linked to reduced summer flows and high water temperatures (Kinkead, 2004).

The hydrology of Hangman Creek is flashy, with high flows 2-3 orders of magnitude higher than base flows. Mainstem Hangman Creek often reaches flows over 300 cfs immediately following rainstorms, but falls to less than one cfs in the summer. Highest flows typically occur in February and March. Indian Creek is the only upper-basin tributary with significant summer flow, and it also falls to less than one cfs for much of the summer.

High water temperatures are another important limiting factor for salmonids in the basin. In the mainstem, mean weekly temperatures commonly exceed 20°C, with maximum weekly temperatures reaching 25°C or more.

In 2003-2004, Hardin-Davis Inc. carried out studies of physical habitat and temperature in the mainstem and two tributaries of Hangman Creek (Figure 1). Physical habitat was evaluated using the Physical Habitat Simulation (Bovee 1982), in which habitat is quantified as a function of flow. Water temperatures were evaluated using the SNTEMP model (Bartholow 1989). The objectives of this report are as follows:

1. Summarize physical habitat vs. flow at PHABSIM study sites for existing flow conditions.
2. Estimate physical habitat conditions that could occur with additional base flow.
3. Summarize SNTEMP results in the mainstem under existing conditions.
4. Estimate the effects of increased base flow and improved shade on water temperatures.
5. Integrate physical habitat and temperature results to estimate the potential overall habitat benefits of increased flow and reduced temperature.

II. METHODS

PHYSICAL HABITAT MODEL

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).

PHABSIM assumes 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 three main components of PHABSIM are a hydraulic model (based on field measurements), 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 weights and sums all the usable habitat. When the model is used over a range of flows, it generates a WUA vs. flow curve.

The PHABSIM study of Hangman Creek followed procedures outlined by the Instream Flow Group (Bovee, 1982), and guidelines established by the State of Washington (WDFW and WDOE, 2000). The PHABSIM study consisted of the following steps:

- Site selection
- Field data collection
- Computer simulation of hydraulics
- Selection of habitat suitability criteria (HSC)
- Determination of weighted usable area (WUA) as a function of flow

<u>Site Selection</u>: Habitat mapping was carried out in 2003 to help guide the placement of PHABSIM sites and transects. Distances mapped included 4.6 miles in the mainstem, 2.8 miles in Indian Creek, and 1.0 miles in Nehchen Creek. Mesohabitat (pool, riffle, run) percentages were quantified; in addition width, substrate, and shade data were collected.

Seven sites, with a total of 30 transects, were chosen in 2003 for habitat modeling. Sites were selected to represent a range of conditions from relatively pristine to heavily impacted. Twelve transects were placed in the mainstem, seven in Indian Creek, and 11 in Nehchen Creek (Table 1).

<u>Field measurements</u>: Transect measurements were made in early April, early May, and late June of 2004. The discharge conditions during these visits are summarized in Table 2. At the April (high flow) visit, velocities and discharge were measured at every transect. During the other site visits, one or more transects per site were measured for discharge. Water surface elevations were measured at each transect at each flow.

A rainfall-induced high flow event occurred in late May, between our middle and low flow measurements. Discharge at the mouth of Hangman Creek in Spokane reached approximately 2500 cfs on May 23; discharge within the study area was likely 1500 cfs or more on May 22. The high flow caused minor streambed changes in some of the PHABSIM sites.

Calibration: Field data were checked and put into a format for hydraulic simulation. Input files for each transect were supplied to the Coeur d'Alene Tribe in electronic form. The field data were used to calibrate the IFG-4 hydraulic simulation program (Milhous et al., 1989), using software developed by TRPA (1998). Calibration consisted of developing a stage-discharge curve for each transect, and matching the measured vs. simulated velocities. Once calibrated, the data files were used to simulate hydraulic conditions at an appropriate range of discharges (Table 2).

Habitat suitability criteria: Habitat suitability criteria (HSC) were developed for rainbow trout and speckled dace (*Rhinichthys osculus*) from literature sources. Rainbow trout were selected since they are the primary game fish that occurs in the basin. Speckled dace, which also occur widely in the basin, were selected to represent non-game fish. For rainbow trout in the mainstem sites, we used HSC developed for the mainstem of lower Hangman Creek (HDI, 2003). These HSC were based on criteria published by WDFW (2002) as well as other sources. For the tributary sites (Nehchen and Indian Creeks) we also used HSC from the lower Hangman study (HDI 2003); but these were based mainly on observations in small streams. HSC for juvenile and adult speckled dace, based on several literature sources, were also taken from the HDI (2003) report. Final HSC curves are in Appendix 1.

Determination of WUA: Using the HABSIM program, the hydraulic output files, containing simulated depths and velocities for a range of flows, were combined with the HSC files. The result was a calculation of WUA for each site, for each flow. WUA is expressed in surface area (ft^2) of habitat per 1000 linear feet of stream.

STREAM TEMPERATURE MODEL

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). The model 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.

The SNTEMP model uses input data on stream geometry, shade, discharge, and meteorology to predict average water temperature for each time period of interest, at each location in the stream network. For Hangman Creek, a weekly time step was used. This time step was deemed most appropriate based on estimated travel time; it also minimized problems with daily temperature fluctuations. Stream network locations were selected at the upstream and downstream ends of the reach, and above and below each tributary.

The length of the study reach was approximately 18 miles, from upstream of South Fork Road to the state line. Modeling was focused on the mainstem, since temperature problems are most severe there.

Approximately 20 inputs are required in the SNTEMP model. Sources of data include field measurements, published data, and default values (Table 3). Default values were applied only for variables that generally have a negligible effect on model predictions (Bartholow 1989). The variables that usually 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.

The SNTEMP model was run in calibration mode, and the output (mean weekly stream temperature) was compared to measured values at ten locations. Weeks modeled ran from June 3 through September 22 (Table 4) in order to span the low-flow/high-temperature period.

The basic calibration factor in the SNTEMP model is wind speed. Increased wind speed causes modeled temperatures to decrease and vice-versa. On mainstem Hangman Creek, small wind-speed adjustments caused most of the modeled temperatures to be within 1°C of measured values, therefore no further calibration steps were taken.

Once the SNTEMP model was calibrated, three scenarios were simulated. In the first scenario, one cfs was added to the mainstem flow. This was simulated by adding 0.25 cfs each at the upstream end of the reach and at the confluences of Nehchen, Sheep, and Mission Creeks. This represents a simulated increase in the tributary contributions to the mainstem flow.

In the second scenario, shade values were increased to simulate riparian restoration. Baseline shade values were taken from habitat mapping data. Along Hangman Creek upstream of Nehchen Creek, density of riparian trees ranged from ten to ninety percent, but was generally less than thirty percent. From Nehchen Creek to the state line, riparian tree density ranged from ten to thirty percent. For the improved-shade scenario, density was simulated as eighty percent upstream of Nehchen Creek and fifty percent downstream.

The third scenario combined the first two. That is, one cfs was added to the mainstem flow, and improved shade was also simulated.

INTEGRATION OF PHYSICAL HABITAT AND TEMPERATURE MODELS

The results of the PHABSIM and SNTEMP simulations were combined to obtain an estimate of total habitat area (HA) in each study reach (Bovee 1982). Habitat area in a reach is calculated by:

$$HA = WUA * L * TWF$$

Where L is the reach length in thousands of feet, and TWF is a temperature weighting factor between 0 and 1. Thus, HA combines WUA per unit length of stream, total length of the reach, and temperature suitability in the reach for a given flow. Stream lengths used in calculating HA were taken from topographic maps and habitat surveys.

The temperature weighting factor was based on general WDOE guidelines on temperature for trout (B. Caldwell, pers. comm.). Average weekly temperatures less than 18°C were assigned a weighting factor of 1.0, and temperatures greater than 22°C were assigned a weight of 0. Two intermediate values were also assigned (Table 5). Flow and temperature conditions for the integration were based on observations and model results from Week 29 (July 15-21). This week was chosen because it had high air temperatures, low flow, and acceptable SNTEMP calibration results.

III. RESULTS

PHYSICAL HABITAT MODEL

In general, hydraulic calibration was straightforward. Measured and simulated water surface elevations (WSEL) were within 0.05 ft of measured values at almost all transects. On several transects, bed shifts between middle and low flow measurements caused anomalous WSEL measurements at low flow; in these cases the low-flow input WSEL was estimated using data from adjacent transects. The WSEL adjustments are unlikely to have had a significant effect on any of the WUA values that were later calculated. Simulated velocities at the measured high flow were generally within 10% of measured velocities at that flow. Measured data and necessary adjustments for model input are listed in Appendix 2.

HABITAT VS. DISCHARGE

Indian Creek: Small-stream rainbow trout WUA increased steeply as a function of flow up to 5 cfs (Figure 2). At flows above 5 cfs, small-stream rainbow trout WUA increases more gradually, then levels off and begins to decline past 10 cfs. Speckled dace adult WUA rises more gradually, with a plateau from about 3-10 cfs. Speckled dace juvenile WUA is similar, with a plateau from 2-5 cfs.

Nehchen Creek, upper site: Small-stream rainbow trout WUA increases very steeply as a function of flow from 0.5 cfs up to about 4 cfs, where it levels off (Figure 3). Speckled dace adult WUA rises more gradually, while speckled dace juvenile WUA declines as a function of discharge.

Nehchen Creek, pasture site: Small-stream rainbow trout WUA increases steeply as a function of flow from 0.5 cfs up to about 4 cfs, then rises more gradually as flow increases (Figure 4). Speckled dace adult WUA rises slightly as flow increases. Juvenile dace WUA is much higher here than at other sites, and declines as a function of flow.

Nehchen Creek, lower site: Small-stream rainbow trout WUA increases very steeply as a function of flow from 0.5 cfs up to about 5 cfs, where it levels off (Figure 5). Speckled dace adult and juvenile WUA change very little, declining gradually as flow increases.

Hangman Creek, Sweat Lodge site: Rainbow trout adult and juvenile WUA (standard HSC) both rise steadily as a function of discharge. Adult WUA is still rising at 40 cfs (the highest flow modeled), while juvenile WUA peaks at 36 cfs. Speckled dace WUA is relatively flat over the range of one to twenty cfs (Figure 6).

Hangman Creek, Old Mill Rd site: Rainbow trout adult and juvenile WUA (standard HSC) both rise steadily as a function of discharge. Both life stages are still rising at 40 cfs, the highest flow modeled. Speckled dace WUA declines as a function of discharge for both juvenile and adult (Figure 7).

Other PHABSIM results: The percentage gain of WUA per additional 1 cfs flow addition was high in the tributary sites (Table 6). This gain was most noticeable at the lowest flows. At the mainstem sites, the percentage gain was significant, but much less than at the tributary sites.

Rainbow trout adult WUA was about 6% of total surface area at 5 cfs for all sites except Indian Creek. At Indian Creek the value was 10% (Table 7).

STREAM TEMPERATURE MODEL

Calibration results for the ten logger locations are displayed by site in Figures 8-17. Results are displayed for representative weeks in Figures 18-23. Averaged over all weeks, calibration errors were generally greater than 1°C for upstream sites, and less than 1°C for downstream sites (Table 8).

Simulation results for all scenarios (baseline, added flow, improved shade, and shade plus flow) are displayed for ten sites (Figures 24-33). Results are displayed longitudinally for selected weeks in Figures 34-39.

INTEGRATION OF PHYSICAL HABITAT AND TEMPERATURE MODELS

Total habitat area (HA) is compared for baseline and scenario conditions in the tributaries in Figure 41. Shade was not a scenario in the tributaries, since SNTEMP was not applied in the tributaries, and since baseline temperatures were generally less than 18°C. Total HA is compared for baseline and three scenarios in the mainstem in Figure 42.

IV. DISCUSSION

PHYSICAL HABITAT MODEL

In general, WUA for trout increases with flow; peak WUA at all sites occurs at discharges far exceeding summer base flows. Maximum WUA is not a realistic management goal, since the amount of water needed to approach maximum WUA is not attainable. However, the WUA results can lend some insight into where habitat or flow management might do the most good. The percent WUA compared to total surface area is a general indication of habitat quality. The percent gain in WUA per unit of additional flow indicates the potential benefit of added flow at each site.

In Indian Creek, rainbow trout WUA is a relatively high percentage of total surface area compared to other sites (Table 7). The percent increase in WUA per one cfs added flow is also very high for Indian Creek (Table 6). These statistics indicate that habitat quality in Indian Creek is higher than in any of the Nehchen Creek (or mainstem) sites, and also that small increases in base flow would yield relatively large increases in physical habitat.

In Nehchen Creek, rainbow trout WUA at each of the three sites is about 6% of total surface area at 5 cfs. The steep increase in WUA at the lowest flows indicates that even very small increases in base flow would greatly increase physical habitat.

In mainstem Hangman Creek, at the Sweat Lodge site, the increase in adult WUA is not particularly steep compared to the tributary sites. However, it is steepest at the lowest flows. WUA is only about 5% of total surface area at 5 cfs, indicating relatively poor physical habitat conditions. At the Old Mill Road site, the rate of increase in WUA is more gradual than at the Sweat Lodge site. WUA is less than 6% of total surface area at 5 cfs.

Overall, the PHABSIM sites show a relatively low percentage of WUA compared to total surface area. As a percentage of total surface area at 5 cfs, the WUA ranges from about 10% at Indian Creek to about 6% at all the other sites (Table 6). A variety of factors are probably involved, but the most important is probably lack of cover. Most of the points (cells) measured on the transects had neither cover (undercuts, logs, overhanging vegetation) nor large substrate (boulders). As a result, the composite PHABSIM rating for most of the cells was low.

The percent WUA increase per unit flow is highest in the tributaries. This is probably because depths in the tributaries are marginal for adult trout; thus, small increases in depth yield big increases in WUA.

STREAM TEMPERATURE MODEL

Calibration: Agreement with measured results was variable at the four upstream sites; agreement improved significantly downstream of Nehchen Creek (Table 8). The difference in calibration results between upstream and downstream sites could be due to several factors. Discharge inputs were probably less accurate in the upper reaches and tributaries. Also, small amounts of groundwater input, unaccounted for by SNTEMP, can affect measured temperature results; the effects of groundwater would be greater in the upstream reaches, where base flow is lower. Discharge, shade conditions, and stream width were all more uniform downstream of Nehchen Creek, and SNTEMP results are sensitive to all these factors.

Scenarios: The addition of 1 cfs to the mainstem had only a small effect on water temperature. For each site, and for each week, the simulated temperature with added flow was only slightly lower than the baseline temperature (Figures 24-39). A small amount of cool water added to the mainstem was quickly heated to the baseline temperature due to a combination of high channel width, low discharge, and high air temperature.

