Threemile Creek Natural Background Temperature

Modeling Stream Temperature under System Potential Shade

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Acronyms, Abbreviations, and Symbols

°C	degrees Celsius
AME	absolute mean error
cfs	cubic feet per second, a measure of the rate of discharge of a liquid stream
cm	centimeter
cms	cubic meters per second
DEQ	Idaho Department of Environmental Quality
EPA	US Environmental Protection Agency
GIS	geographic information system
IDAPA	refers to citations of Idaho Administrative Code
ISDA	Idaho State Department of Agriculture
km	kilometer
m	meter
NPDES	National Pollutant Discharge Elimination System
PNV	potential natural vegetation
SI	International System of Units, the metric system of measurement
SOP	standard operating procedure
STP	sewage treatment plant
TMDL	total maximum daily load

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Executive Summary

Stream temperature is critical to aquatic life and instream processes. The Idaho Department of Environmental Quality (DEQ) water quality standards set stream temperature criteria as follows:

- For protecting the cold water aquatic life beneficial use—22 ºC maximum and 19 ºC average (IDAPA 58.01.02.250.02.b)
- For protecting the salmonid spawning beneficial use—13 ºC maximum and 9 ºC average (IDAPA 58.01.02.250.02.f)

The Grangeville sewage treatment plant (STP) outfall received temperature wasteload allocations for Threemile Creek in the South Fork Clearwater River subbasin total maximum daily load (TMDL) (DEQ and EPA 2003). The wasteload allocations apply only during critical periods:

- Salmonid spawning—April 1 through May 31
- Cold water aquatic life—July 15 through September 15

The STP wasteload allocations are based on the water quality standards:

> If temperature criteria for the designated aquatic life use are exceeded in the receiving waters upstream of the discharge due to natural background conditions, then wastewater must not raise the receiving water temperatures by more than three tenths (0.3) degrees C. (IDAPA 58.01.02.401.01.c)

This study uses modeling to identify the stream temperature immediately upstream of the Grangeville STP outfall that would occur under natural background conditions.

DEQ develops temperature load allocations for impaired streams by determining system potential shade (i.e., expected shade under natural conditions). However, a heat load allocation using shade as a surrogate measure does not identify the stream temperatures under system potential shade. Shade is only one component affecting the heat load to the stream. A model that simulates all of the heat exchange processes will identify the natural background stream temperature under system potential shade.

The QUAL2Kw model (Pelletier and Chapra 2008a, 2008b) was used to simulate water temperatures for this study. Data sources for the study included the following:

- The model was first calibrated to Data regarding streamflow; physical parameters such as channel width, depth, and slope; and existing shade conditions collected during DEQ site visits (See Appendix B)
- Reach details such as elevation, location, slope, and azimuth and existing and potential shade identified by DEQ geographic information system (GIS) analysis
- Inputs such as ground water inflow and temperature from DEQ model analysis
- DEQ continuous data for stream temperatures in 2010
- Idaho State Department of Agriculture ground water temperatures
- DEQ air program meteorological data
- MesoWest meteorological data

The QUAL2Kw model scenarios for calibration included the following:

- May 15, 2010, to represent the salmonid spawning critical period and higher streamflows
- August 15, 2010, to represent the cold water aquatic life critical period and baseflow conditions

The model results for system potential shade in May showed that natural background stream temperatures would not exceed the 13 ºC maximum water quality criterion. However, even under system potential shade, the 9 ºC mean criterion would be exceeded in the reach immediately upstream of the Grangeville STP outfall. The peak maximum prediction is 11.9 ºC and the peak average prediction is 10.1 ºC.

The model results for system potential shade in August showed that predicted natural background stream temperatures would not exceed the temperature criteria for cold water aquatic life, averaging 4 ºC less than existing stream temperatures. The peak maximum prediction is 16.2 ºC and the peak average prediction is 14.8 ºC.

The temperature wasteload allocations given to the Grangeville STP in the South Fork Clearwater TMDL (DEQ and EPA 2003) are based on a range of effluent flows and streamflows. Modeled stream temperatures for these discharge ranges can be used to develop new wasteload allocations for the TMDL five-year review.

Overall, the QUAL2Kw model was a good choice for being able to identify natural background temperatures within 0.1 ºC accuracy. The modeling exercise was able to identify the most important field data for well-calibrated model simulations, including collecting dewpoint temperature along with air temperature in the riparian area. This work is a valid foundation for future stream temperature modeling efforts.

1 Introduction—Stream Temperature

Stream temperature is an important part of stream ecology. Temperature drives instream processes such as metabolism and decomposition, affects plant growth, and influences habitat for aquatic life (Sinokrot and Stefan 1993; Bogan et al. 2003). Human alterations of natural landscapes cause increases in stream temperatures. When aquatic life depends on cooler temperatures, increased heating restricts available habitat (Poole and Berman 2001).

The Idaho Department of Environmental Quality (DEQ) water quality standards for cold water aquatic life dictate that human activities may not cause water temperatures to exceed 22 ºC at any time or exceed a daily average of 19 ºC (IDAPA 58.01.02.250.02.b). All surface waters of the state of Idaho are presumed to support cold water aquatic life (IDAPA 58.01.02.101.01.a). Furthermore, some surface waters are designated for salmonid spawning. Salmonids are fish within the Salmonidae family, like salmon or trout, which require cooler temperatures to complete their life cycles. Water quality standards for salmonid spawning are 13 ºC maximum or 9 ºC daily average stream temperatures (IDAPA 58.01.02.250.02.f).

Incoming solar energy—shortwave radiation—is the primary driver of stream temperature (Sinokrot and Stefan 1993; Younus et al. 2000). Other important components of stream temperature include the following:

- Longwave radiation (i.e., reflected solar radiation) is reflected into a stream from the surroundings but is also reflected back into the surroundings from the stream.
- Evaporation from the stream surface causes cooling.
- Convection is heat exchange with the atmosphere.
- Conduction is heat exchange that occurs between the streambed and the water.
- Hyporheic exchange is an alternative flow path of surface water through permeable substrates under and near the streambed. Flow in the hyporheic zone can come from the stream itself or from water percolating to the stream from the surroundings (Evans and Petts 1997).

A graphic representation of these heat fluxes is shown in Figure 1. The relative contributions of the heat exchange processes—depending on size, geomorphology, and condition of the stream—are approximated by the width of the arrows in Figure 1. This graphic is not to scale and represents the weight of the contribution of each of the components in the Threemile Creek temperature regime as determined during model calibration.

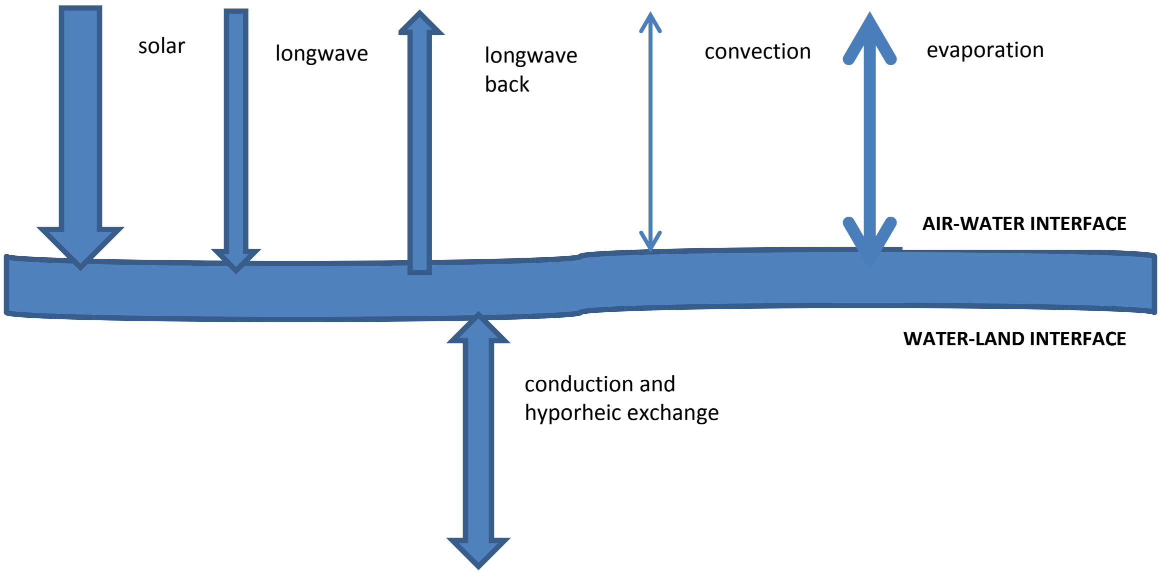

Figure 1. Heat exchange processes that affect water temperature.

Heat exchange processes are affected by physical features such as the following:

- Stream depth
- Ground water volume and temperature
- Meteorological parameters like air temperature, relative humidity, and wind speed
- Shade provided by topography or canopy cover from riparian vegetation

Air and water temperatures are highly correlated, showing the same daily and seasonal patterns. However, air temperature is not the primary driver of water temperature. Heat exchange between air and water is from convection, which is only a small part of the overall heat flux (Figure 1). Shortwave solar radiation is the largest thermal input to air and water temperatures, so clear skies and unshaded streams will result in the highest water temperatures (Johnson 2003).

Johnson (2004) showed that substrate and shading affect temperature in small streams. Experimental shading of the stream caused the largest magnitude of change in maximum stream temperatures. In this study, substrate type and hyporheic flow had a dampening effect on minimum and maximum temperatures, decreasing the diurnal variation. The moderating influence of hyporheic flow has a proportionately larger effect in small streams like Threemile Creek, with an average 2 cubic feet per second (cfs) baseflow. Other studies underline the importance of hyporheic flow in influencing stream temperatures (Malard et al. 2001; Younus et al. 2000).