Increased shade had a larger effect on simulated water temperature, often lowering the temperature by 3°C or more. When added flow and increased shade were combined, the temperature reduction was only slightly more than with shade alone (Figures 24-39).

As an illustration of the comparative effects of increased flow and increased shade on the mainstem, the effects of the three scenarios were averaged for all sites, and compared for Week 29 (Figure 40). In this case, flow alone reduced temperature in the mainstem by an average of 0.2°C, while shade alone caused about ten times this reduction.

INTEGRATION OF PHYSICAL HABITAT AND TEMPERATURE MODELS

In the tributaries, a flow increase of 0.5 cfs approximately tripled habitat area (Figure 41). The increase is greatest in Indian Creek. The tributaries have small channels, and so a small increase in depth and velocity is enough to cause a sharp increase in WUA. Existing temperatures are in the acceptable range, thus habitat area is simply a product of WUA and total reach length.

In the mainstem, an increase of one cfs causes only a small increase in habitat area in the middle mainstem (Sweat Lodge), and none in the lower mainstem (Old Mill Rd). Temperature problems override WUA even with an increase in flow. Increased shade causes a large increase in habitat area. Even though the quality of physical habitat is still low in these reaches, there are many more miles with a positive habitat score. The total amount of potential habitat is thus greater here than in the tributaries.

V. CONCLUSIONS

Hangman Basin streams have extremely low base flows and poor temperature conditions. Physical habitat (WUA) and temperature in many areas are marginal for trout survival. The results of this study suggest that a modest increase in summer low flow and improved riparian shading could substantially improve physical habitat throughout the basin for resident salmonids, principally rainbow trout.

Indian Creek had the highest existing habitat quality of all the sites modeled. Protecting this existing habitat in Indian Creek should be a very high priority. As shown in the simulations, increased flow would have great benefits in Indian Creek and Nehchen Creek. The gain per unit cfs at these sites ranged from 56% to over 100% at the lowest flows.

In the mainstem, increased flow alone would yield small benefits, since summer water temperatures would remain too high. The best management strategy in the mainstem appears to be riparian restoration; increased shade could make much more of the mainstem available for trout. Over the long term, riparian restoration could also improve fish cover values, which would further increase WUA.

If restoration projects are undertaken, the existing PHABSIM and SNTEMP sites (or additional sites in the basin) should be re-measured periodically to monitor physical habitat, shade, and temperature. PHABSIM can give a quantitative index of habitat response to physical changes in the stream and banks (Hardin 1987).

Further research is needed to identify whether increases in base flow are attainable, and if so, how they might be attained. Research is also needed to determine whether increased riparian trees and shrubs will negatively influence base flow. A comprehensive monitoring effort will be critical in evaluating the success of any habitat restoration efforts.

VI. LITERATURE CITED

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

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 District.

Hardin-Davis, Inc. 2003. Latah Creek Instream Flow Study: Final Report. Prepared for the Latah (Hangman) Creek Watershed Planning Unit (WRIA 56), May 2003.

Hardin, T.S. 1988. The use of habitat models to evaluate stream improvement structures, In-Stream Rehabilitation Manual, Oregon Chapter American Fisheries Society.

Johnson. S.L. 2004. Factors influencing stream temperatures in small streams: substrate effects and a shading experiment. Canadian Journal of Fish and Aquatic Sciences. 61:913-923.

Kinkead, B. 2004 (draft). Fisheries enhancement on the Coeur d'Alene Indian Reservation.

Milhous, R.T., M.A. Updike, and D.M. Schneider 1989. Computer reference manual for the Physical Habitat Simulation System (PHABSIM) – Version II. U.S. Fish and Wildlife Service, Fort Collins, CO. March 1989.

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.

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.

Theurer, F.D., K.A. Voos, and W.J. Miller 1984. Instream Water Temperature Model, Instream Flow Information Paper 16. U.S. Fish Wildlife Service, Fort Collins, CO.

Thomas R. Payne and Associates 1998. RHABSIM 2.0 User's Manual. TRPA, Arcata, CA..

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

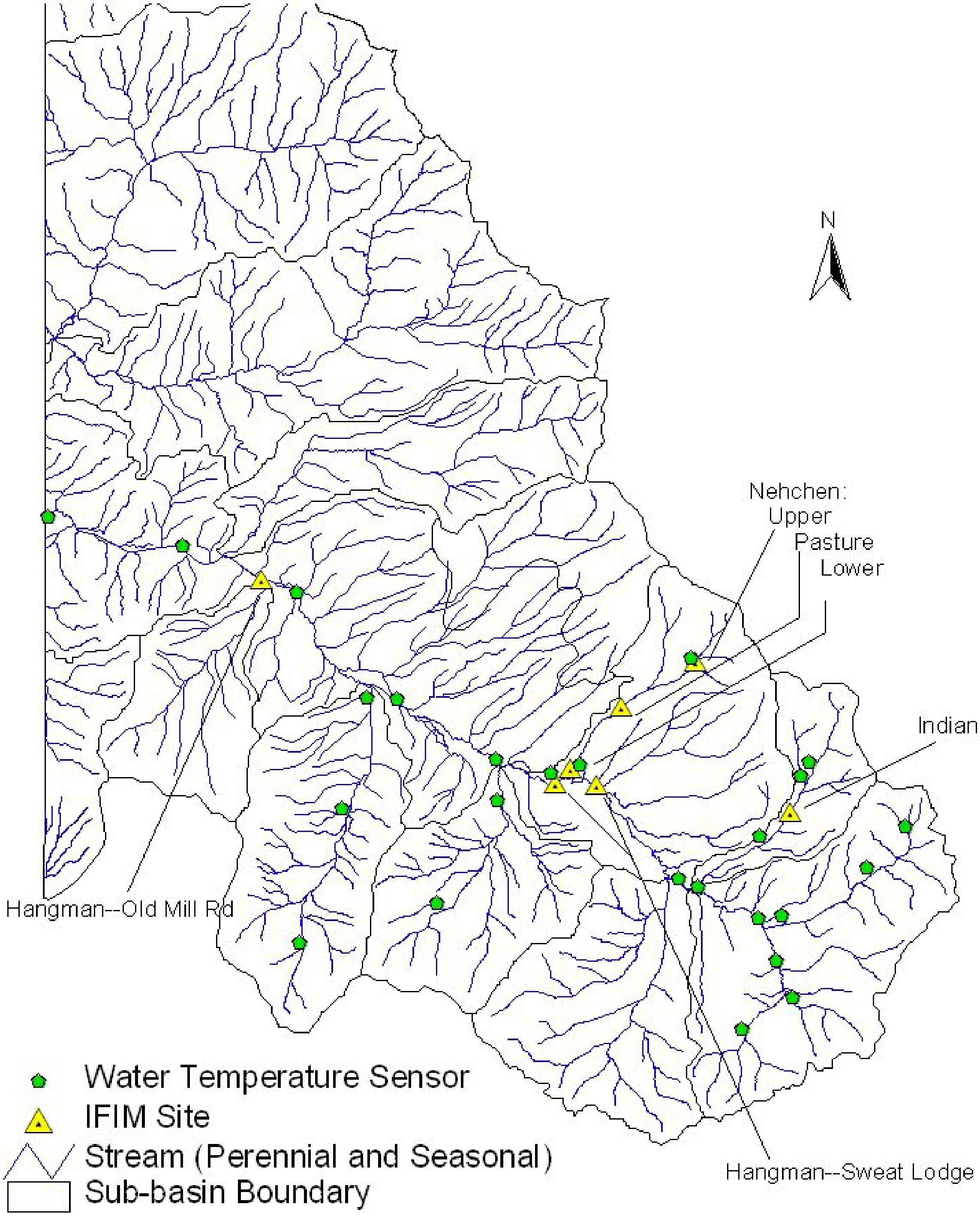


Figure 1. Map of the Hangman Creek study area, showing locations of PHABSIM sites and stream temperature loggers.

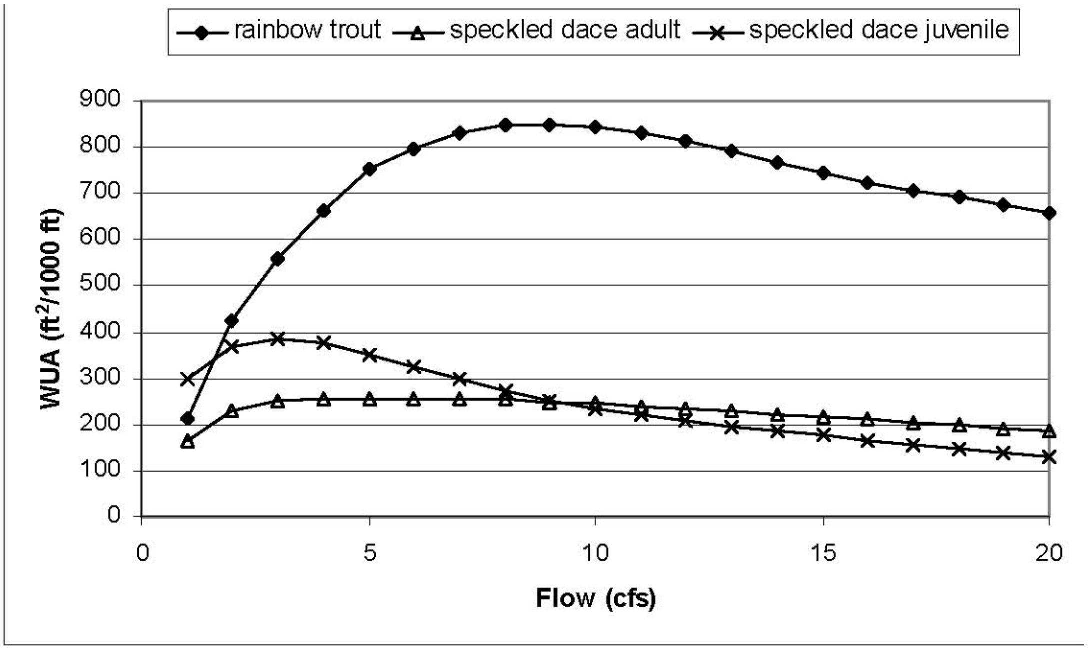


Figure 2. WUA vs. flow for rainbow trout and speckled dace, Indian Creek.

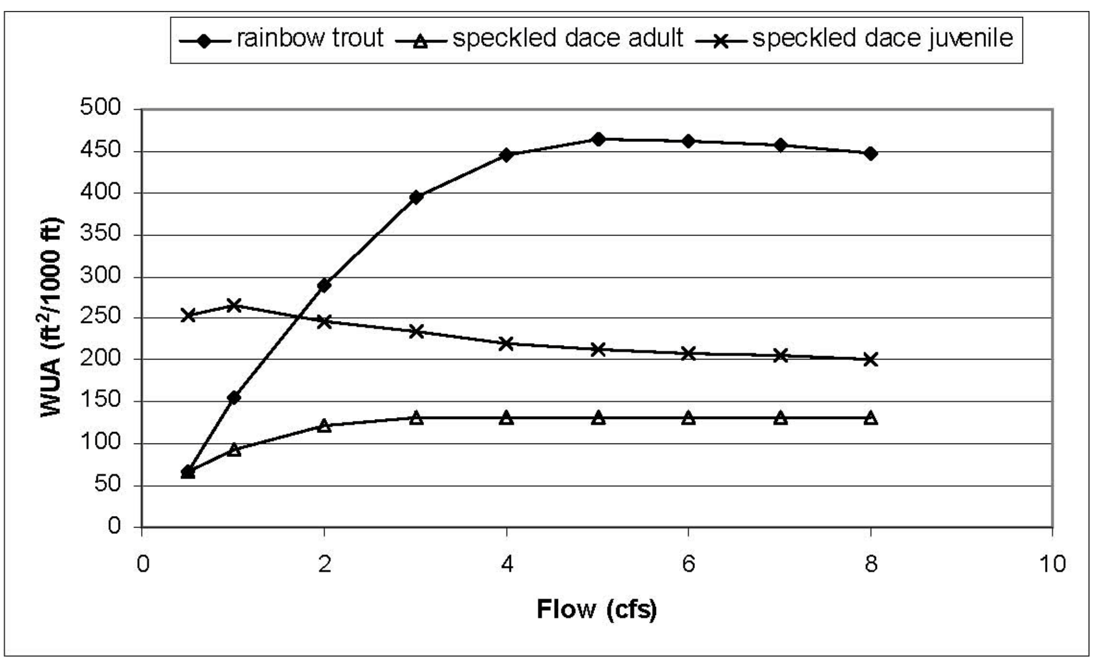


Figure 3. WUA vs. flow for rainbow trout and speckled dace, Upper Nehchen Creek.

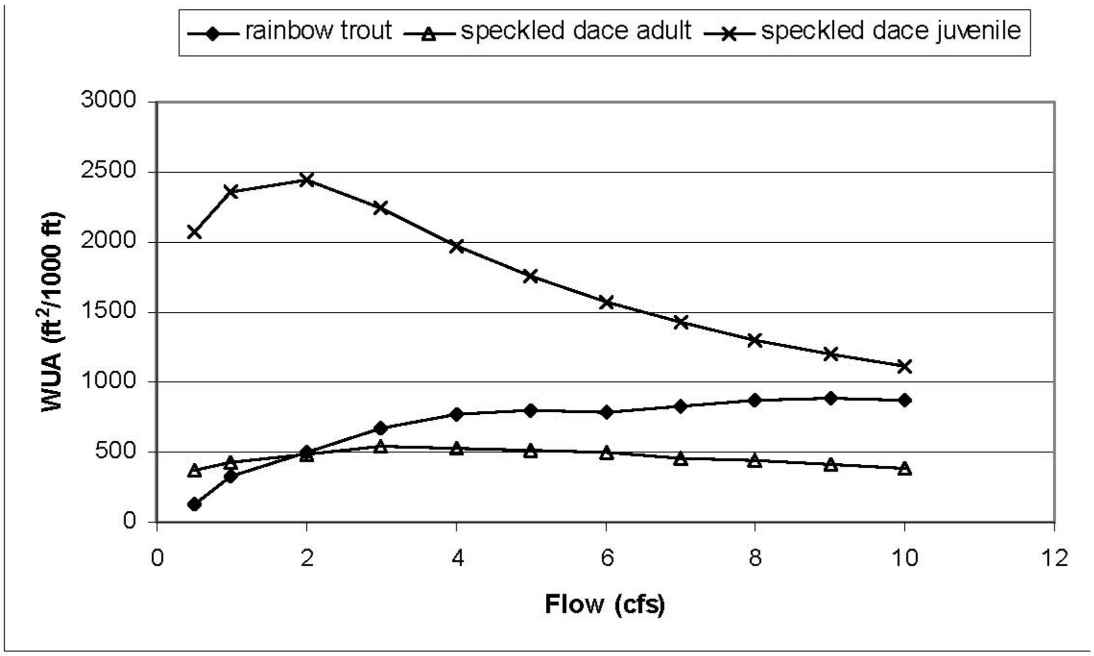


Figure 4. WUA vs. flow for rainbow trout and speckled dace, Nehchen Creek, pasture site.

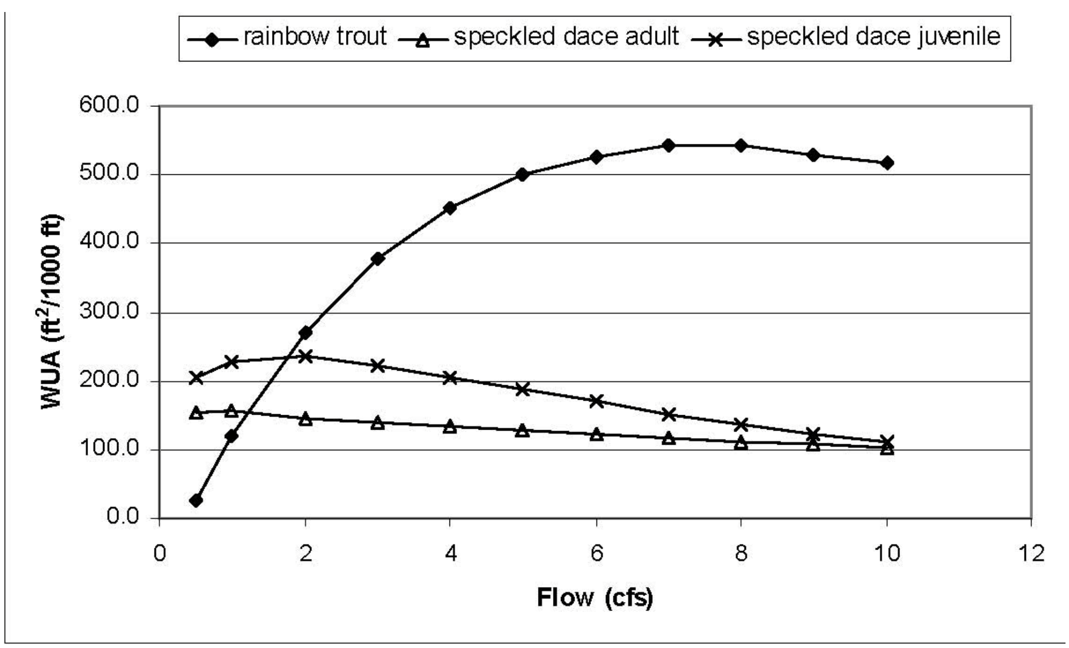


Figure 5. WUA vs. flow for rainbow trout and speckled dace, Lower Nehchen Creek.

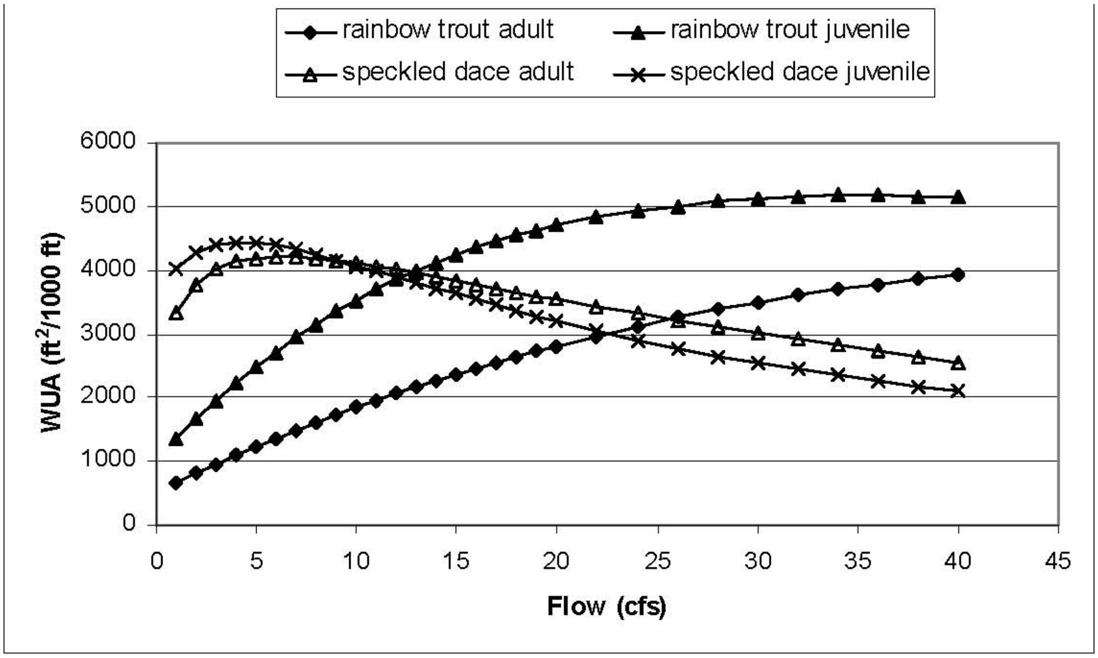


Figure 6. WUA vs. flow for rainbow trout and speckled dace, mainstem Hangman Creek, Sweat Lodge site.

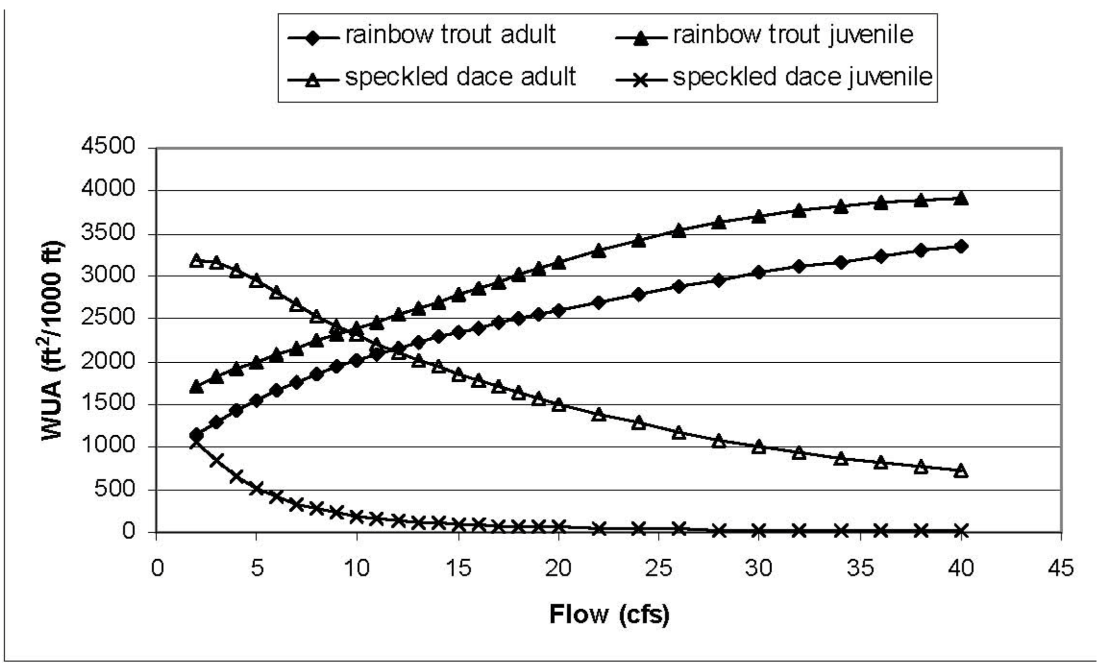


Figure 7. WUA vs. flow for rainbow trout and speckled dace, mainstem Hangman Creek, Old Mill Road site.

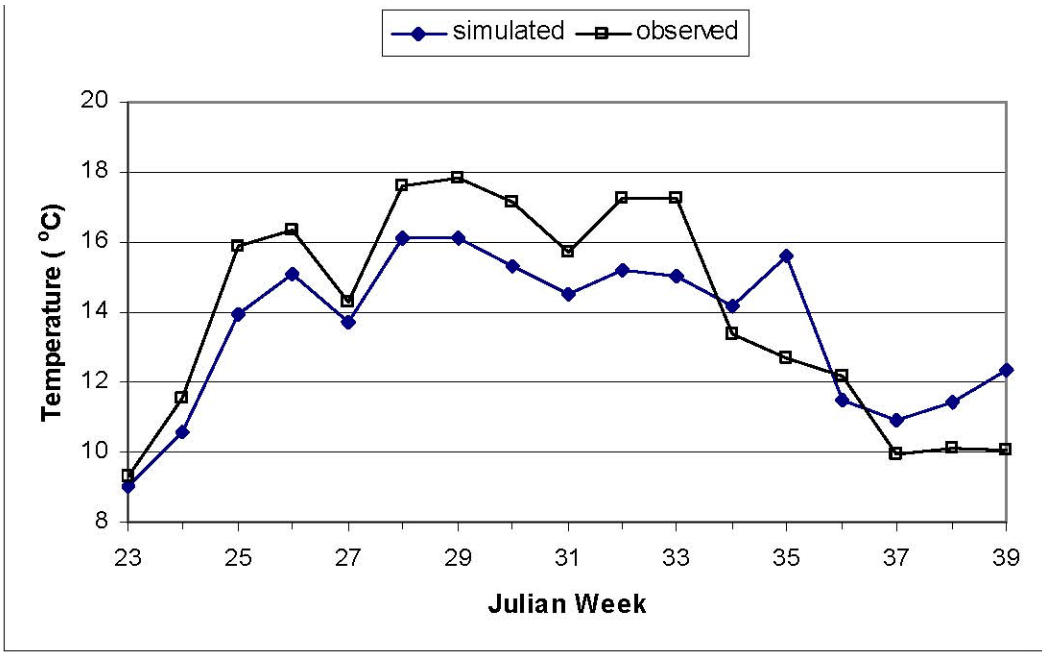


Figure 8. Measured vs. modeled weekly temperatures for Hangman Creek, RM 17.3 (S.F. Road).

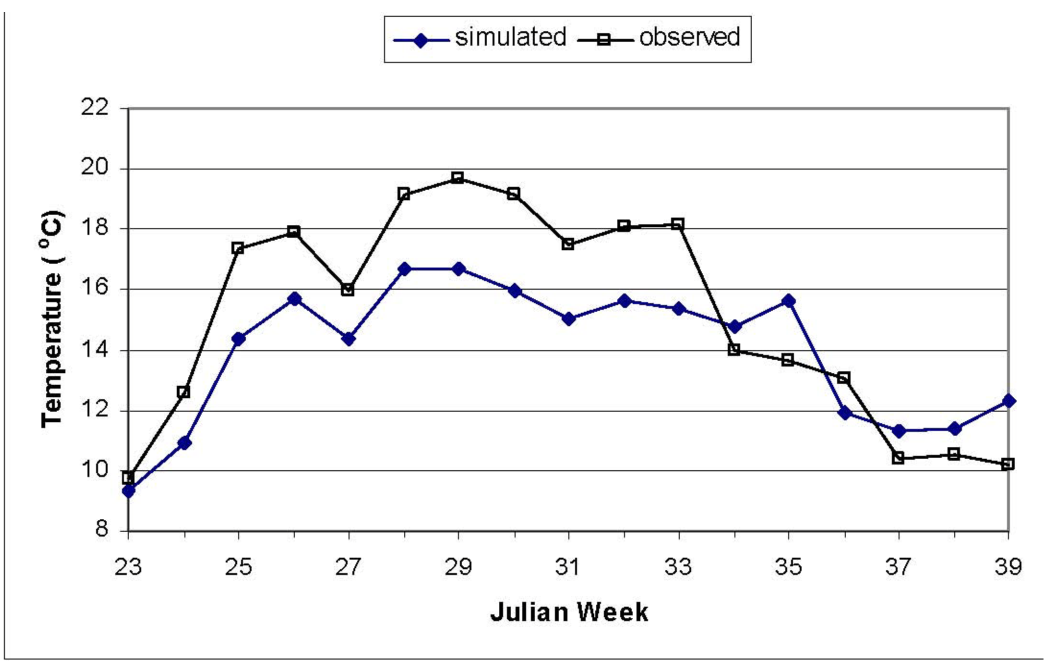


Figure 9. Measured vs. modeled weekly temperatures for Hangman Creek, RM 17.0 (Bennett).

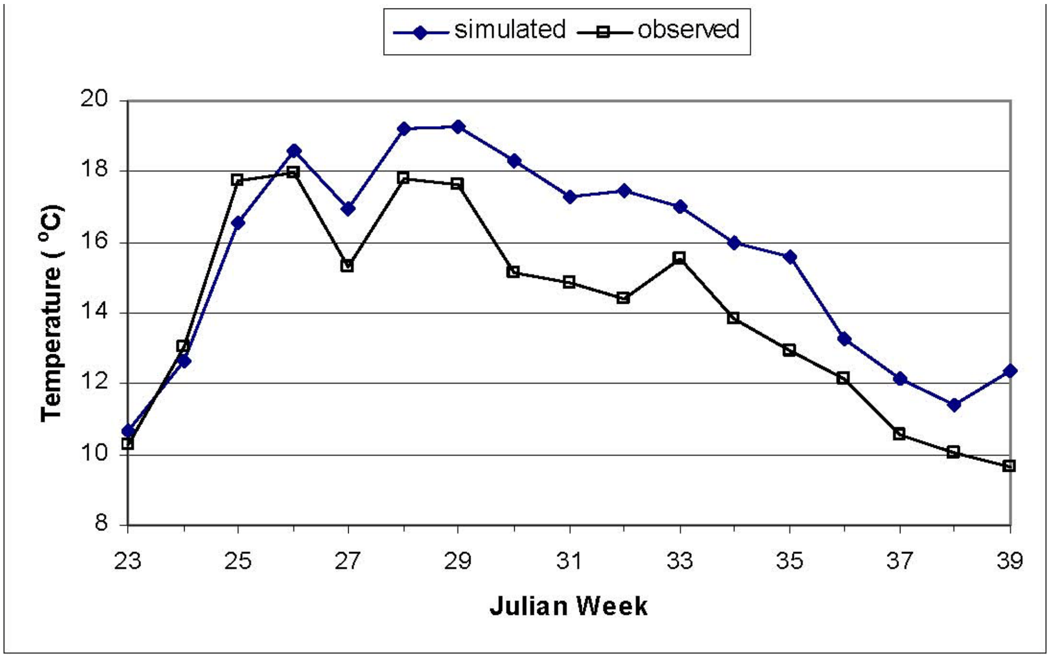


Figure 10. Measured vs. modeled weekly temperatures for Hangman Creek, RM 15.5 (Crawford).