2 Threemile Creek Stream Temperature Regulatory Issues

Threemile Creek in Idaho County flows through the county seat at Grangeville and into the South Fork Clearwater River in north-central Idaho (Figure 2). Threemile Creek drains part of the Camas Prairie, with annual peak flows in the mid-winter to early spring from rain-on-snow or rapid snowmelt events. The Camas Prairie in this regions is characterized by low elevation plateaus and rolling topography. The basalt parent material results in silt-loam soils and gravel and cobble substrates in the stream.

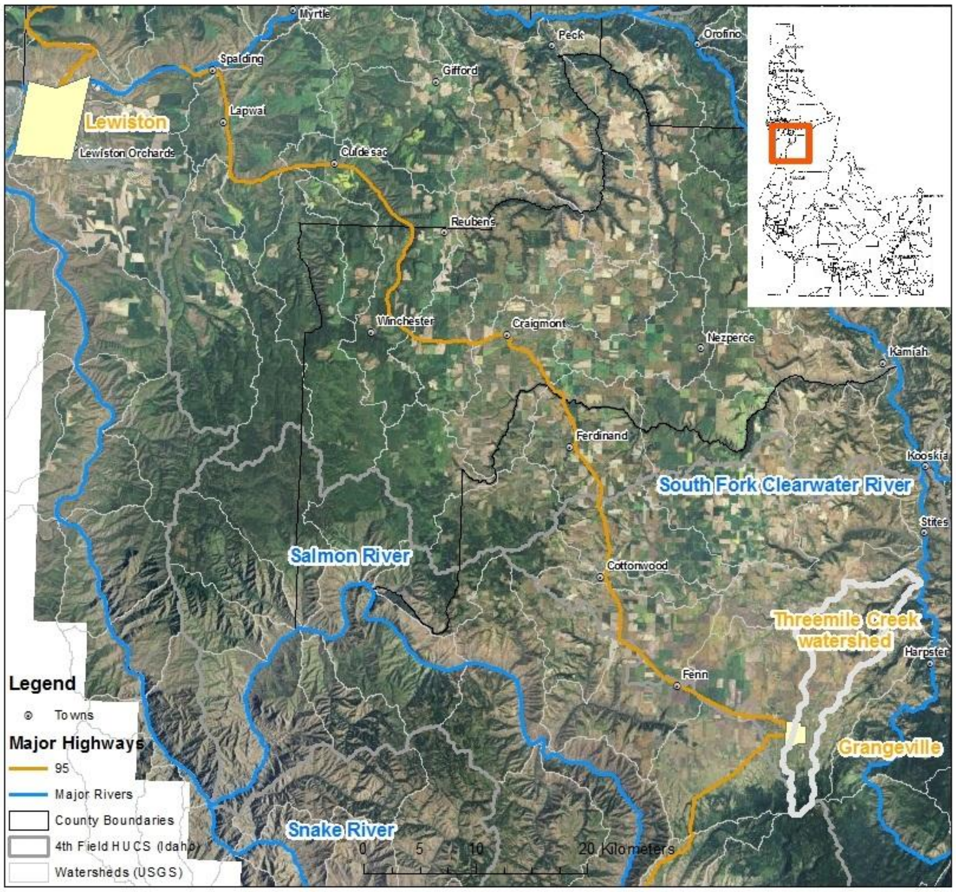

Figure 2. Threemile Creek watershed in north-central Idaho.

Threemile Creek is designated for cold water aquatic life, salmonid spawning, and secondary contact recreation in the Idaho water quality standards at IDAPA 58.01.02.120.07. Stream temperatures in Threemile Creek typically exceed standards for salmonid spawning April 1 through May 31and standards for cold water aquatic life July 15 through September 15. These date ranges were established in the SF Clearwater River TMDL temperature analysis (DEQ 2003).

The City of Grangeville sewage treatment plant (STP) outfall enters Threemile Creek about 9 kilometers downstream of the headwaters of Threemile Creek and contributes an excess heat load to the stream. However, the South Fork Clearwater River TMDL (DEQ and EPA 2003) showed that stream temperatures were already elevated upstream of the STP. Furthermore, the TMDL indicated that high summer water temperatures were one of the primary limiting factors for fish production.

2.1 Wasteload Allocations

A wasteload allocation is the portion of a total maximum daily load (TMDL) attributed to point sources. The South Fork Clearwater River TMDL identified temperature wasteload allocations for the City of Grangeville STP (DEQ and EPA 2003). The STP wasteload allocations are based on IDAPA 58.01.02.401.01.c:

> "If temperature criteria for the designated aquatic life use are exceeded in the receiving waters upstream of the discharge due to natural background conditions, then wastewater must not raise the receiving water temperatures by more than three tenths (0.3) degrees C. (3-29-12)"

In Idaho's water quality standards, natural background conditions occur when no human sources of pollution have affected the watershed. Since stream temperatures under natural background temperatures are unknown, the temperature wasteload allocations were calculated for effluent limits that would not increase temperature criteria more than 0.3 °C during critical periods. The critical periods and temperature criteria are as follows:

- Salmonid spawning—April 1 through May 31—9 °C daily average and 13 °C daily maximum
- Cold water aquatic life—July 15 through September 15—19 °C daily average and 22 °C daily maximum

The wasteload allocations apply only during times when the receiving waters are expected to exceed numeric temperature criteria, based on historic data. Appendix A duplicates Tables 46 and 47 from pages 186 and 187 of the South Fork Clearwater River TMDL, identifying the effluent discharge limits that would not increase criteria temperatures more than 0.3 °C during the critical periods for salmonid spawning and cold water aquatic life (DEQ and EPA 2003).

2.2 Point Source Permit

The US Environmental Protection Agency (EPA) national pollutant discharge elimination system (NPDES) permit issued October 1, 2005 for the Grangeville STP did not include a limitation on effluent temperature. DEQ requested the temperature limitation exclusion to determine the following:

1. The appropriateness of salmonid spawning as a beneficial use designation
2. Compliance of the effluent discharge with Idaho's point source temperature provision for natural background conditions

DEQ conducted a study from 2005 through 2006 evaluating the salmonid spawning beneficial use for Threemile Creek (DEQ 2008). Biological data analysis showed that salmonid spawning and cold water aquatic life are currently existing uses in Threemile Creek. In addition, temperature data demonstrated that the STP effluent increased the stream temperature more than 0.3 °C during periods when upstream temperatures exceeded aquatic life temperature criteria. Although temperature criteria are exceeded, it is unknown what the stream temperature upstream of the STP would be under natural background conditions.

3 Threemile Creek Stream Temperature Model

This study identifies the stream temperature immediately upstream of the Grangeville STP outfall that would occur under natural background conditions. Idaho evaluates natural background shade under potential natural vegetation (PNV) conditions. With no human-caused disturbances to riparian vegetation, PNV would provide system potential shade, resulting in natural background stream temperatures. DEQ develops temperature load allocations for impaired streams by showing effective shade level as a function of channel width and PNV conditions. The difference between this target shade level and existing shade equals the excess heat load (Shumar and De Varona 2009), expressed in kilowatt hours per day.

A heat load allocation using shade as a surrogate measure does not identify the stream temperatures under system potential shade. Shade is only one component affecting the heat load to the stream. A model that simulates all of the heat exchange processes—incorporating the physical features that affect heat exchange—will identify the natural background stream temperature under system potential shade.

The QUAL2Kw model (Pelletier and Chapra 2008a, 2008b) was used to identify natural background water temperatures for this study and revise wasteload allocations to the Grangeville STP. The model was calibrated to known stream values to increase the accuracy of natural background temperature model results. The QUAL2Kw model scenarios for calibration included the following:

- May 15, 2010, to represent the salmonid spawning critical period and higher streamflows
- August 15, 2010, to represent the cold water aquatic life critical period and baseflow conditions

3.1 Data Sources and Analysis

Data sources DEQ used to develop a stream temperature model include the following:

- Data regarding streamflow; physical parameters such as channel width, depth, and slope; and existing shade conditions collected during DEQ site visits (See Appendix B)
- Reach details such as elevation, location, slope, and azimuth and existing and potential shade identified by DEQ geographic information system (GIS) analysis
- Inputs such as ground water inflow and temperature from DEQ model analysis
- DEQ continuous data for stream temperatures in 2010
- Idaho State Department of Agriculture ground water temperatures
- DEQ air program meteorological data
- MesoWest meteorological data

3.1.1 Reach, Shade, and Temperature Data

To identify the natural background stream temperature under system potential shade, DEQ collected data upstream of the Grangeville STP. The study area includes upper Threemile Creek from the forested headwaters, through a meadow and the town of Grangeville, ending just above the STP outfall for a total 9-kilometer reach. The monitoring locations are depicted in Figure 3.