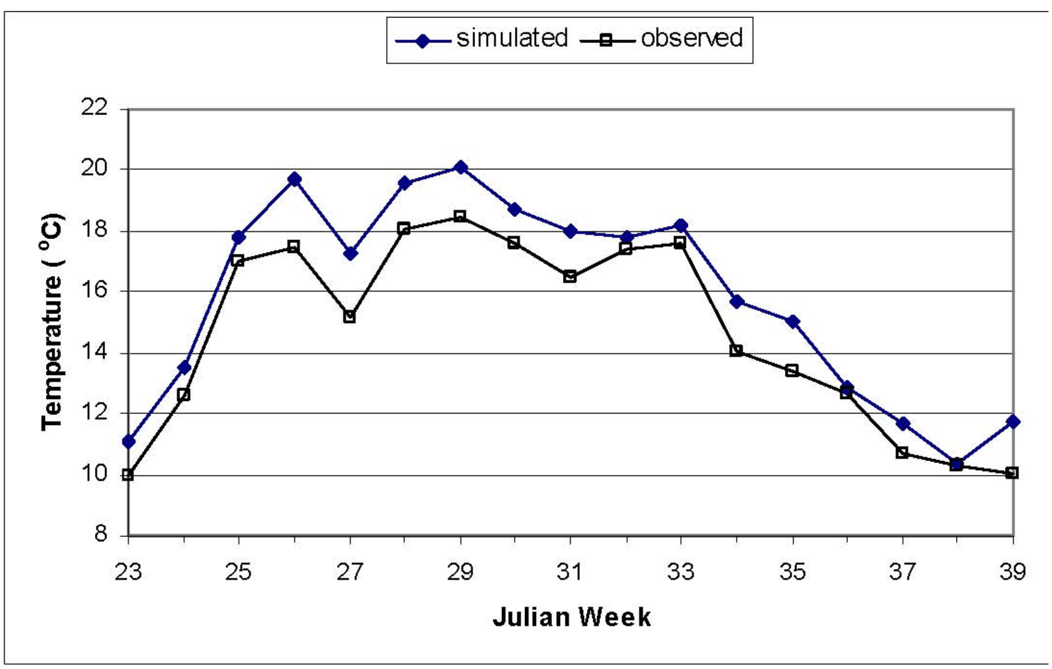


Figure 11. Measured vs. modeled weekly temperatures for Hangman Creek, RM 14.3 (Larsen).

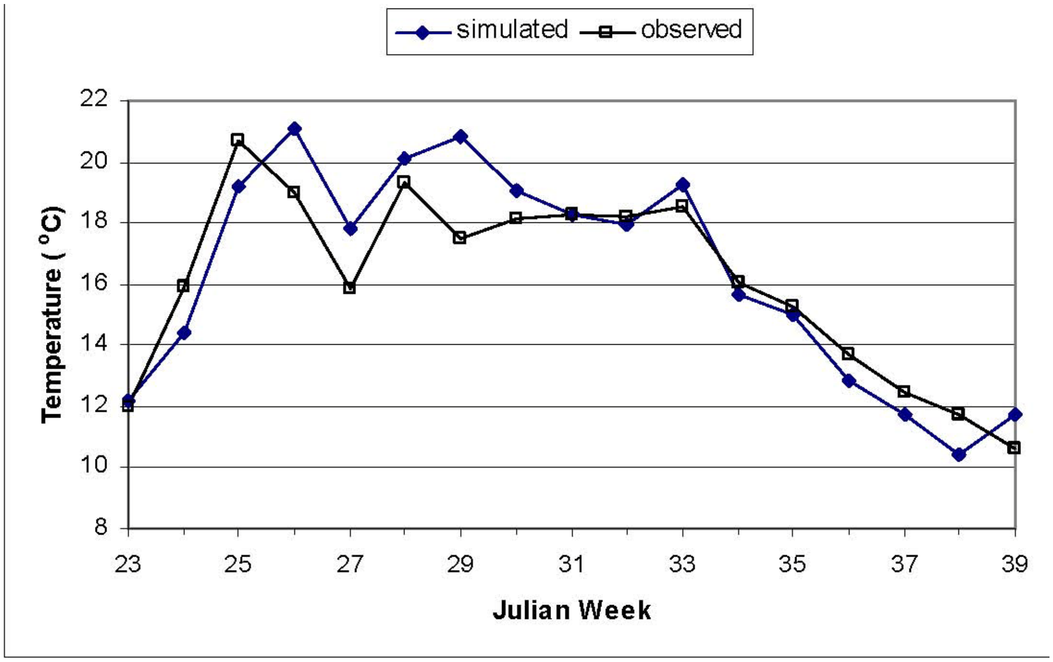


Figure 12. Measured vs. modeled weekly temperatures for Hangman Creek, RM 12.7 (Nehchen Hump).

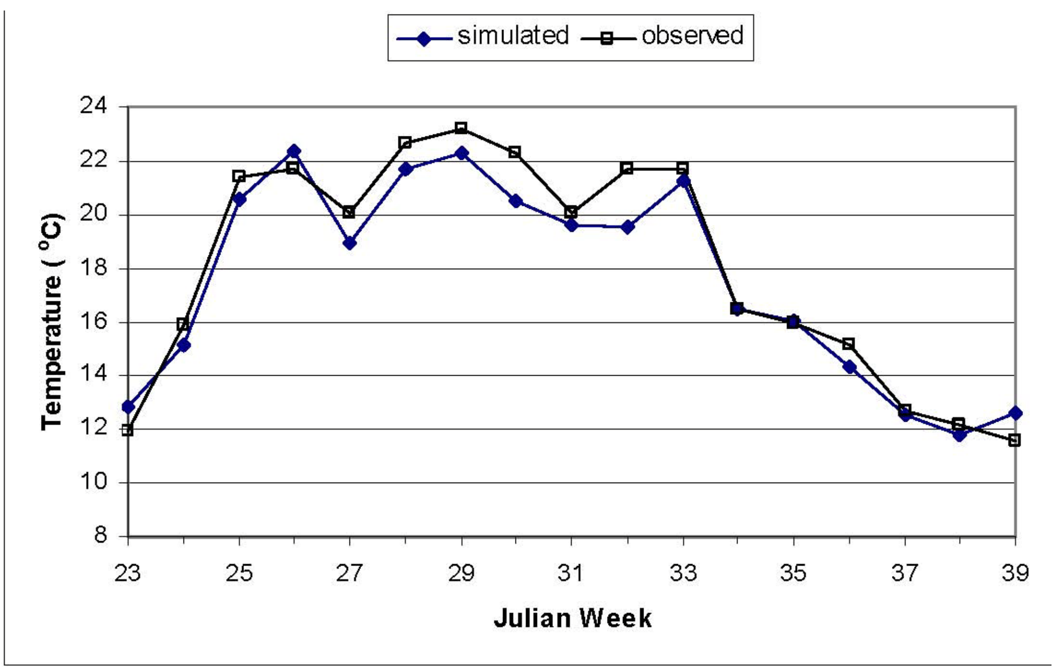


Figure 13. Measured vs. modeled weekly temperatures for Hangman Creek, RM 10.6 (Buckless).

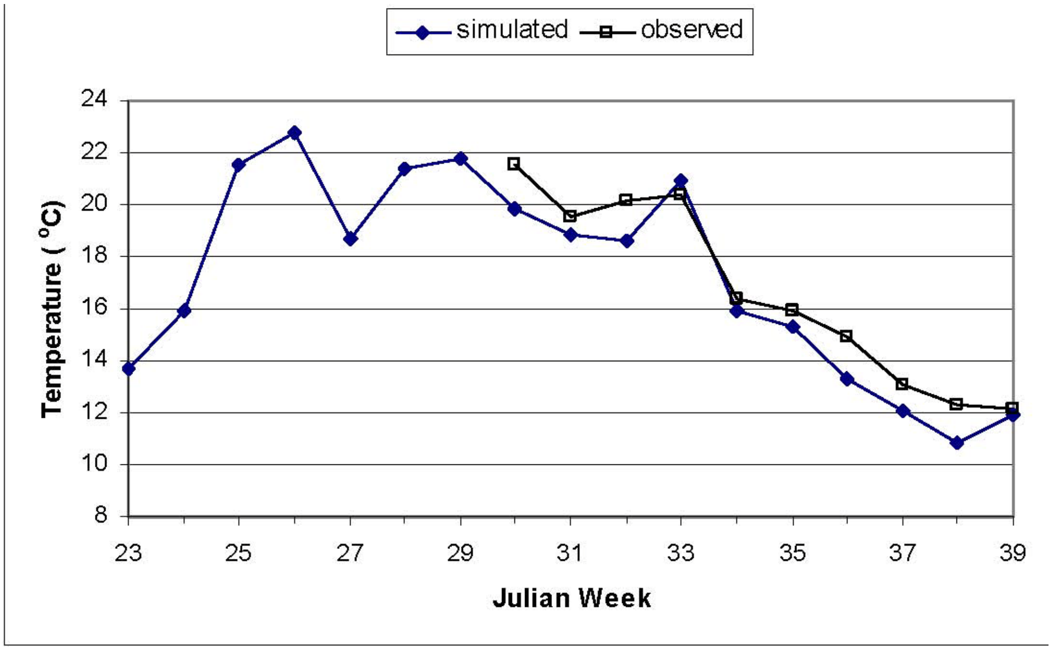


Figure 14. Measured vs. modeled weekly temperatures for Hangman Creek, RM 8.3 (Hwy 95).

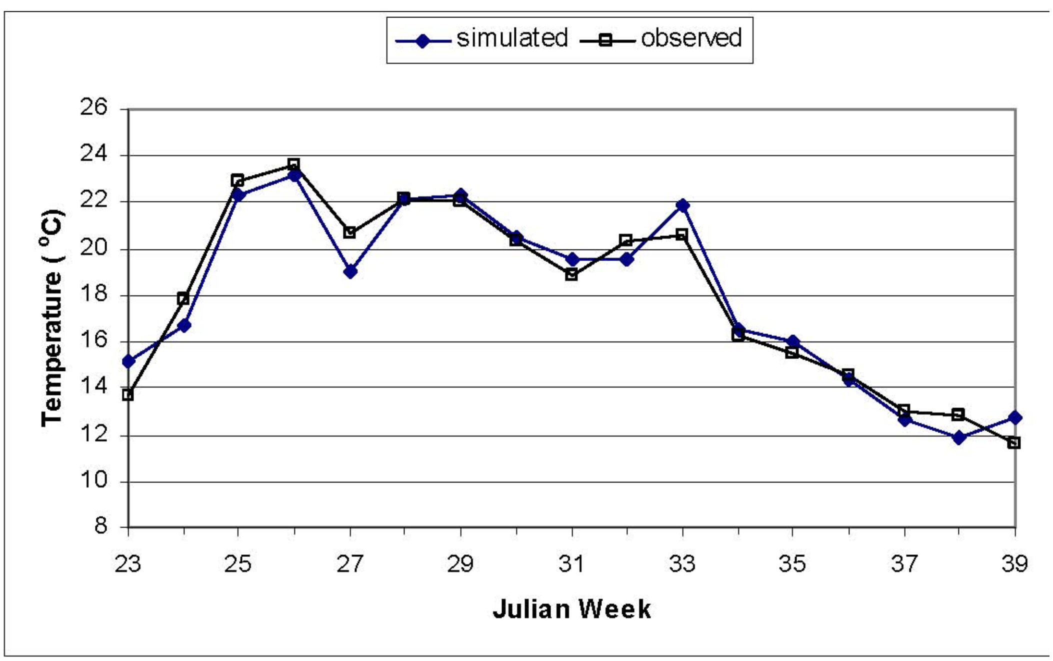


Figure 15. Measured vs. modeled weekly temperatures for Hangman Creek, RM 5.0 (Tribal Farm).

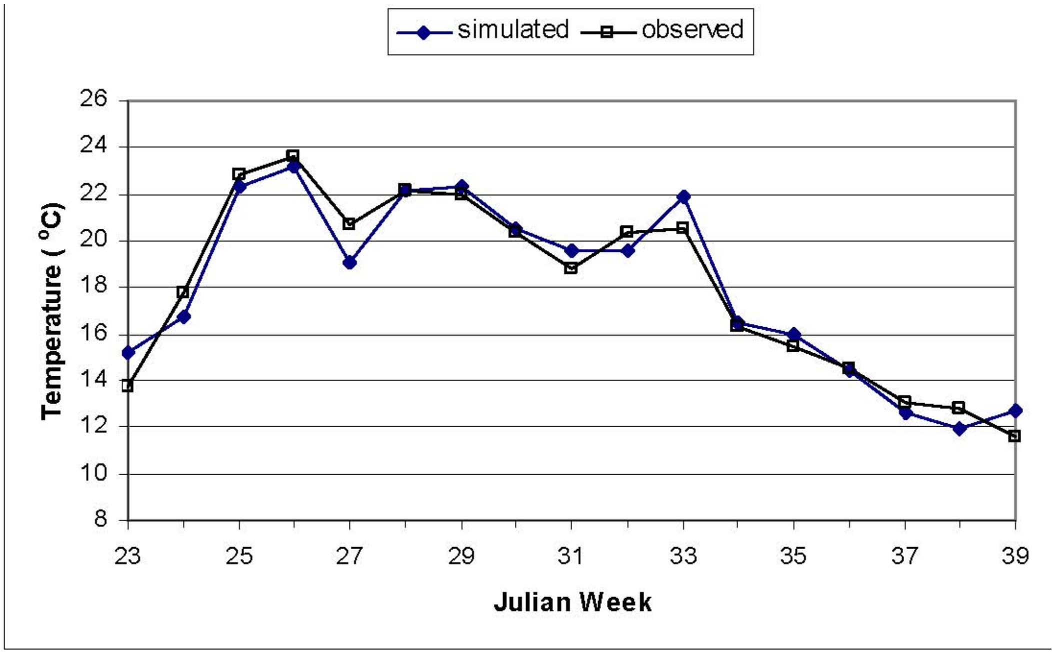


Figure 16. Measured vs. modeled weekly temperatures for Hangman Creek, RM 3.1 (Liberty Butte).

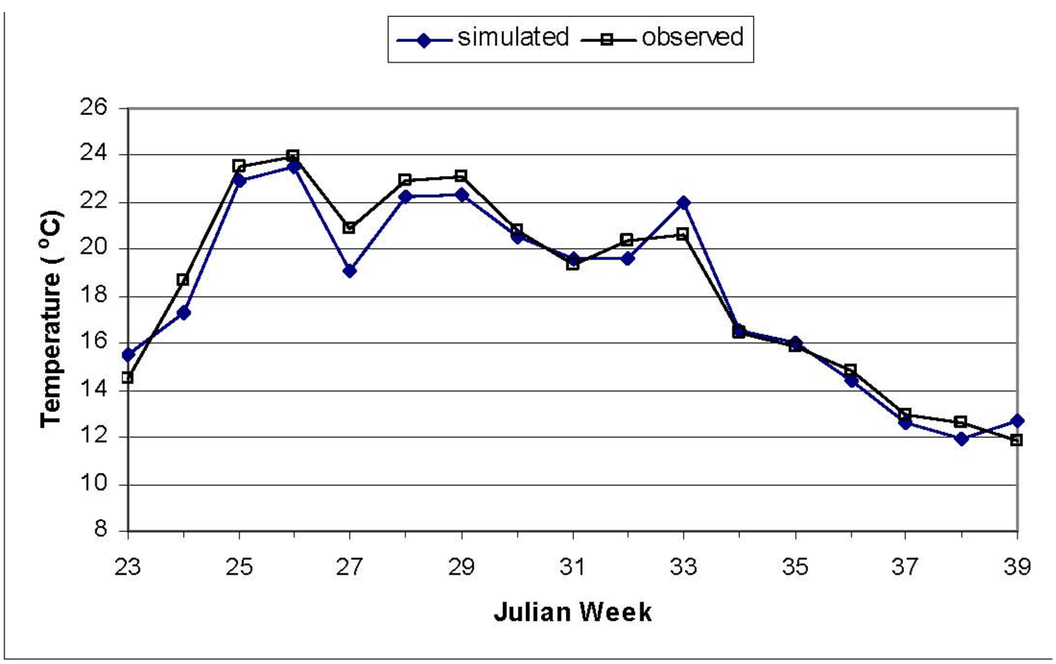


Figure 17. Measured vs. modeled weekly temperatures for Hangman Creek, RM 0.0 (State Line).

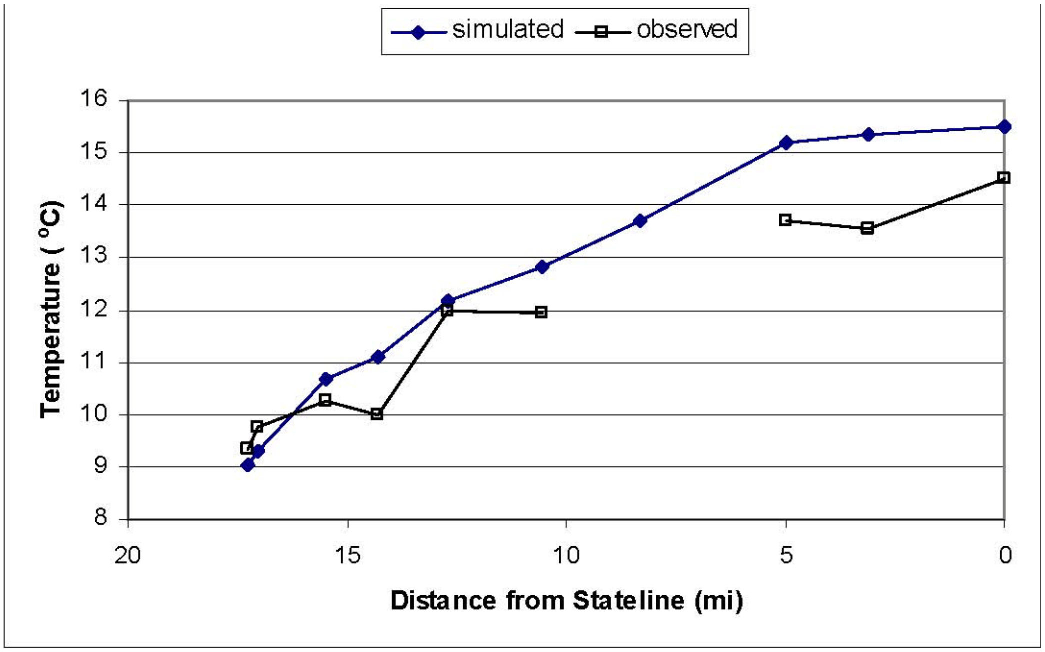


Figure 18. Longitudinal comparison of measured and modeled temperatures for Week 23 (June 3-9).

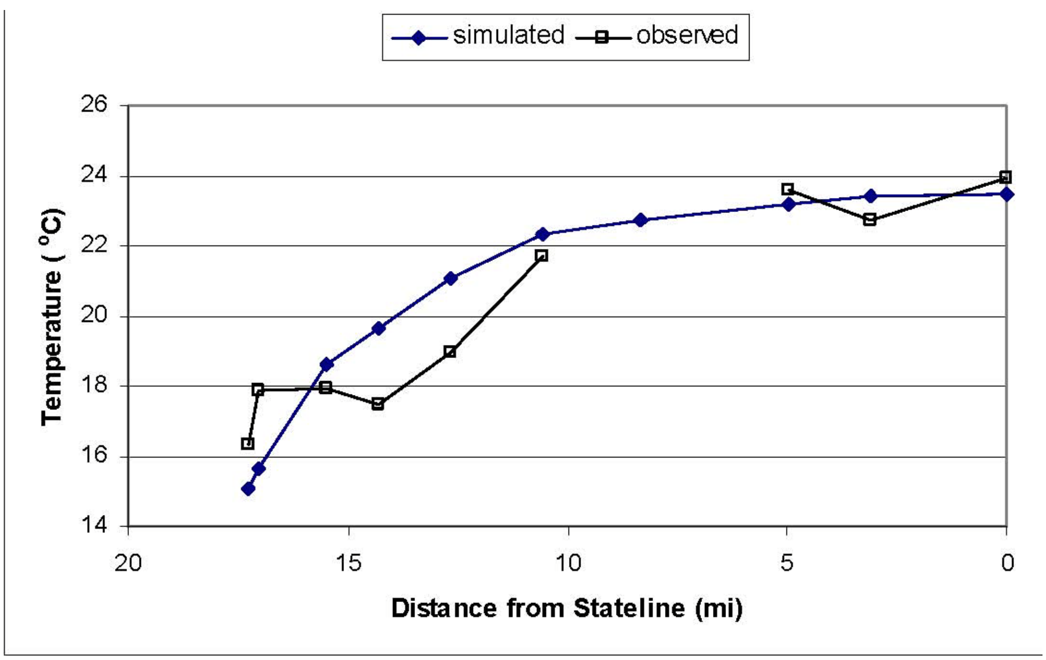


Figure 19. Longitudinal comparison of measured and modeled temperatures for Week 26 (June 24-30).

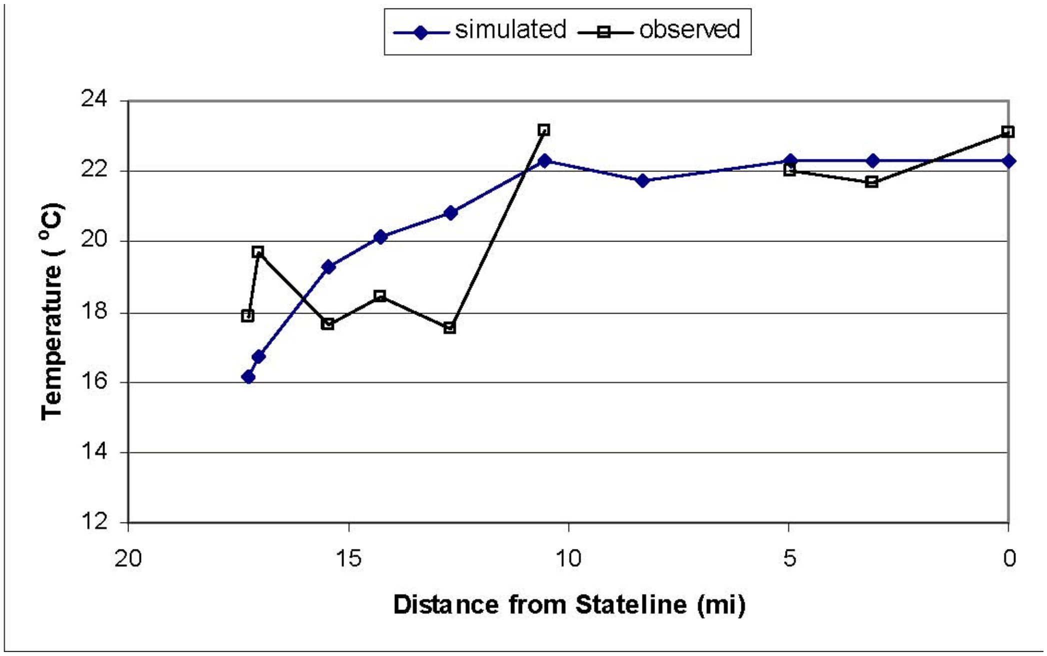


Figure 20. Longitudinal comparison of measured and modeled temperatures for Week 29 (July 15-21).

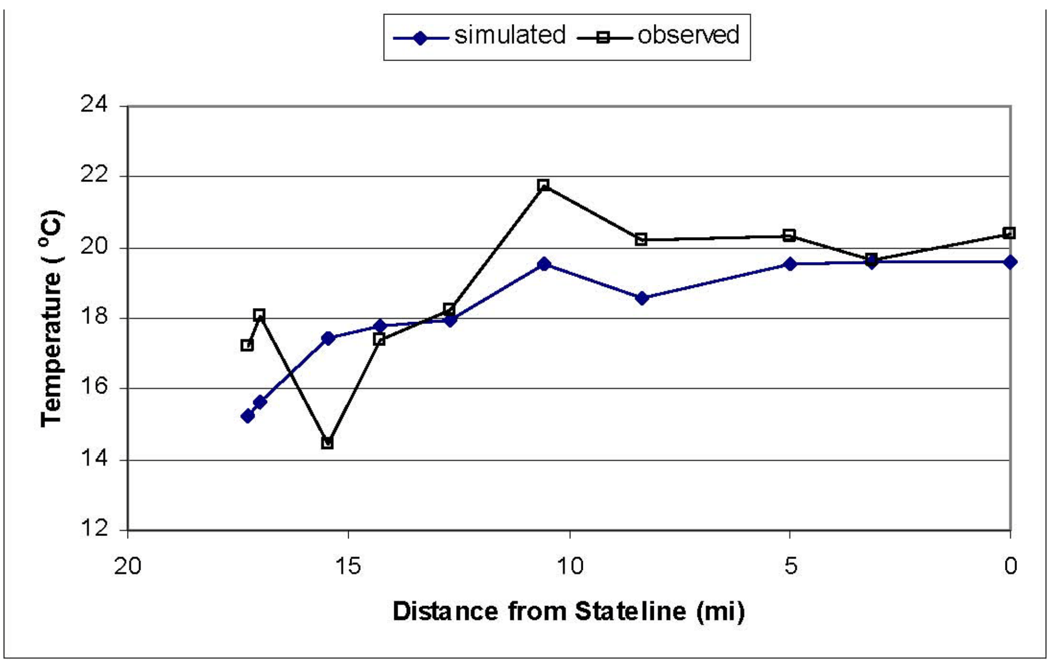


Figure 21. Longitudinal comparison of measured and modeled temperatures for Week 32 (August 5-11).

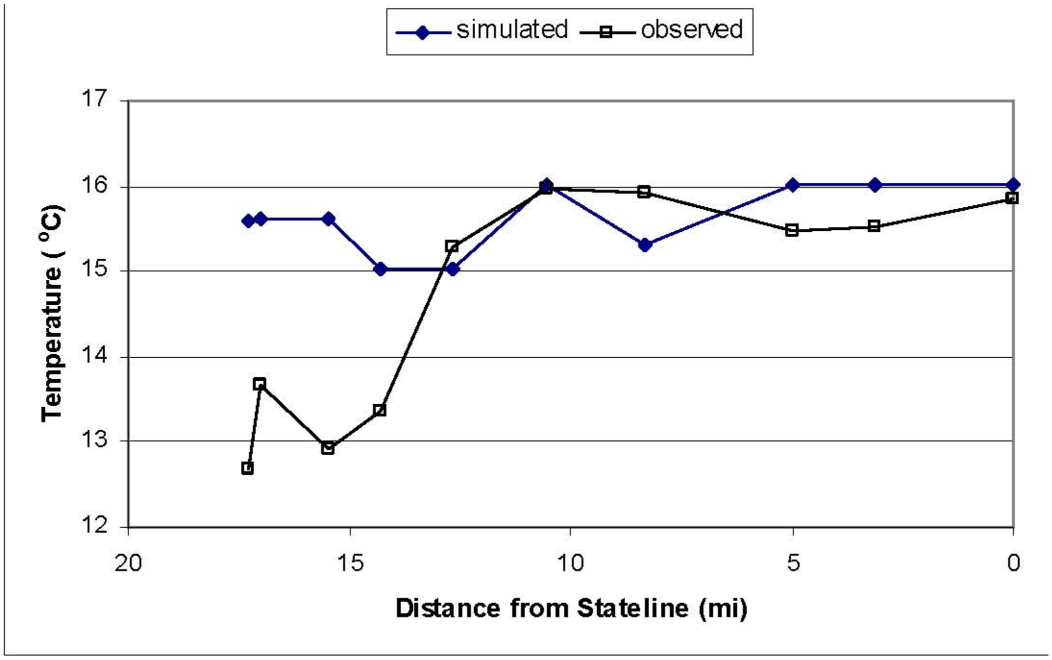


Figure 22. Longitudinal comparison of measured and modeled temperatures for Week 35 (August 26-September 1).