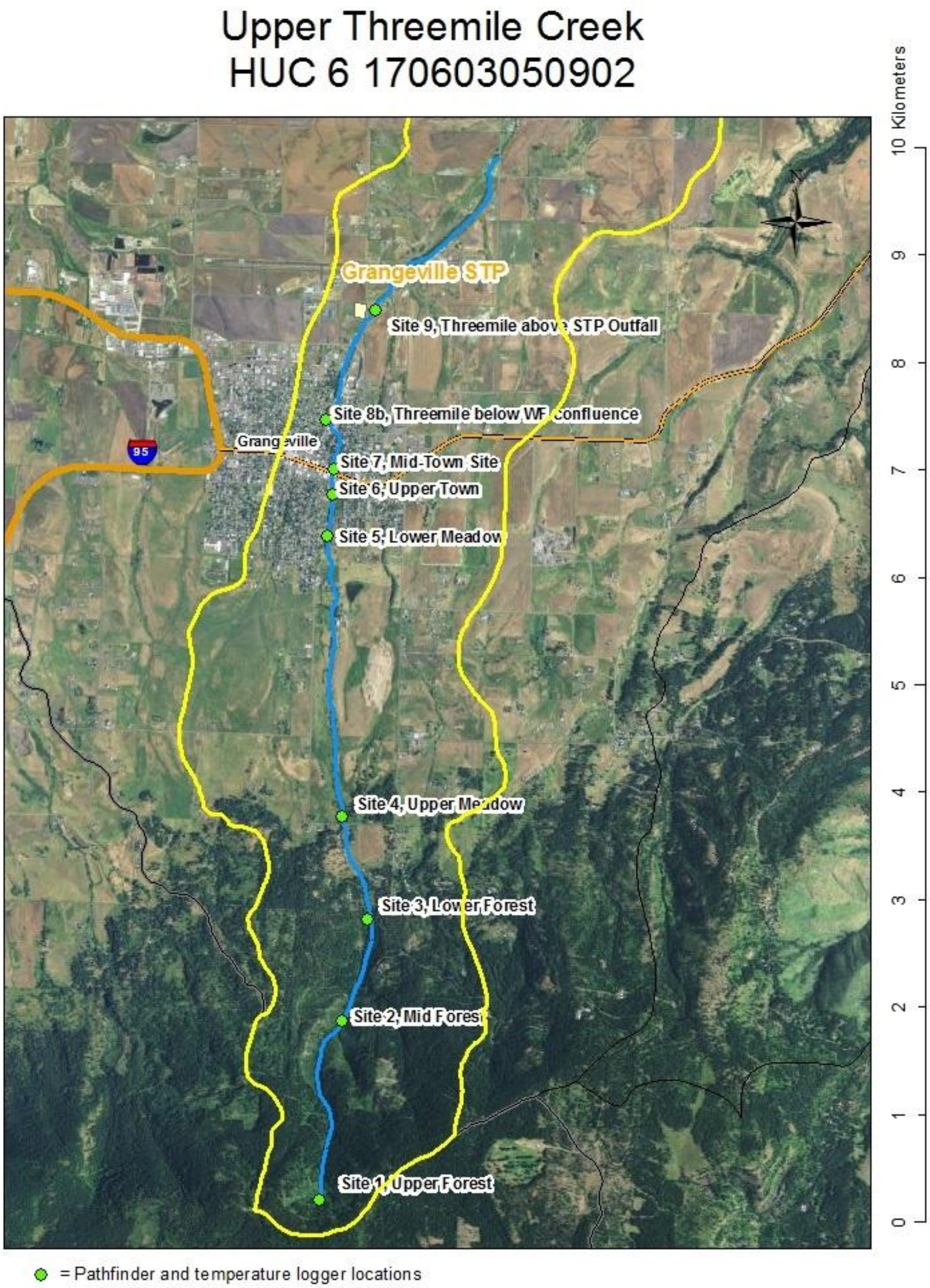

Figure 3. Upper Threemile Creek monitoring locations for temperature study.

Sites 1 through 3 are in the forested reach, sites 4 and 5 encompass the meadow, and sites 6 through 9 are in the town of Grangeville. Site 8 (not pictured) is actually located on West Fork Threemile Creek—the discharge and temperature data from this location is included in the model as a point source—so site 8b, which is actually on Threemile Creek itself, contains the parameters included in the model of the stream reach.

In 2010, DEQ deployed water temperature loggers, including paired quality assurance units, in these locations. Air temperature loggers were included at sites 2, 4, and 9. Methods followed the recently updated DEQ protocol for placement and retrieval of temperature data loggers in Idaho streams (DEQ 2013a). Streamflow and channel measurements were taken in May to characterize the critical period for salmonid spawning, and streamflow and Solar Pathfinder shade measurements in July characterize the cold water aquatic life beneficial use and field-verify existing shade conditions. The streamflow and channel measurements follow DEQ methods currently documented in the June 2013 *Beneficial Use Reconnaissance Program Field Manual for Streams* (DEQ 2013b). Reach parameters and instantaneous streamflow measurements are summarized in Table 1. The memoranda that report the field investigations in full are duplicated in Appendix B.

Table 1. Physical parameters measured on Threemile Creek.

Flow and channel measurements on Threemile Creek, May 2010										
Site numbers	***Site 1***	***Site 2***	***Site 3***	***Site 4***	***Site 5***	***Site 6***	***Site 7***	***Site 8***	***Site 8b***	***Site 9***
Site names	**Upper Forest**	**Mid-forest**	**Lower Forest**	**Upper Meadow**	**Lower Meadow**	**Upper Town**	**Mid Town**	**Tributary Stream, West Fork**	**Below West Fork Confluence**	**Above WWTP outfall**
Location	45.864 -116.117	45.879 -116.114	45.888 -116.112	45.896 -116.115	45.920 -116.118	45.923 -116.117	45.926 -116.117	45.929 -116.119	45.929 -116.119	45.939 -116.112
Streamflow (cfs)		2.1	4	5.4	4.7	4	4.7	0.8	4.6	gage ht = 0.68 ft.
Gradient (%)		10.50	6	4	2.2	2	3	2	2	1
Bankfull Width (ft)		6.4	7.5	16	8	15	9.5	8	10	10.8
Wetted Width (ft)		4	4.9	9	5.4	6	5.4	3.5	7	6.8
Max wetted depth (ft)		0.4	0.5	0.5	0.75	1	0.75	0.4	1.1	1.2
Ave wetted depth (ft)		0.29	0.39	0.31	0.6	0.66	0.52	0.23	0.74	0.33
Left Bank Angle (°)		60	42	63	35	45	27	45	42	80
Right Bank Angle (°)		78	75	65	24	15	20	30	45	32
Incision Depth (ft)		0	0	0	0	0	2.95	5.3	4	2.8
Left incision angle (°)							20	35	30	24
Right incision angle (°)							20	55	45	29
Comments			Archery range	naturalized meadow	lower meadow	S. 1st Street	Main Street	road culvert		pasture below city
Flow and channel measurements on Threemile Creek, July 2010										
Streamflow (cfs)	0.066	1.1	1.7	1.8	2	1.8	1.7	0.01	1.9	1.56
Wetted width (ft)		4	2	8.5	5.5	6	4.5	4.6	4.5	
Wetted depth (ft)		0.25	0.37	0.24	0.34	0.4	0.46	0.2	0.41	

The field measurements used in the model include streamflow and wetted width.

Mark Shumar (DEQ) developed system potential shade values for these monitoring locations based on PNV communities of the Nez Perce breakland forest. The northern Idaho black hawthorn vegetation community was used for the remaining sites in the meadow and town. Methods for determining PNV community types are documented in Shumar and De Varona (2009). These vegetation communities describe potential riparian vegetation in the absence of human disturbances and do not necessarily describe the existing riparian vegetation.

Solar Pathfinder data corroborate geographic information system (GIS) estimates for existing shade. A GIS layer consisting of 136 total data points—including 84 Solar Pathfinder data points and 52 polylines—contained the existing shade estimations. Figure 4 shows an example of the Pathfinder data locations at monitoring sites 3 and 4, with the existing shade classes on the stream reach between the two monitoring locations.

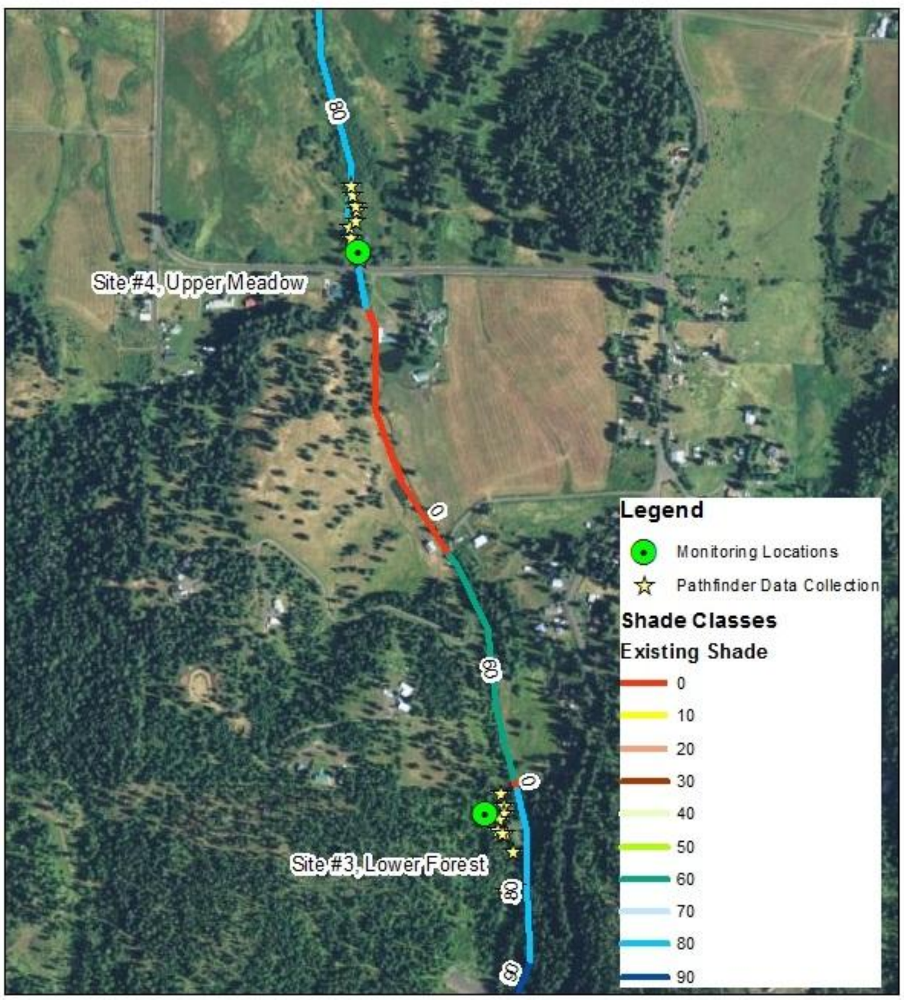

Figure 4. Pathfinder data points at Site #3 and Site #4 with estimated existing shade classes in stream reach.

Since the existing shade classes were provided in 10% increments, this represents uncertainty in the existing shade values. There are three ways to interpret these shade data for entry into the model:

1. Shade was measured near Site #4 at 10 pathfinder locations below the temperature logger. Average shade was 81.5%, which could be used for model data point.
2. The straight average of shade classes—zero and 60%--in the stream reach above the monitoring site equals 30%.
3. A weighted average shade for the reaches above the monitoring location could be used for the existing shade estimate. The 60% shade reach is 370 meters long and the zero% shade reach is 420 meters long, which equals a 28.1 % weighted average shade.

All of these methods were used during calibration runs of the model and the weighted average shade values—weighted according to length--ended up achieving the best stream temperature simulations. A weighted average shade value was calculated for each modeled reach based on the product of the existing shade determinations and the length of each reach. The values in Table 2 reflect these calculated weighted averages that were used for existing shade inputs in the model.

Table 2. Existing and system potential shade for the Threemile Creek monitoring locations.

Location	Weighted Average Existing Shade	System Potential Shade
Site 1, Upper Forest	70%	95%
Site 2, Mid-Forest	78%	95%
Site 3, Lower Forest	83%	95%
Site 4, Upper Meadow	28%	94%
Site 5, Lower Meadow	69%	88%
Site 6, Upper Town	90%	88%
Site 7, Mid-Town	68%	88%
Site 8b, Below West Fork Confluence	69%	88%
Site 9, Above STP Outfall	68%	88%

The weighted average existing shade values are more reasonable for temperature simulation since the temperature at one monitoring location is expected to represent cumulative factors upstream of the monitoring site. See Poole, et. al 2001 for cumulative factors affecting stream temperature.

The data from the 2010 continuous stream temperature loggers are summarized during critical periods for salmonid spawning and cold water aquatic life in Appendix C. These data identify the dates and locations where exceedances of temperature water quality standards occur. Of the forest and upper meadow sites, there were no exceedances of salmonid spawning or cold water aquatic life criteria during critical periods except for some early April exceedances at Site 3—Lower Forest, where there were 8 exceedances of the daily maximum temperature standard in the data period of record from March 8 through May 31 2010. The lower meadow and town sites all consistently exhibited temperature exceedances during both critical periods.

3.1.2 Meteorological Data

Air temperature, dewpoint temperature, and wind speed data came from the Mesowest Grangeville station GVLI1. Solar radiation data came from the Grangeville station operated by the DEQ air quality monitoring program (DEQ 2010). The data used in the model are summarized in Table 3. Dewpoint temperature measured along with air temperature is vital for stream temperature calibration in the model, so the DEQ air temperature data measured on site was not used to provide better modeling results.

Table 3. Summary of meteorological data

Parameter	May 15, 2010	August 15, 2010
Air temperature (°C)	Average 15.9 Max 22.8 Min 7.9	Average 21.0 Max 29.6 Min 12.5
Dewpoint temperature (°C)	Average 2.6 Max 5.1 Min 0.1	Average 9.2 Max 13.9 Min 5.8
Wind speed (meters/second)	Average 4.8 Max 8.0 Min 1.6	Average 1.9 Max 3.7 Min 0.5
Solar radiation (Watts/meter^2)	Average 278.6 Max 864.0 Min 0.0	Average 293.49 Max 833.0 Min 0.0

3.1.3 Ground Water Data

Required ground water data for model inputs include ground water volume and temperature.

3.1.3.1 Ground Water Volume

In QUAL2Kw input data, ground water inflows to the stream and outflows back to ground water are simulated as diffuse sources. The consistently cool temperatures and increases in streamflow measured by DEQ in 2010 at the three forested monitoring locations demonstrate the inflow of cool ground water recharging the stream. These findings indicate a gaining reach, where the water table is higher than the streambed. In the reaches through the meadow and town, streamflow measurements show alternations between gaining and losing reaches. The volume of the ground water inflow and outflow is an unknown variable, so the values in the model equal the remainder of the water mass balances, where:

$$\text{Surface Runoff} \pm \text{Groundwater Inflow or Outflow} = \text{Total Streamflow}$$

3.1.3.2 Ground Water Temperature

Ground water temperature model inputs are from ISDA data (ISDA 2006 and 2007). The ground water data are collected in compliance with the ISDA standard operating procedures (SOP) identified in the quality assurance project plans (ISDA 2008) approved by the EPA Region 10 Quality Assurance group. The procedure referenced in this document is EPA SOP#4: “Preparations and Sampling at Domestic Wells.” When field parameters including pH, temperature, and specific conductance are stabilized, well purging is adequate. Specific conductance within 5%, pH within 0.1 units, and temperature within 0.2 °C indicate stable measurements. Samples are collected when the well is fully purged according to these standards.

Two ISDA wells that were sampled, numbers 9500701 and 9507101, are in the Threemile Creek watershed (Figure 5).

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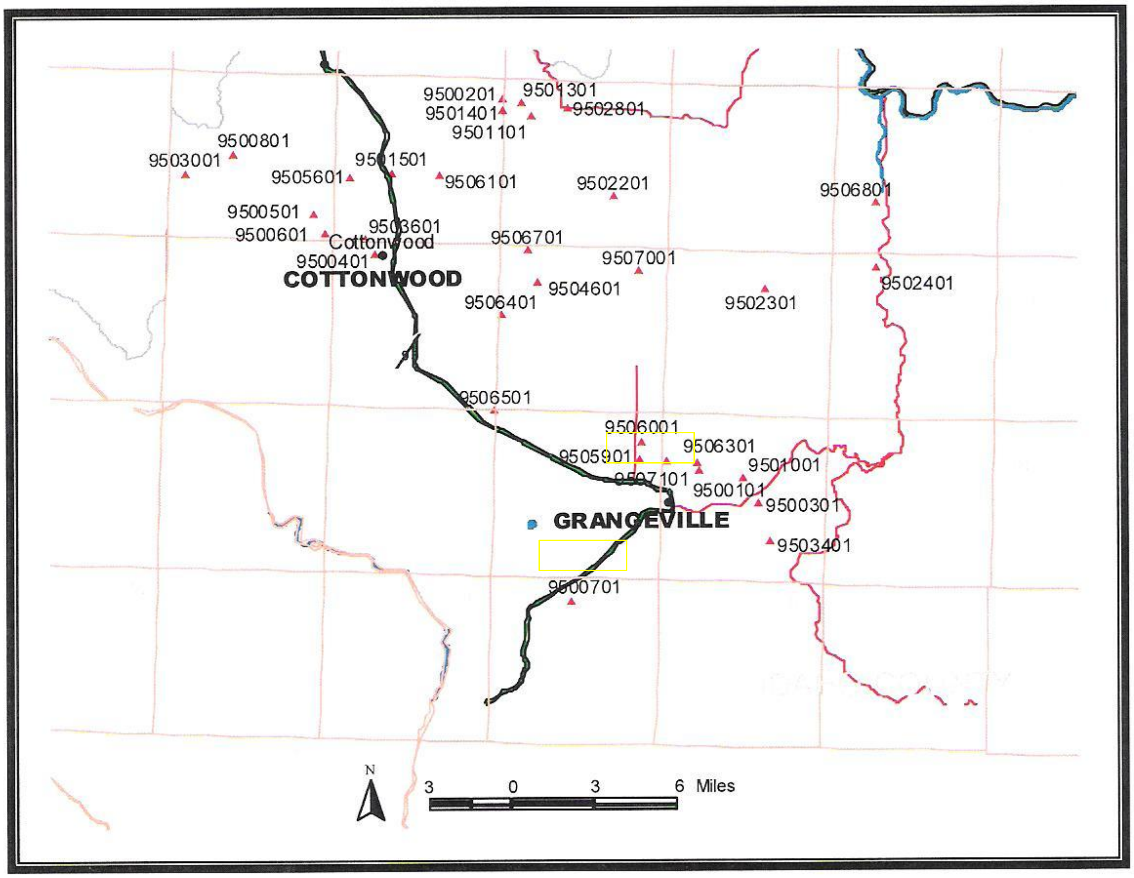

Figure 5.Idaho State Department of Agriculture ground water monitoring locations.

Well 9500701 is in the upper meadow reach of Threemile Creek. From 2001 through 2008, the ground water temperature averaged 11.9 °C at this well. Well 9507101, in the city of Grangeville, averaged 16.9 °C during the same date range. No data were available for the modeled date ranges of May and August 2010.