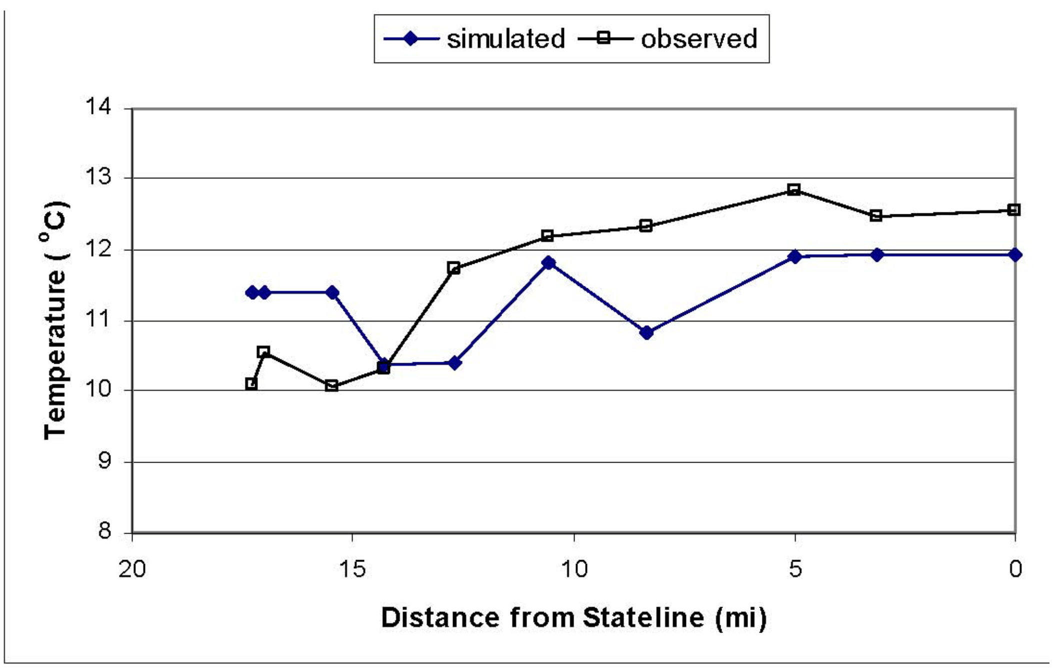


Figure 23. Longitudinal comparison of measured and modeled temperatures for Week 38 (Sept. 16-22).

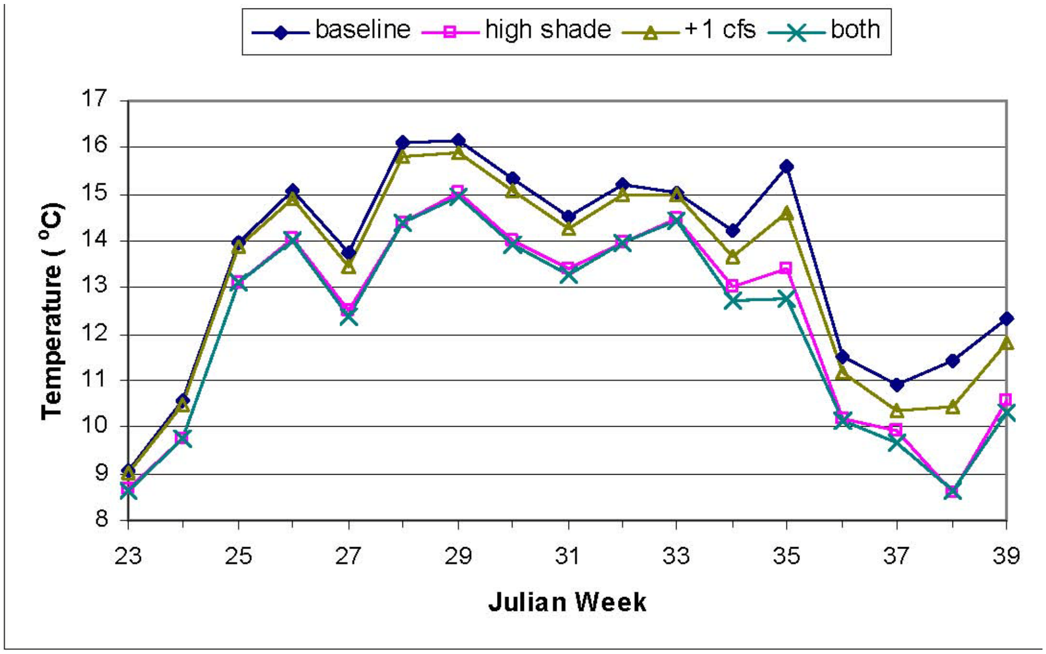


Figure 24. Baseline and scenario temperatures for Hangman Creek, RM 17.3 (S.F. Road).

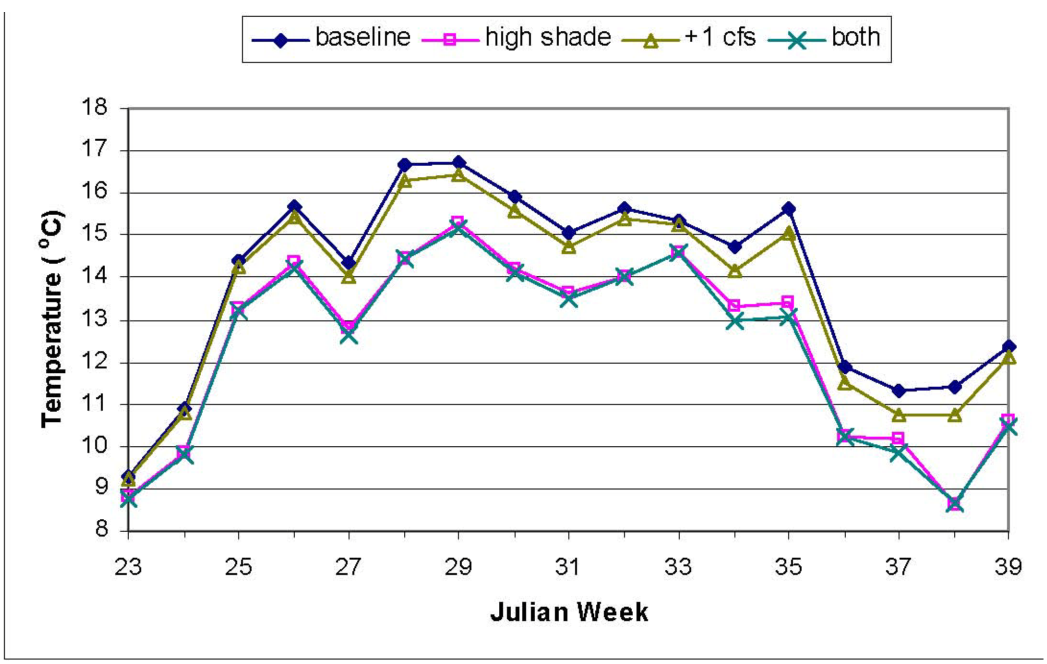


Figure 25. Baseline and scenario temperatures for Hangman Creek, RM 17.0 (Bennett).

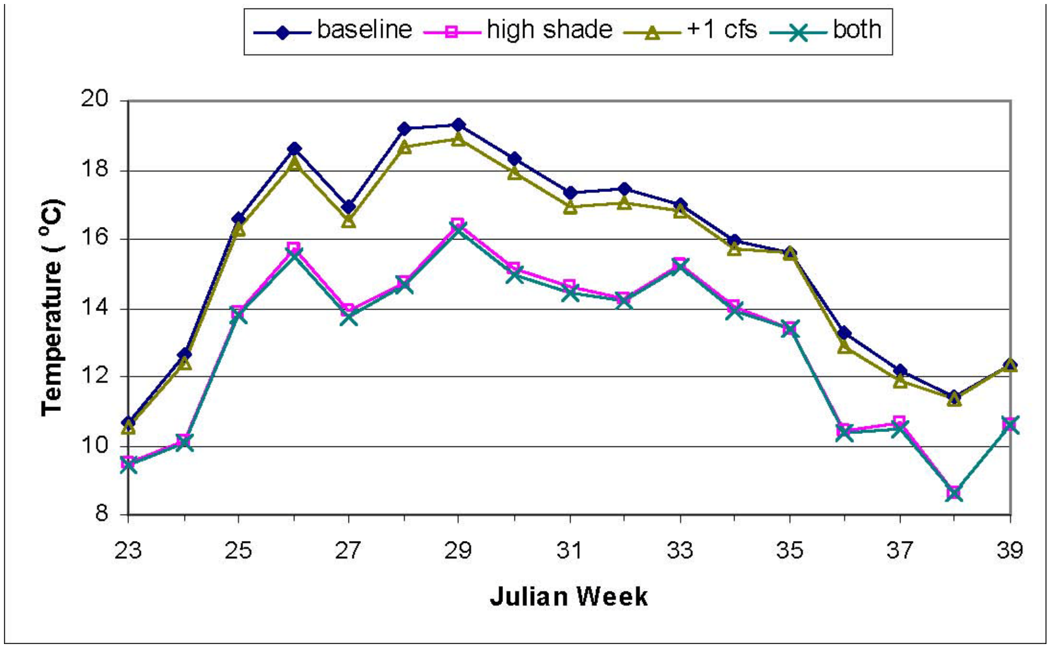


Figure 26. Baseline and scenario temperatures for Hangman Creek, RM 15.5 (Crawford).

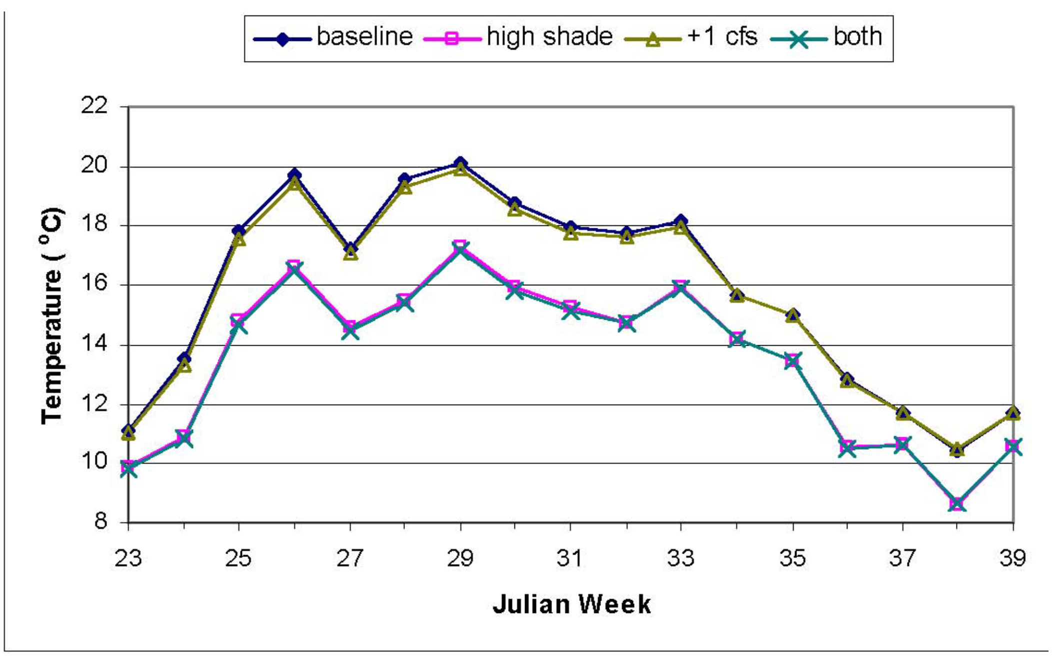


Figure 27. Baseline and scenario temperatures for Hangman Creek, RM 14.3 (Larsen).

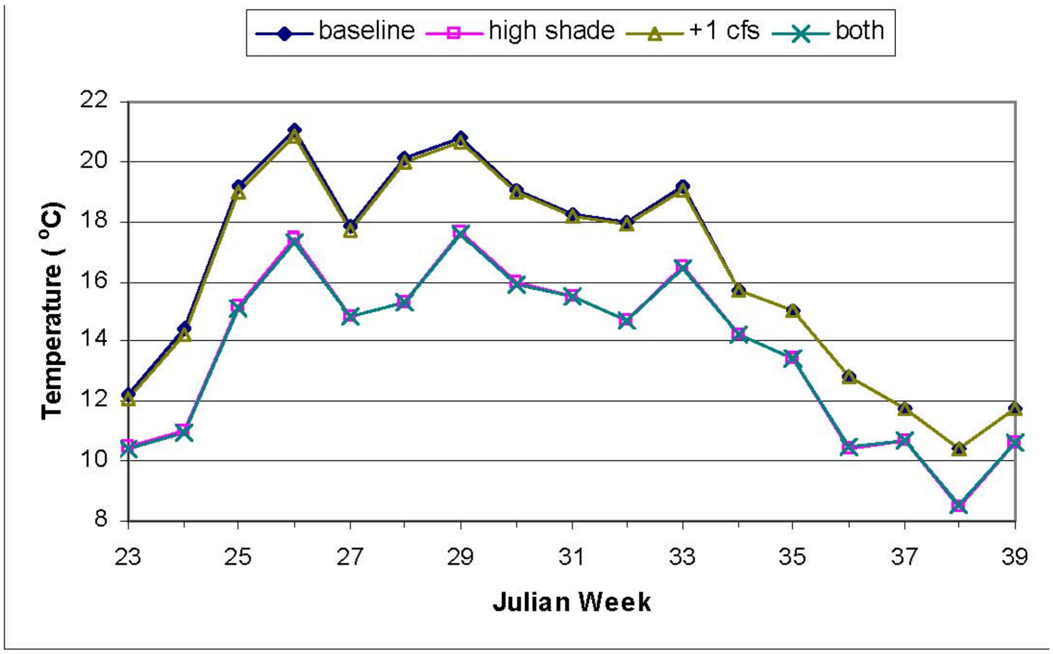


Figure 28. Baseline and scenario temperatures for Hangman Creek, RM 12.7 (Nehchen Hump).

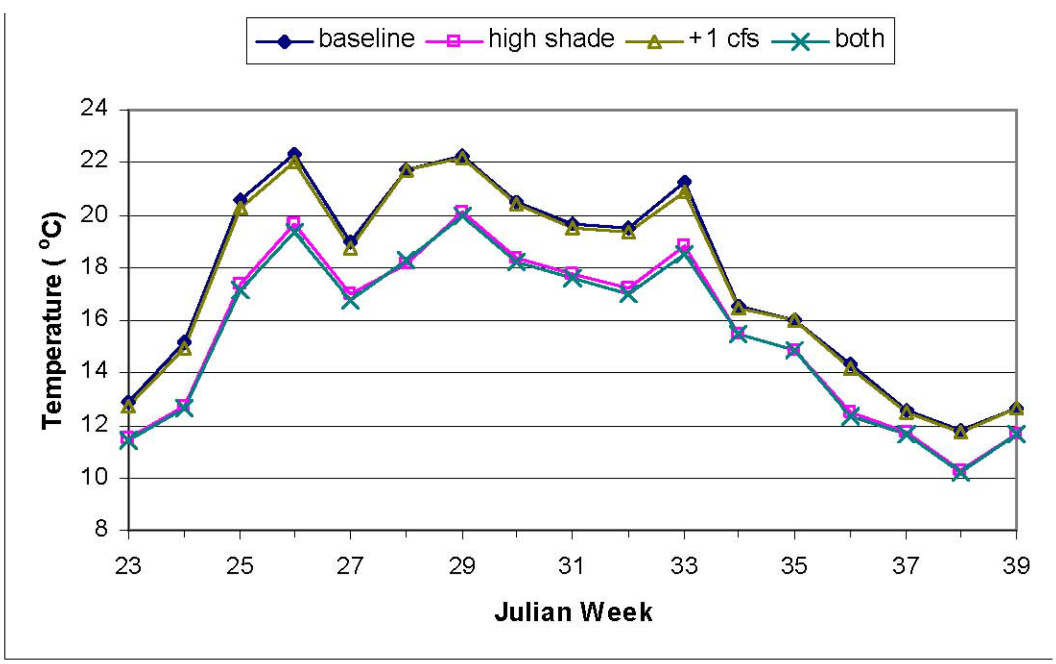


Figure 29. Baseline and scenario temperatures for Hangman Creek, RM 10.6 (Buckless).

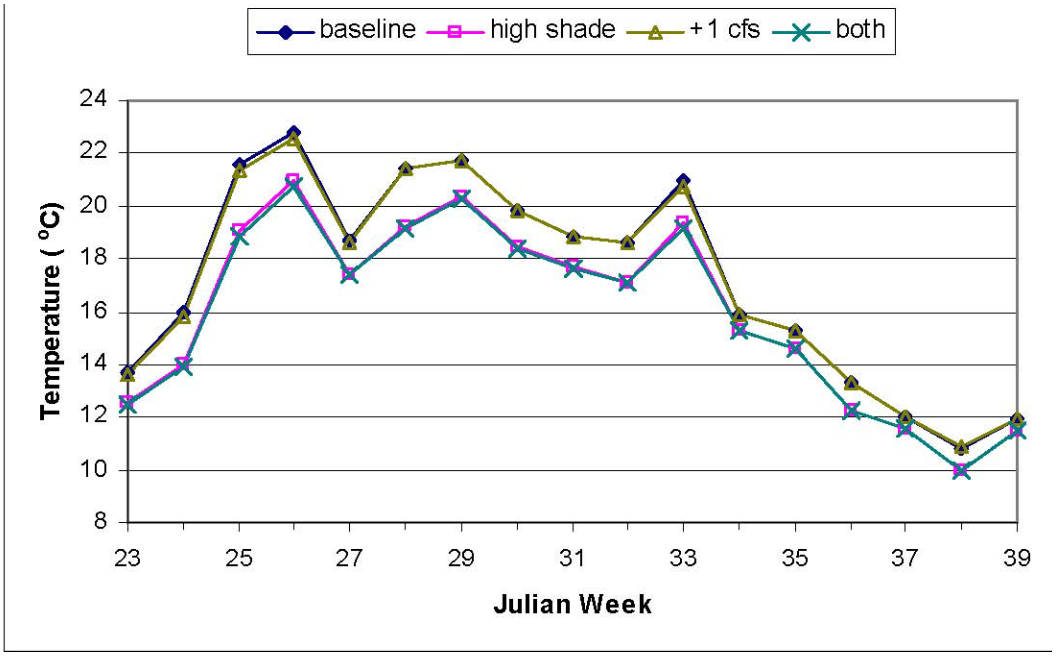


Figure 30. Baseline and scenario temperatures for Hangman Creek, RM 8.3 (Hwy 95).

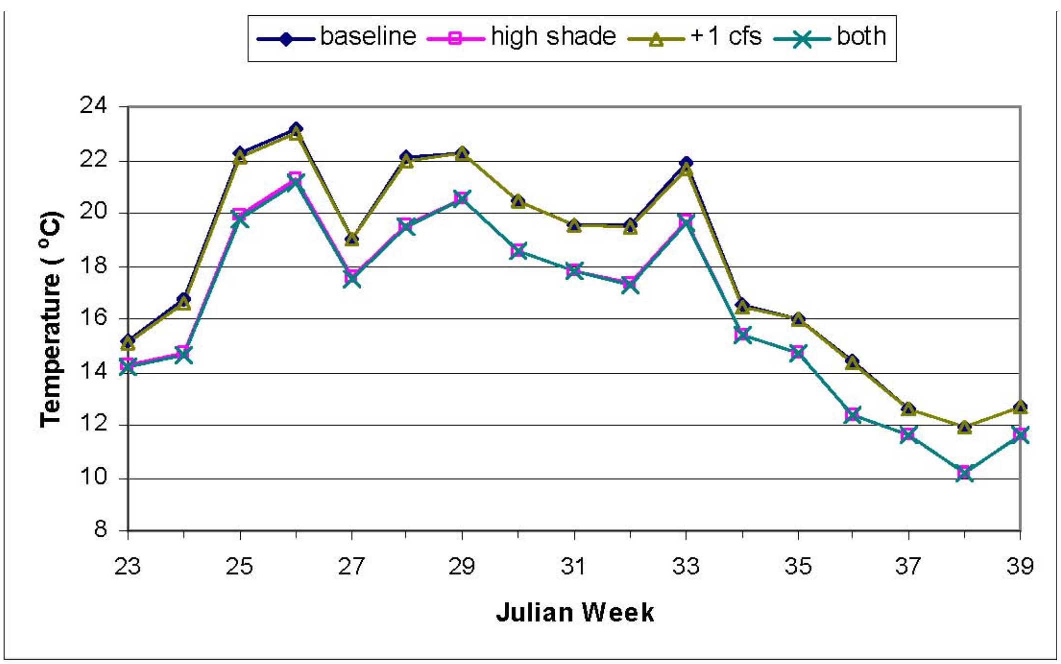


Figure 31. Baseline and scenario temperatures for Hangman Creek, RM 5.0 (Tribal Farm).

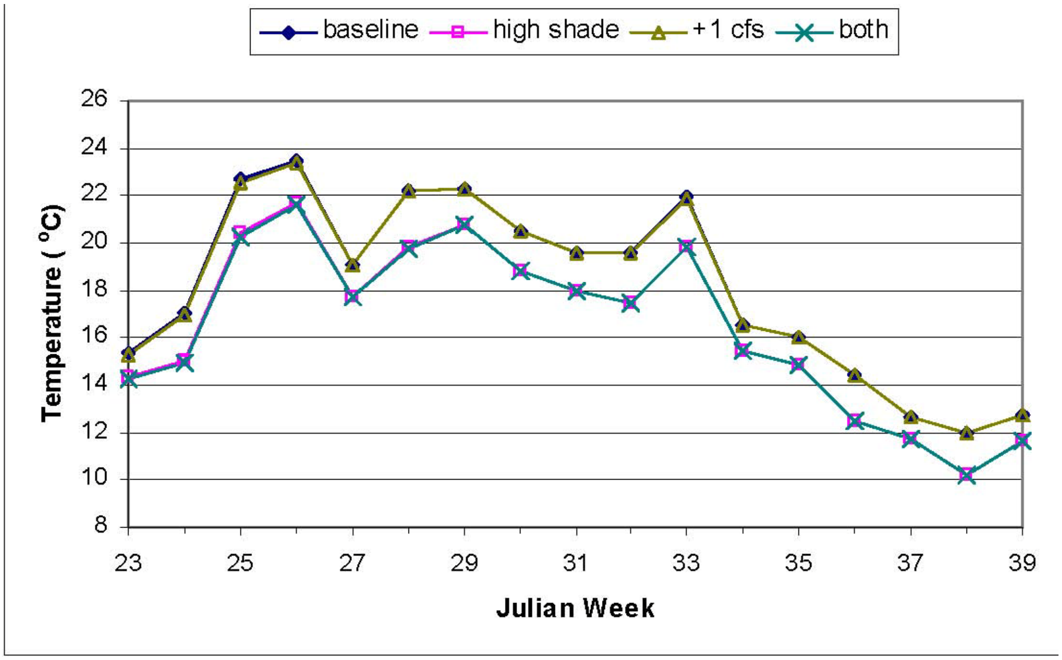


Figure 32. Baseline and scenario temperatures for Hangman Creek, RM 3.1 (Liberty Butte).

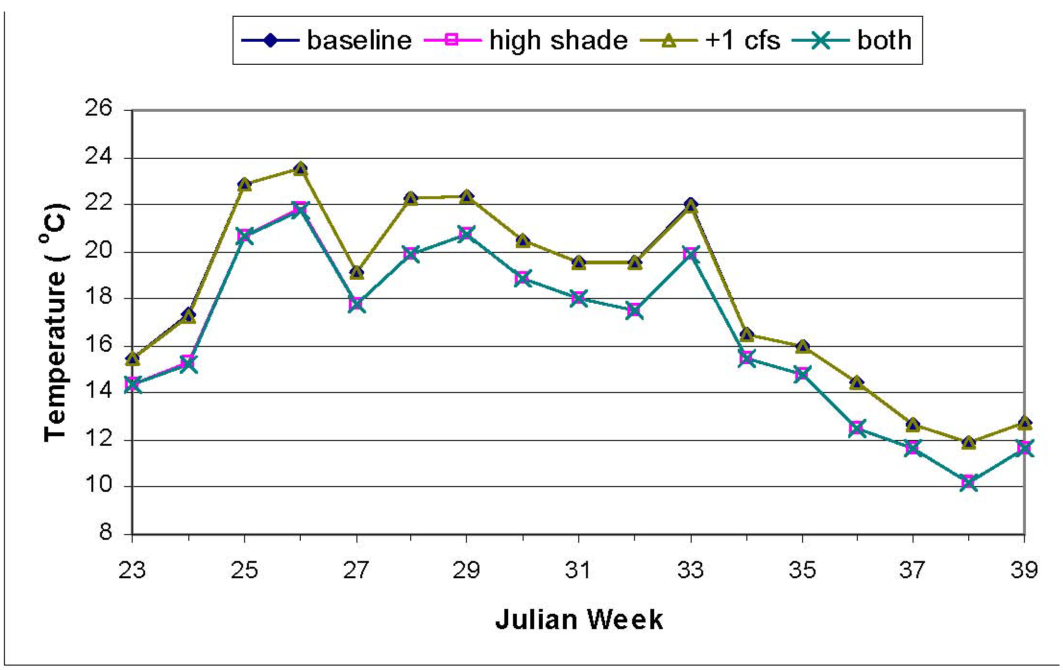


Figure 33. Baseline and scenario temperatures for Hangman Creek, RM 0.0 (State Line).

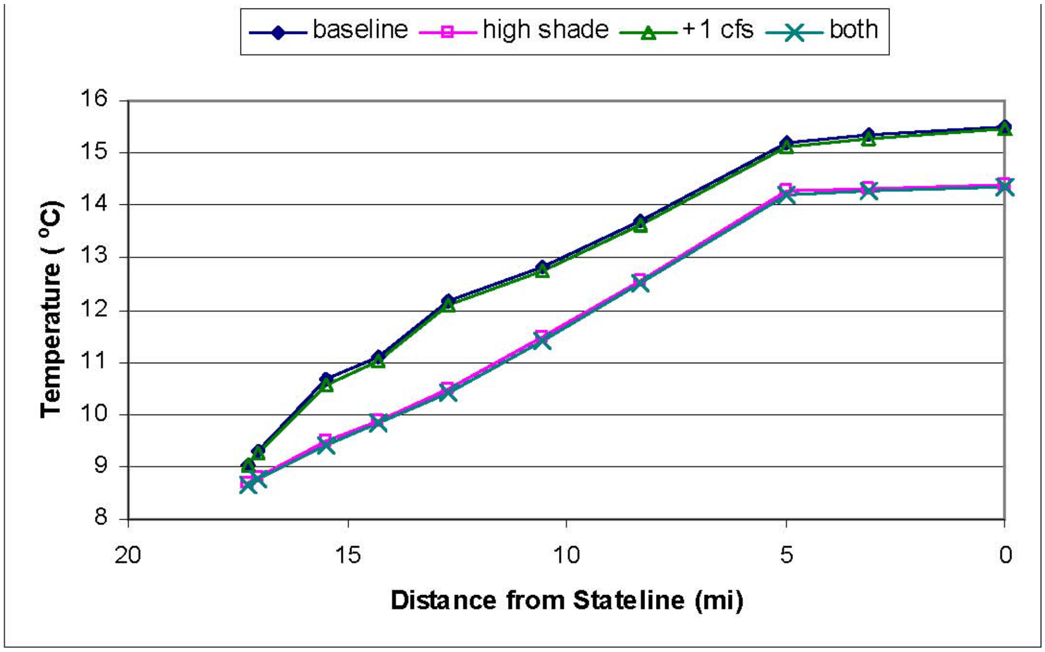


Figure 34. Longitudinal comparison of baseline and scenario temperatures for Week 23 (June 3-9).

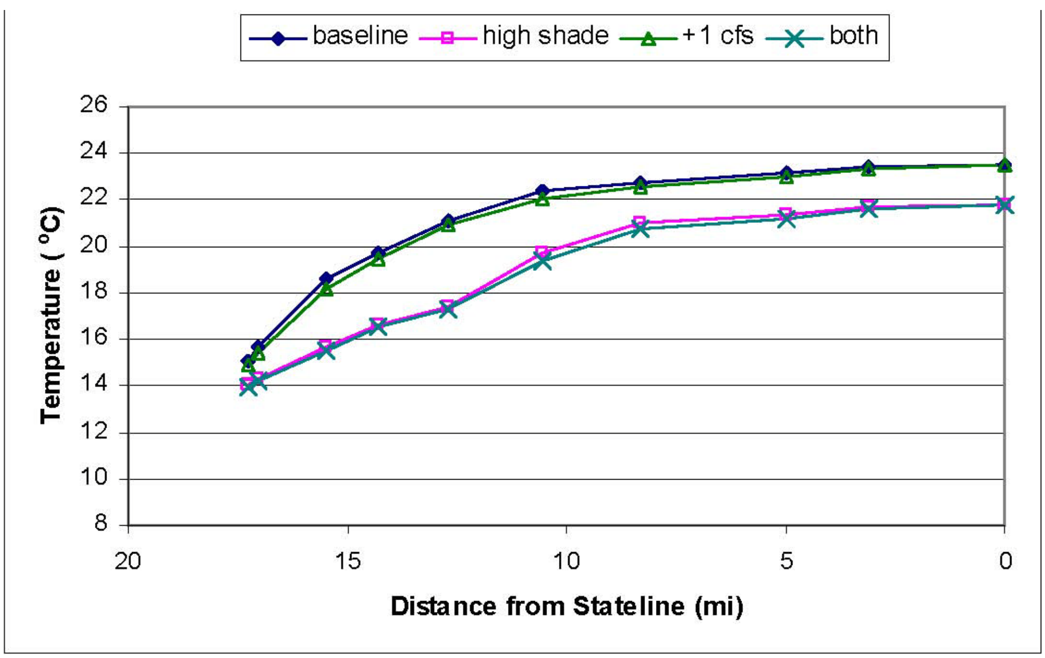


Figure 35. Longitudinal comparison of baseline and scenario temperatures for Week 26 (June 24-30).