Although these groundwater temperature data averages provided some guidance, the wells were too far away to capture the actual inputs to the stream. Additionally, the temperature and volume inputs from the surroundings to Threemile Creek are not all strictly groundwater, but a certain component are comprised of near-surface infiltration from runoff of various land uses adjacent to the stream. Calibration primarily determined the groundwater volume and temperature values used in the final model simulations. Calibration efforts are summarized in Section 3.4.

3.2 Model Selection

The QUAL2Kw model has been used during many similar modeling efforts throughout the United States and is appropriate to simulate Threemile Creek stream temperatures. QUAL2Kw is maintained and supported by civil and environmental engineers at the Washington Department of Ecology and is used for all of the temperature TMDLs in the state. It is a spreadsheet-based model programmed in Visual Basic for Applications. The model functions (Pelletier and Chapra 2008b, p. 4) making it suitable for modeling stream temperatures include in part:

- One-dimensional—The channel is well-mixed vertically and laterally.
- Steady-state hydraulics—Nonuniform, steady flow is simulated.
- Diel heat budget—The heat budget and temperature are simulated as a function of meteorology on a diel time scale.
- Heat and mass inputs—Point and nonpoint loads and abstractions are simulated.

3.3 Model Input Datasets

The QUAL2Kw model simulates heat exchange processes that drive stream temperature fluxes:

- Hourly shortwave solar radiation is an input variable
- Hourly weather parameters and shade are input variables
- Atmospheric longwave radiation, evaporation, convection, and conduction are simulated by equations selected on the "Light and Heat" worksheet of the model
- Thermal conductivity and thermal diffusivity terms identified through literature values of the thermal properties of streambed materials
- Hyporheic exchange is adjusted through calibration of sediment hyporheic zone thickness, sediment porosity, and fraction of hyporheic exchange flow

Table 4 summarizes sources of variables required for QUAL2Kw to simulate temperatures.

Table 4. Model data requirements and collection source.

	Parameter	Data Source
Flow/ Location	Discharge	DEQ site visit
	Ground water inflow	DEQ model analysis
	Elevation	DEQ GIS analysis
	Latitude/Longitude	DEQ GIS analysis
Physical	Channel azimuth	DEQ GIS analysis
	Cross-sectional area	DEQ site visit
	Geometric coefficients	DEQ model analysis
	Reach length and slope	DEQ GIS analysis
	Width—bankfull and wetted	DEQ site visit
Temperature	Temperature—ground water	ISDA and calibration
	Temperature—stream	DEQ continuous data
	Temperature—air	Mesowest
	Shade—existing and potential	DEQ site visit
Weather	Percent cloud cover	Mesowest
	Solar radiation	DEQ data
	Wind speed/velocity	Mesowest

3.4 Model Calibration

Once all of the input variables were entered into the worksheets and the best literature values and equations were selected, the model was run and output compared to existing data. This process is used to calibrate the model to ensure accurate modeled stream temperatures. The difference between modeled values and existing data is reported as the absolute mean error (AME), which DEQ proposes to be within:

- Discharge within 0.1 meters per second
- Water depth within 1 centimeter
- Temperature within 1 ºC

The results reports in this model calibration section apply to the temperature regime in Threemile Creek as determined by this modeling effort.

3.4.1 Groundwater volume and temperature calibration

Average ground water temperatures measured by ISDA in 2008 equaled 11.9 °C for well 9500701 and 19.5 °C for well 9507101. Although these wells are in the Threemile Creek watershed, they are not within the riparian zone of the stream. Using these data resulted in inaccurate stream temperature simulations.

Determined during calibration of the model, the volume and temperature values for diffuse sources used in the final model simulations are shown in Table 5. The wide ranges among temperature indicates that the subsurface contribution to streamflow is not derived from groundwater, but from near surface return flows. The temperature and volume of these near surface return flows are affected by land uses adjacent to the stream.

Table 5. Groundwater volume and temperature determined by model calibration.

	May 15, 2010			**August 15, 2010**		
Distance from headwaters (k)	**Withdrawal (m3/s)**	**Inflow (m3/s)**	**Temperature (°C)**	**Withdrawal (m3/s)**	**Inflow (m3/s)**	**Temperature (°C)**
0	0	0.005	5	0	0.002	5
0.0178	0	0.01	5	0	0.006	5.5
0.4089	0	0.023	5	0	0.015	9.5
1.2855	0	0.032	5	0	0.015	11
2.3197	0	0.07	9	0	0.014	11
3.3626	0	0.01	11	0.003	0	9
4.2023	0.003	0	19	0	0.003	9
4.7998	0	0	19	0	0.002	9
5.4548	0.003	0	19	0	0.001	9
6.1188	0.003	0	19	0	0.001	9
6.4838	0.03	0	19	0.006	0	10
6.7698	0	0.006	19	0.005	0	10
7.0993	0	0.015	19	0	0.005	10.5
7.5158	0.001	0	19	0	0.008	10.5
8.3898	0.001	0	19	0	0	10.5
9.0278	0	0	19	0	0	10.5

3.4.2 Water Depth and Discharge

The term with the largest effect in calibrating water depth was the Manning roughness coefficient, which describes the friction of the channel. QUAL2Kw can simulate hydraulic processes using either rating curves or the Manning formula, and the latter was used in the Threemile Creek analysis. The Manning formula assumes steady flow and a trapezoidal channel to express the relationship between flow and depth:

$$Q = \frac{S^{1/2}}{n} \frac{A^{5/3}}{P^{2/3}}$$

where:
- Q = flow (cubic meters per second)
- S = bottom slope (meter/meter)
- n = the Manning roughness coefficient
- A = the cross-sectional area (square meters)
- P = the wetted perimeter (meters)

A higher Manning roughness coefficient in uniform channel parameters will simulate greater depth due to increased friction. Literature values for this coefficient range from 0.012 in man-made concrete channels to 0.10 in mountain streams with boulders. The default value is 0.04, but for the Threemile Creek calibration, DEQ found that roughness values ranged from 0.18 in the forested reaches to 0.1 at the mid-town site.

Figure 6 shows the depth calibration to existing May 2010 data. In the following graphs, the blue line represents the values predicted by the model and the red squares represent measured data. The *x*-axis represents the distance from the headwaters of Threemile Creek at 0 kilometers to the monitoring site just above the Grangeville STP outfall at 8.4 kilometers. Although data were collected in English units, the model operates on SI (metric) units. Therefore, the model results reference SI units.

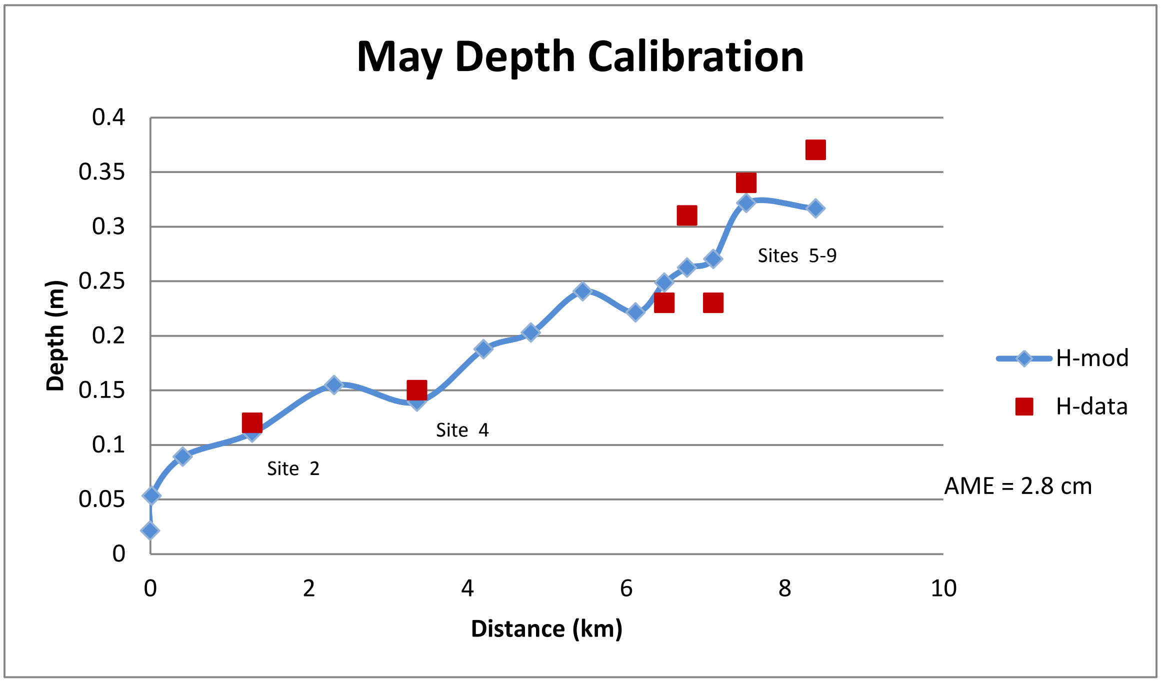

Figure 6.Modeled depth values (H-mod) compared to May 2010 data (H-data).

Based on comments received from modeling experts at Washington Department of Ecology (personal communication NWMOD 2013), DEQ chose to average the depth through the lower stream reaches to achieve a better final temperature calibration. That is, it is possible for the simulation to exactly match existing stream depths in the lower reaches through manipulation of the Manning roughness coefficient, but taking an average depth through these sites results in more accurate and defensible stream temperature predictions.

Discharge was calibrated through trial and error by manipulating the volume of diffuse sources, comprised of ground water inflow and near-surface seepage and return flow. The volume of diffuse inflow and outflow is the largest unknown in this system. It is apparent from the streamflow data that the upper three monitoring sites in the forest are gaining reaches from ground water inflow, and the meadow and town sites alternate between gaining and losing reaches depending on location and time of year. The more altered a hydrologic system becomes, the more near-surface seepages and return flows become unpredictable. Throughout the lower meadow and town, channel dimensions vary due to parking lots, culverts, and bridges. Abrupt changes in channel dimensions make it difficult to calibrate predicted streamflows with existing data. When these circumstances occur, it is better to run the discharge simulation as an average through the widely varying data points in order to achieve better temperature calibrations.

Figure 7 shows the calibration of the model to existing data collected on May 15, 2010. The AME equals 0.004 cubic meters per second, which shows very little error in the streamflow predictions.

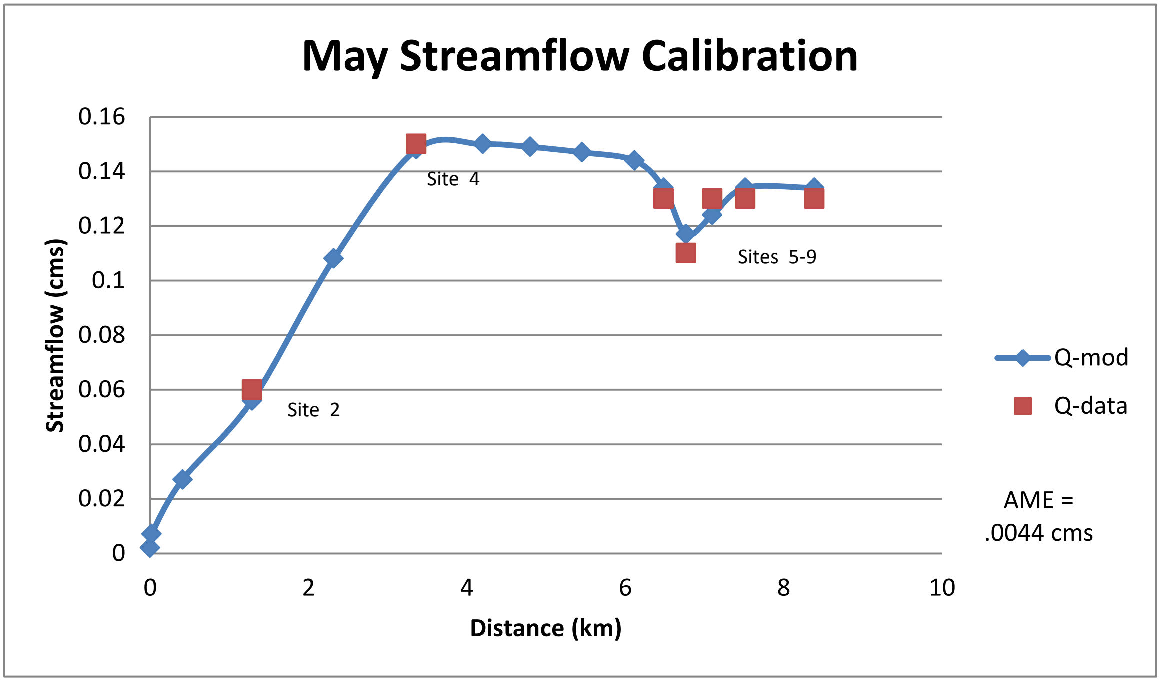

Figure 7. Modeled streamflow values (Q-mod) compared to May 15, 2010, data (Q-data).

The August 2010 scenario had to be calibrated with different Manning roughness coefficient values since the lower streamflows access a different proportion of the streambank than the higher May streamflows. Figure 8 provides the August depth calibration, and Figure 9 provides the August streamflow calibration.

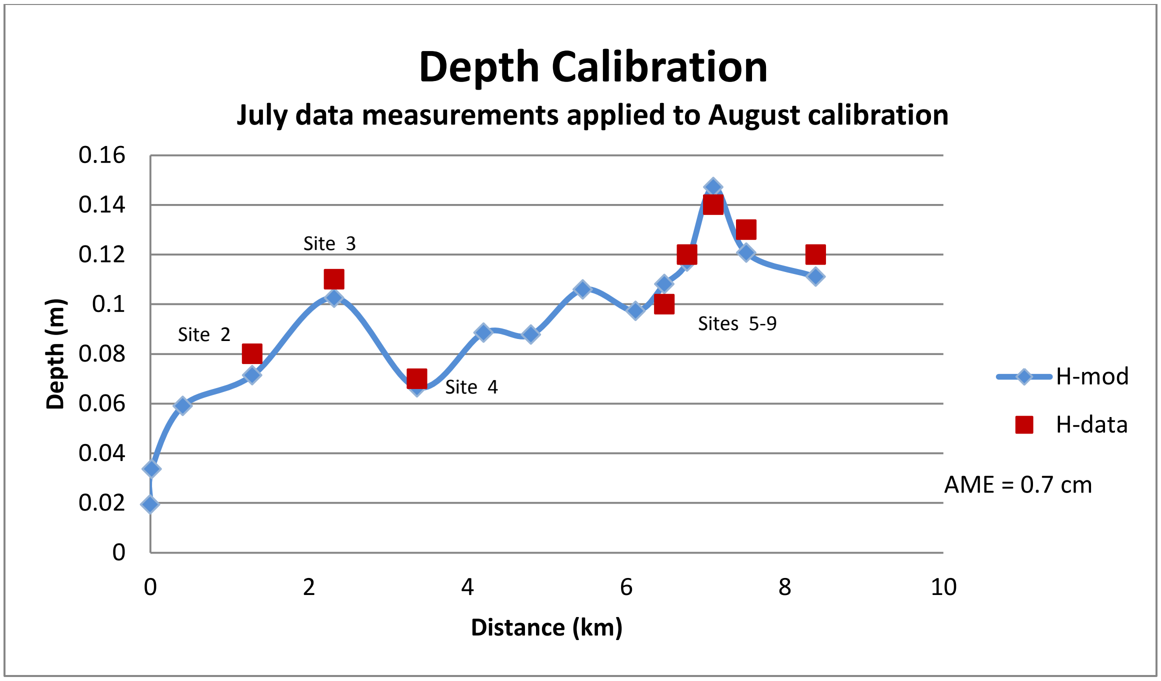

Figure 8. Modeled depth values (H-mod) compared to July 2010 data (H-data).

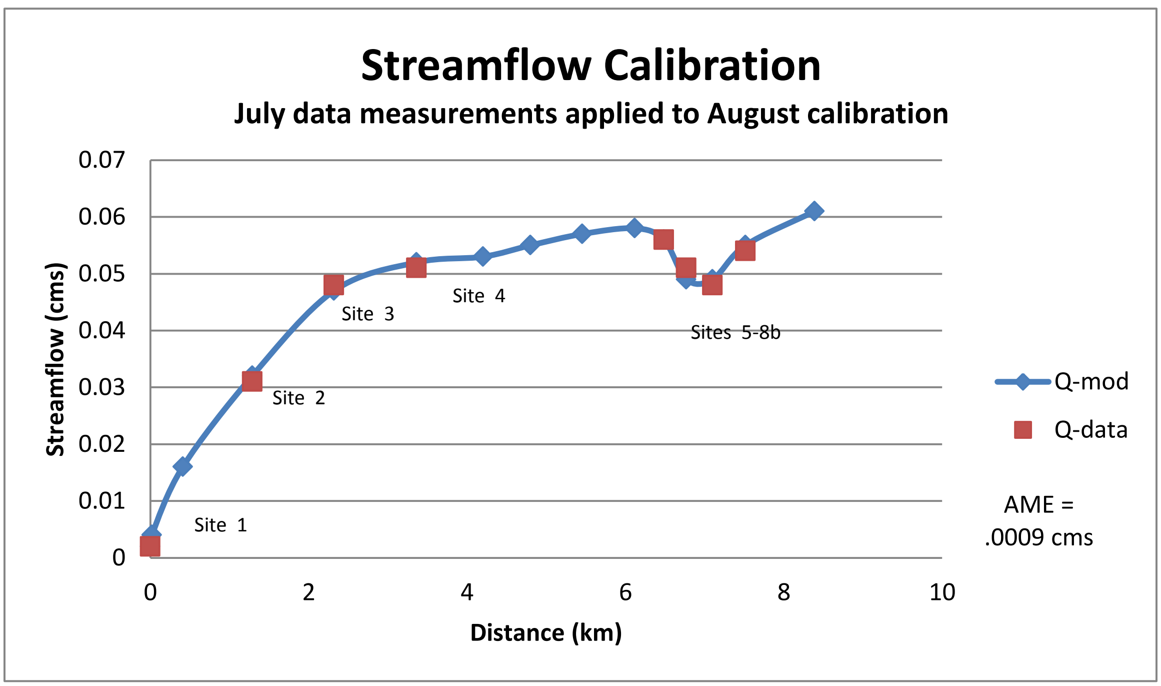

Figure 9. Modeled streamflow values (Q-mod) compared to July 2010 data (Q-data).

The calibration for the August scenarios was very accurate:

- Depth within 0.7 centimeters
- Streamflow within 0.0009 cubic meters per second

Accurate depth and streamflow simulation is essential to accurate temperature simulation.