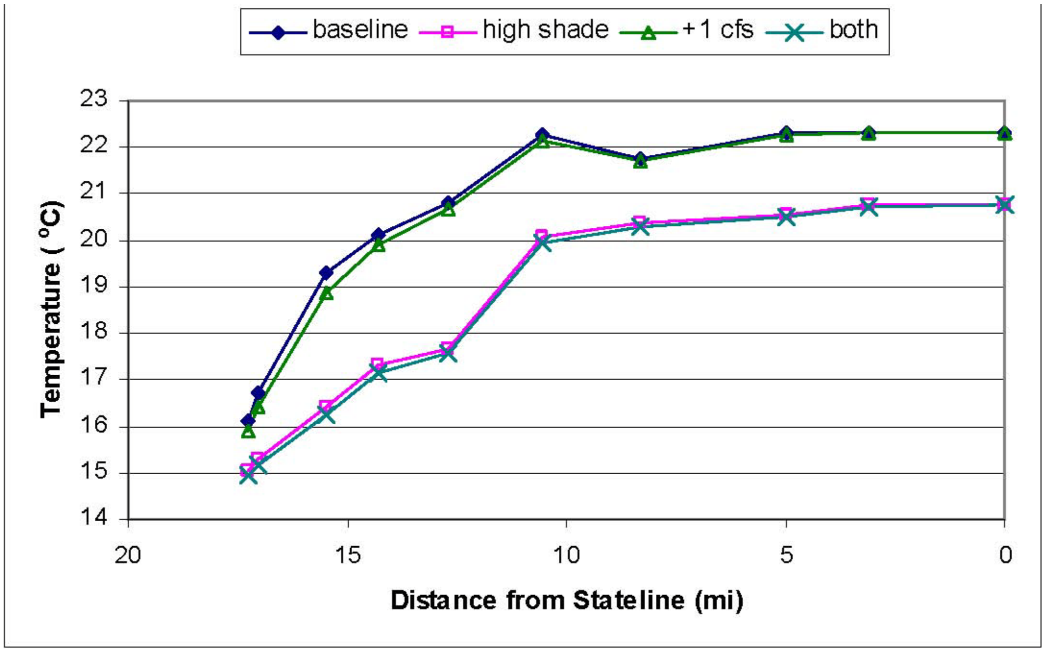


Figure 36. Longitudinal comparison of baseline and scenario temperatures for Week 29 (July 15-21).

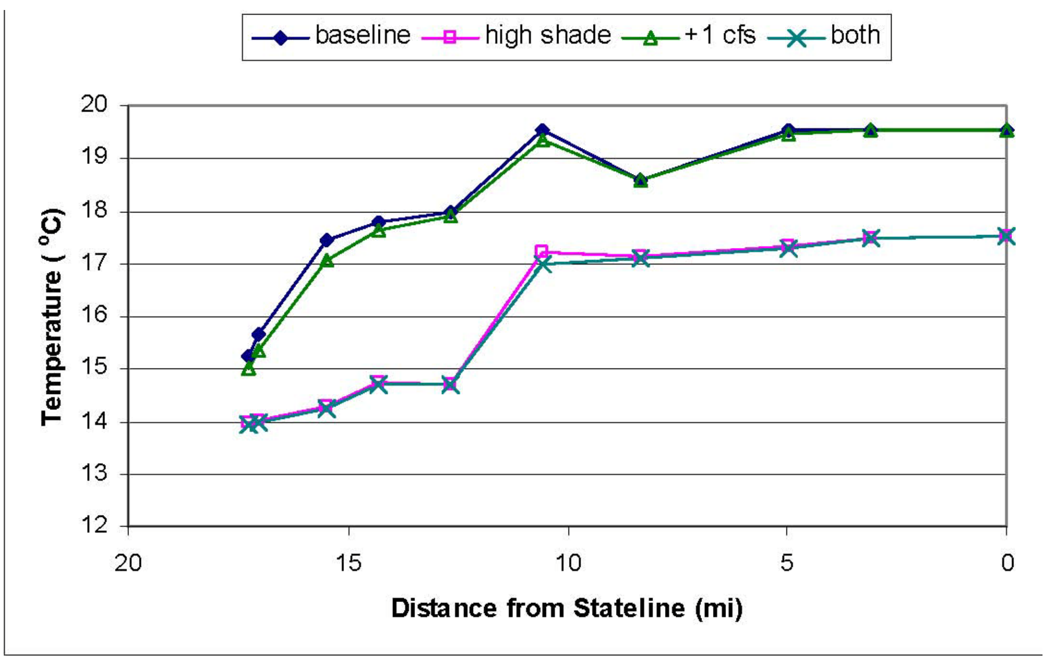


Figure 37. Longitudinal comparison of baseline and scenario temperatures for Week 32 (August 5-11).

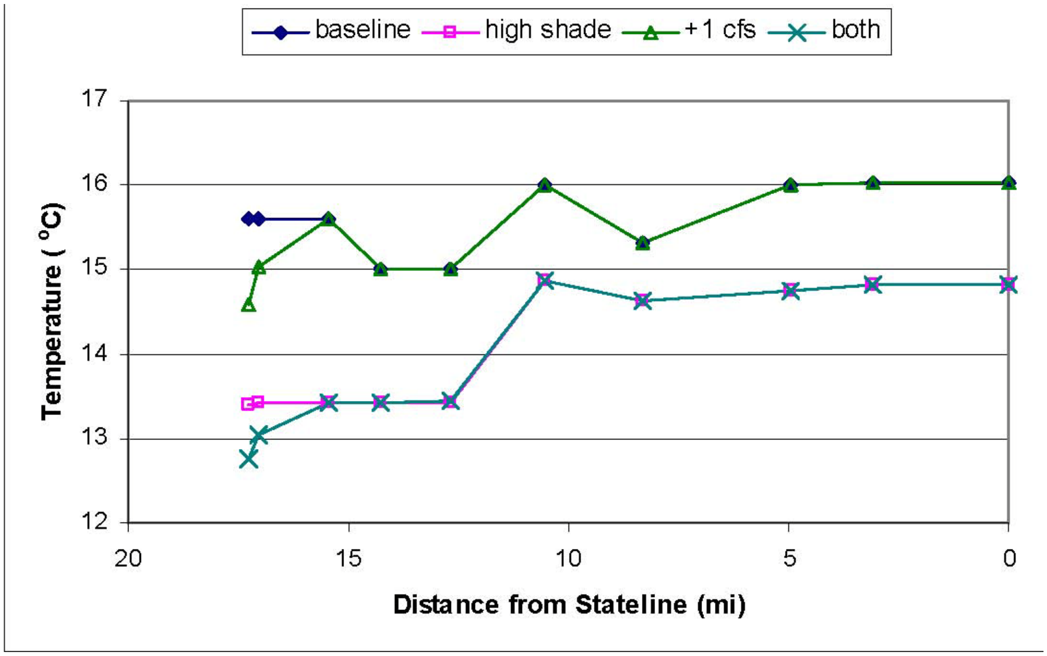


Figure 38. Longitudinal comparison of baseline and scenario temperatures for Week 35 (August 26-September 1).

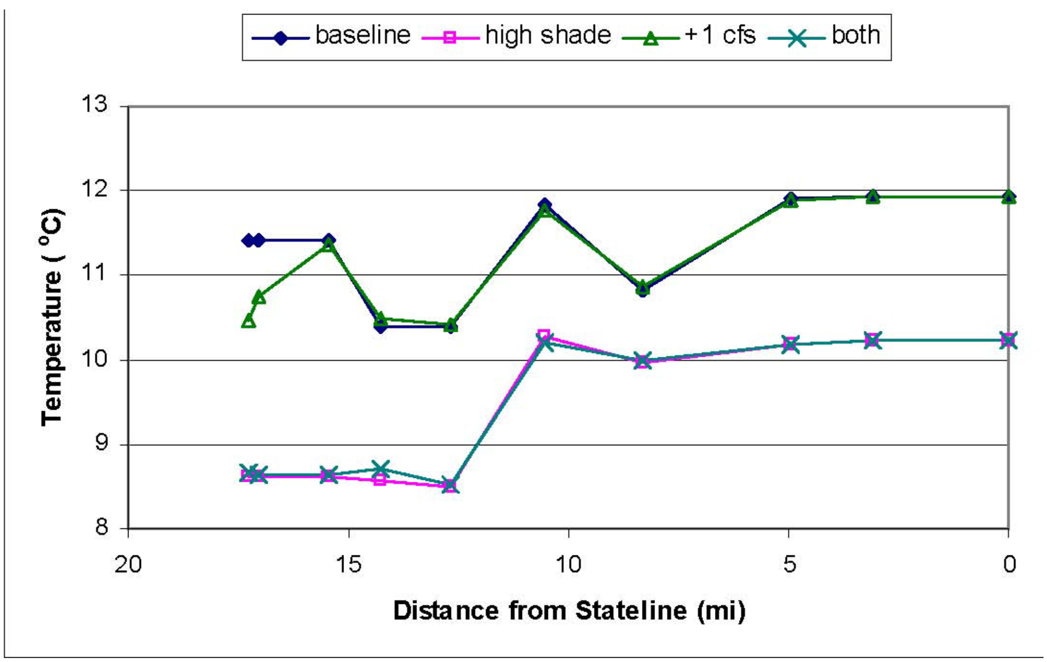


Figure 39. Longitudinal comparison of baseline and scenario temperatures for Week 38 (September 16-22).

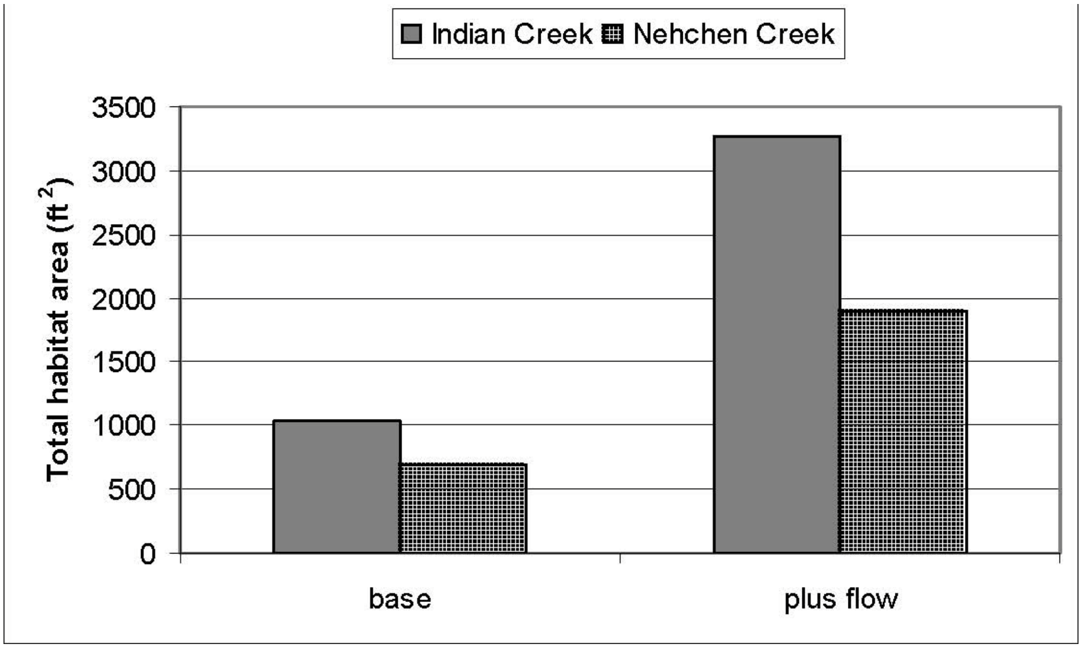


Figure 40. Total habitat area in tributaries for baseline and increased-flow condition.

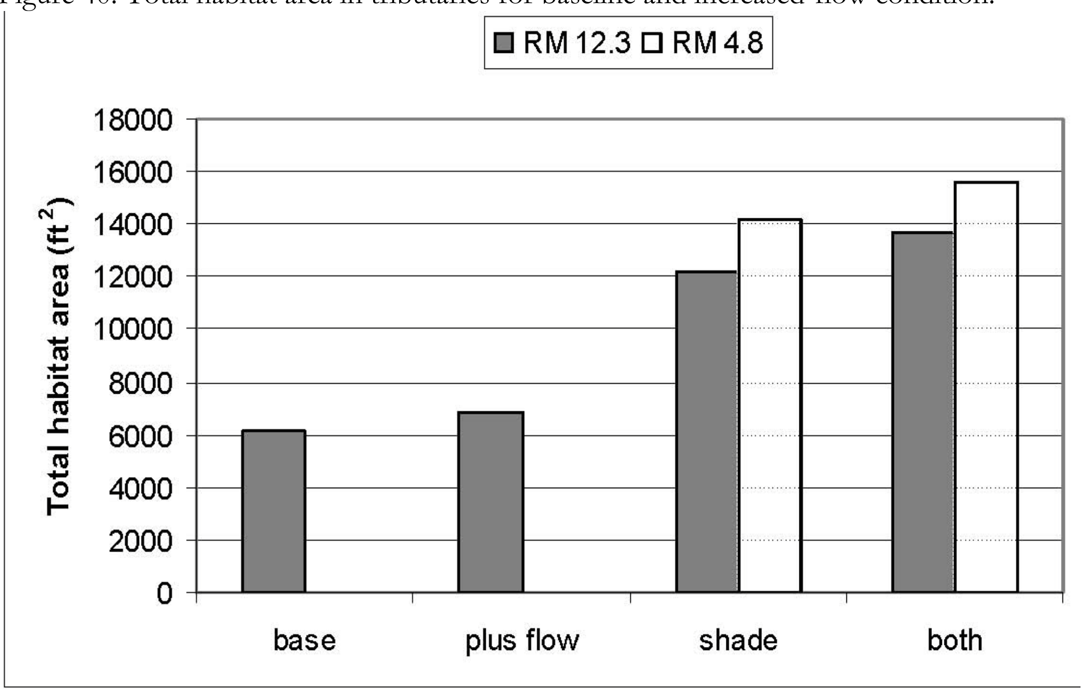


Figure 41. Total habitat area in mainstem Hangman Creek for baseline and scenario conditions