3.4.3 Temperature

Manipulating stream temperature simulations includes more complicating factors than depth or discharge simulations. To decrease uncertainty of simulation results, a range of values was entered for each estimated parameter to see which terms were particularly sensitive to change and important to stream temperature. Estimated values with the greatest effect on final results in this temperature simulation for the Threemile Creek scenario were the following:

- Ground water volume and temperature affected the mean water temperatures.
- Dewpoint temperature affected the magnitude of the diurnal temperature variation.
- Shade and cloud cover also affected the magnitude of the diurnal temperature variation.
- Substrate parameters such as sediment hyporheic zone thickness, sediment porosity, and fraction of hyporheic exchange flow affected the accuracy of the minimum and maximum temperature predictions.

Temperature calibration to stream temperatures under existing shade for May 15, 2010, is shown in Figure 10.

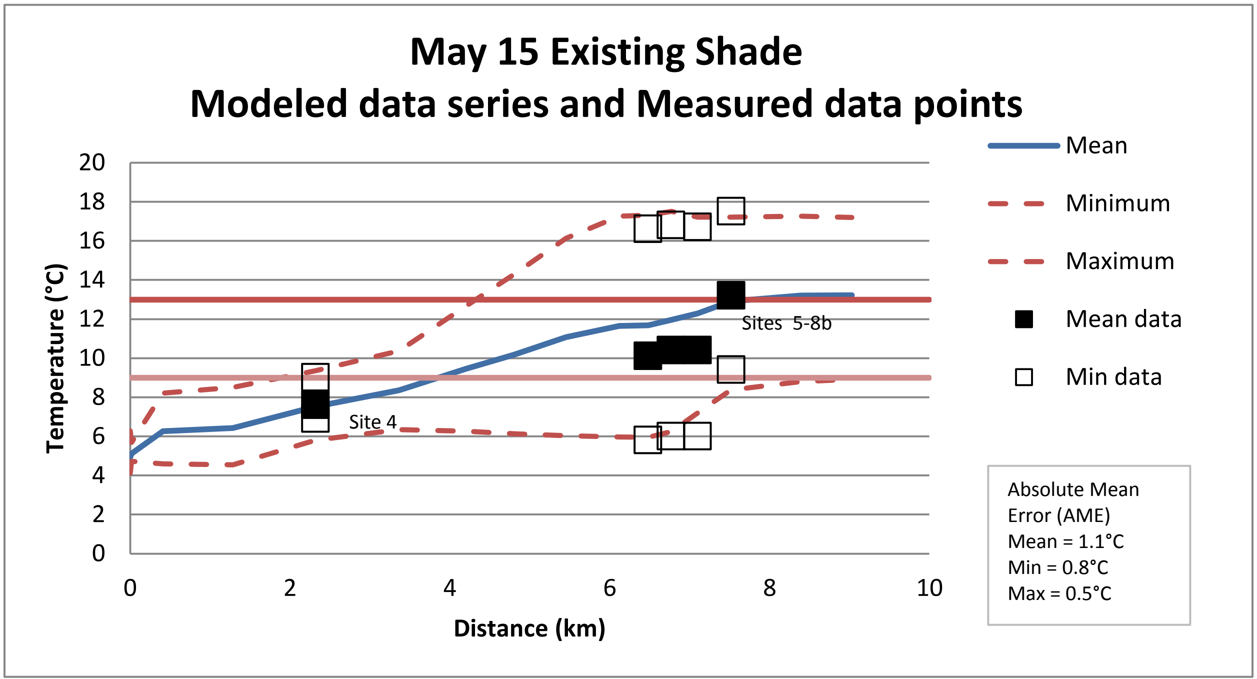

Figure 10. May existing shade temperature calibration of modeled values to measured data points.

Temperature calibration was driven by the need to match the most downstream extent of the model since any compliance issues will need to be met immediately upstream of the STP outfall.

In this scenario, shade had the greatest effect on the maximum temperatures, so the estimations for existing shade were too low in the mid-forest monitoring site. Existing shade was also slightly underestimated at site 8b.

Accurate dewpoint temperature data are important for accurate predictions of streamflow minimum and maximum temperatures. Having the correct dewpoint data along with air temperatures improved the amplitude of predicted minimum and maximum temperatures.

For the May scenario, the predicted minimum and maximum temperatures are within the proposed goal of 1 ºC AME. The AME of the mean temperature predictions are within 1.1 ºC of the actual data.

The model temperature calibration to stream temperatures under existing shade for August 15, 2010, is shown in Figure 11.

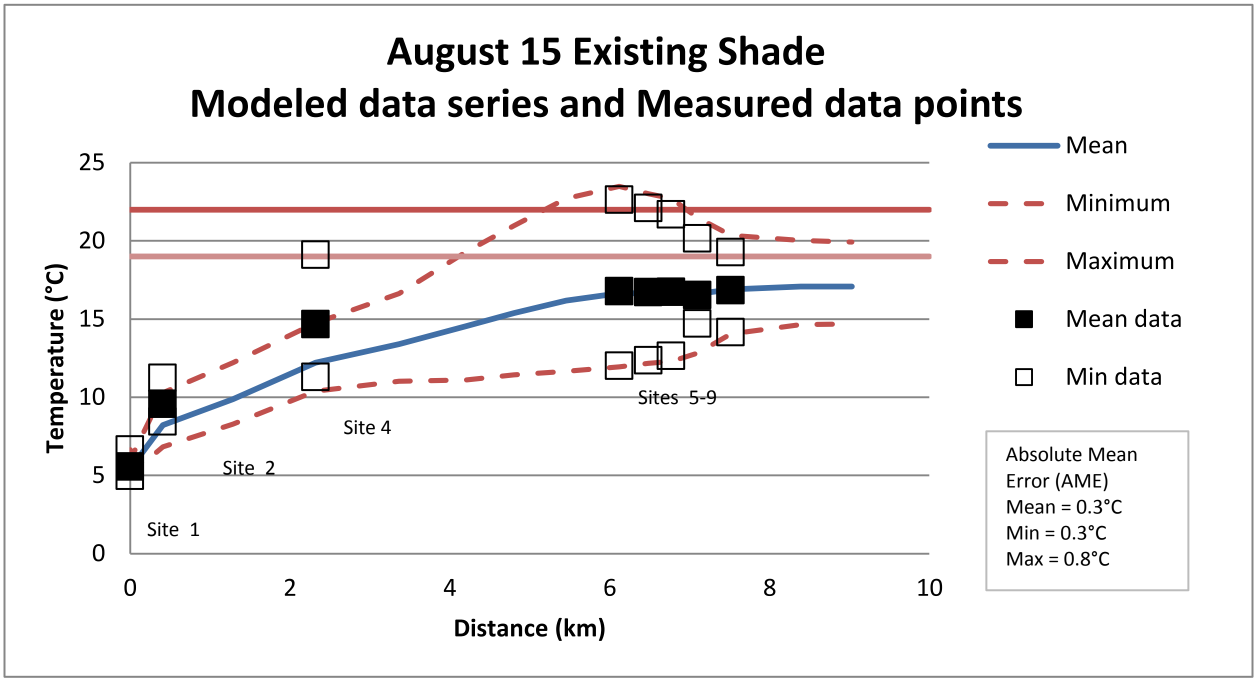

Figure 11. August existing shade temperature calibration of predicted values to measured data points.

Again, the temperature calibration was driven by the need to match the most downstream extent of the model since any compliance issues will need to be met immediately upstream of the STP outfall.

Even though stream temperatures in the forested reach exceeded model predictions, the predicted temperatures in the lower meadow and town stream reaches were accurate. The overall AME of the August scenario is within the goal of 1 ºC.

The accuracy of the model predictions is acceptable for interpretation of water quality standards in the reach immediately upstream of the Grangeville STP outfall.

3.5 Model Results

With adequately calibrated models for existing conditions, the system potential shade values were modeled to identify natural background stream temperatures. PNV was estimated as follows:

- 95% shade in the forest
- 94% shade in the upper meadow
- 88% shade in the lower meadow and town

Figure 12 shows the stream temperatures that would occur with these shade values in May.

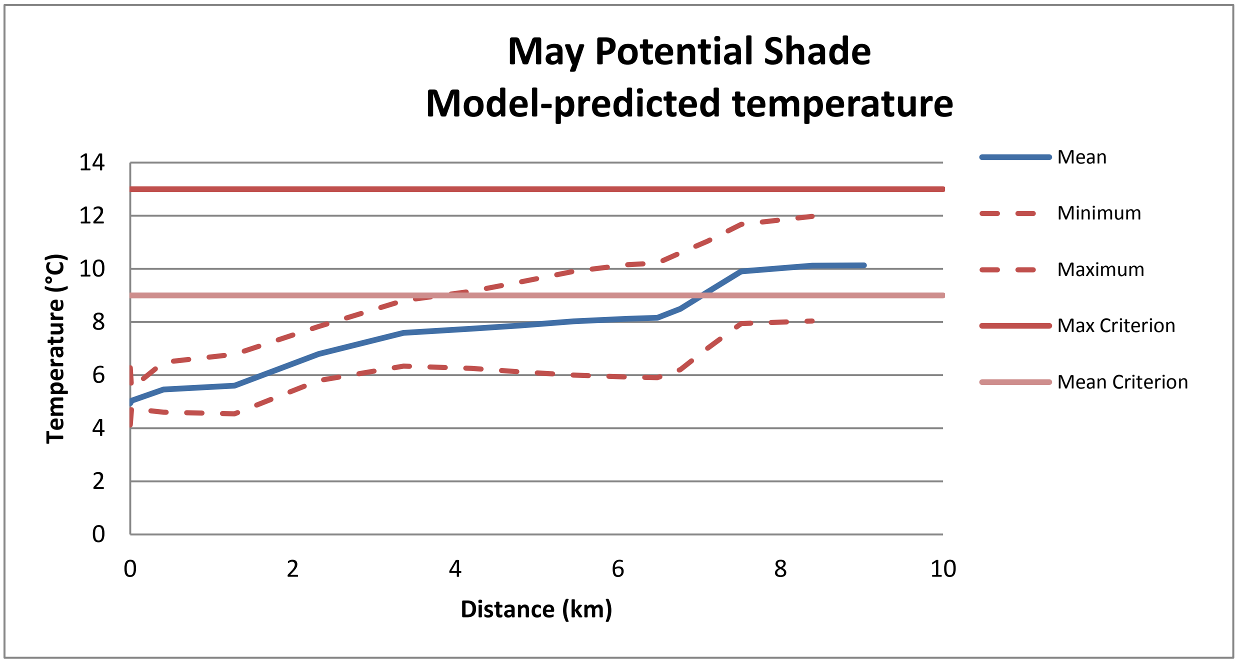

Figure 12. System potential shade temperature analysis for May.

This stream temperature regime for the May modeled scenario is considered to be the natural background condition for Threemile Creek in the reach upstream of the Grangeville STP outfall during salmonid spawning periods. Predicted maximum stream temperatures under system potential shade would not exceed the 13 ºC maximum water quality criterion. However, even under system potential shade, the 9 ºC mean criterion would be exceeded.

Figure 13 shows the stream temperatures under system potential shade values in August.

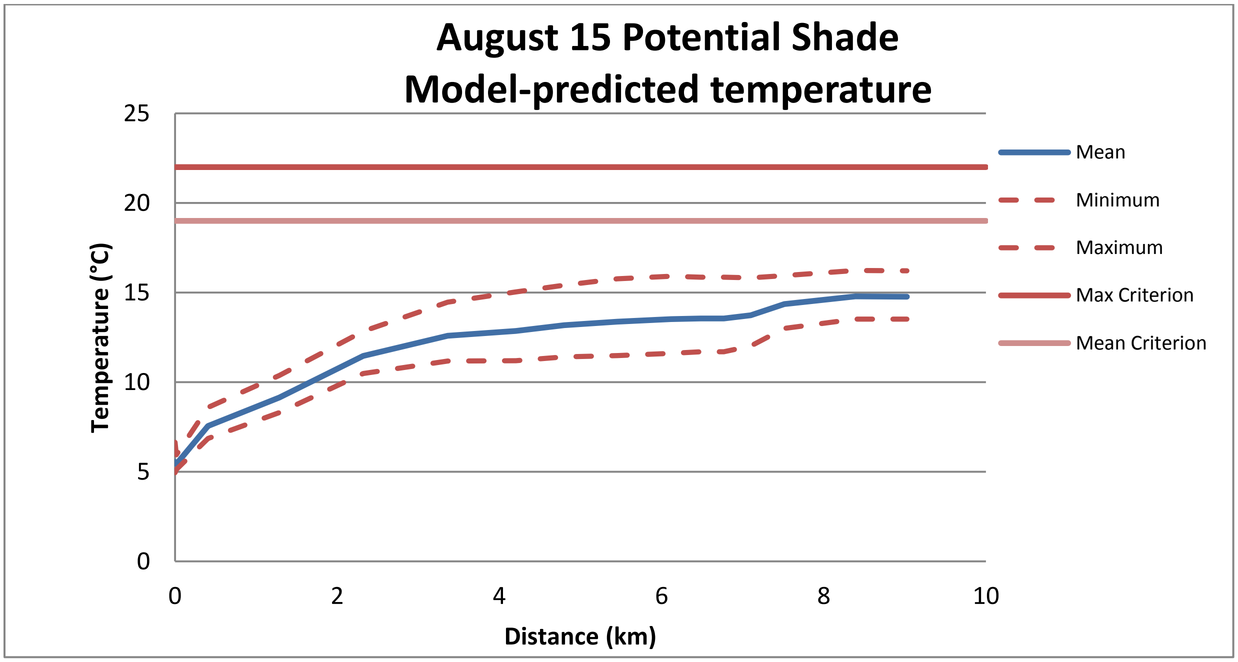

Figure 13. System potential shade temperature analysis for August.

This stream temperature regime for the August modeled scenario is considered to be the natural background condition for evaluating support status of cold water aquatic life beneficial uses. Predicted maximum and mean stream temperatures under system potential shade would not exceed the temperature criteria for cold water aquatic life.

3.6 Application of Model Results: Edited Wasteload Allocations

The original wasteload allocations (Appendix A) given to the Grangeville STP in the South Fork Clearwater River TMDL (DEQ and EPA 2003) identify the effluent discharge temperature limits at a range of effluent and stream discharge volumes that would not increase *criteria temperatures* more than 0.3 ºC during critical periods:

- Salmonid spawning—applicable between April 1 and May 31 at Threemile Creek discharge volumes ranging from 0.1 to 10 cfs
- Cold water aquatic life—applicable between July 15 and September 15 at Threemile Creek discharge volumes ranging from 0.1 to 3.0 cfs

However, the rule is based on *natural background temperatures.* Therefore, these model results can be used to identify wastewater effluent temperatures that would not increase natural background temperatures—those that would occur under system potential shade—more than 0.3 ºC.

Running the calibrated May 15 model under potential shade values at the given range of streamflows, the stream temperatures immediately above the STP outfall are shown in Table 6. Stream temperatures for salmonid spawning (May) under system potential shade.

Table 6. Stream temperatures for salmonid spawning (May) under system potential shade.

Threemile Creek Flow Upstream of STP Outfall (cfs)	Threemile Creek Temperature (ºC) Upstream of STP Outfall		
	Average	Minimum	Maximum
1	10.5	7.0	13.4
3	10.3	7.8	12.4
5	10.0	8.1	11.8
7	9.9	8.2	11.4
9	9.8	8.3	11.1
10	9.7	8.4	10.9

The average existing temperature for May 15, 2010, is 13.3 ºC at a flow of 4.6 cfs. For the range of flows from 3 cfs to 10 cfs, the average predicted temperature under system potential shade ranges from 10.5 ºC to 9.7 ºC—cooler than existing conditions.

Running the calibrated August 15 model under potential shade values at the given range of streamflows, the stream temperatures immediately above the STP outfall are shown in Table 7.

Table 7. Threemile Creek stream temperatures for cold water aquatic life (August) under system potential shade.

Threemile Creek Flow Upstream of STP Outfall (cfs)	Threemile Creek Temperature (ºC) Upstream of STP Outfall		
	Average	Minimum	Maximum
1	14.5	12.4	16.9
2	14.7	13.2	16.5
3	14.8	13.5	16.2

The average existing temperature for August 15, 2010, is 16.8 ºC at a flow of 1.9 cfs. For the range of flows from 1 cfs to 3 cfs, the average predicted temperature under system potential shade ranges from 14.5 ºC to 14.8 ºC—cooler than existing conditions.

4 Conclusion

The purpose of this Threemile Creek temperature study was to determine if temperature criteria for the designated aquatic life use are exceeded in the receiving waters upstream of the Grangeville STP discharge due to natural background conditions. The model was able to show that stream temperatures under system potential shade would not exceed temperature criteria except for some limited exceedances of the 9 ºC mean criterion in May.

Overall, the QUAL2Kw model was a good choice for being able to identify natural background temperatures within 0.1 ºC accuracy. The modeling exercise was able to identify the most important field data for well-calibrated model simulations, including collecting dewpoint temperature along with air temperature in the riparian area. This work is a valid foundation for future stream temperature modeling efforts.

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Glossary

Baseflow	The portion of streamflow that includes ground water and base runoff. This is the average streamflow that occurs most of the year. It is the remainder of the streamflow after peak runoff is over.
Diel	One 24-hour period
Diurnal	Recurring every day; daily
Effluent	Outflow of waste or water from a treatment facility or the outflow of sewage from a sewer system
Heat capacity	The ratio of heat energy absorbed or released by a system to the corresponding change in temperature
Hyporheic flow	Water from a stream channel that enters the streambed and re-emerges downstream. The thickness of this region is the hyporheic zone, and processes that exchange materials or heat are referred to as hyporheic exchange.
Joules	A unit of heat, energy, or work required to produce one watt of power for one second
Longwave	The infrared energy radiated by the earth and the atmosphere; a reflection of shortwave solar radiation
Nonpoint source	Pollution that comes from an unidentifiable source (e.g., stormwater runoff from parking lots, roofs, and streets)
Point source	Pollution that comes from direct sources, such as effluent from a pipe in a wastewater treatment plant
Reach	Any length of stream; specifically, a length of the channel uniform in discharge, depth, area, slope, or riparian condition
Sediment	Soil or rocks in a range of sizes consisting of fragments of weathered minerals suspended, transported, or deposited by water or air
Shortwave	The radiant energy emitted from the sun
TMDL	Total maximum daily load. A TMDL is a water body's load capacity after it has been allocated among pollutant sources. It can be expressed on a time basis other than daily if appropriate. Sediment loads, for example, are often calculated on an annual basis. A TMDL is equal to the load capacity, such that load capacity = margin of safety + natural background + load allocation + wasteload allocation = TMDL. In common usage, a TMDL also refers to the written document that contains the statement of loads and supporting analyses, often incorporating TMDLs for several water bodies and/or pollutants within a given watershed.

Wasteload allocation	The portion of receiving water's load capacity that is allocated to one of its existing or future point sources of pollution. Wasteload allocations specify how much pollutant each point source may release to a water body.
Water balance	Also called hydrologic budget, an accounting of inflow, outflow, and storage in a hydrologic component such as an aquifer, lake, soil zone, or drainage basin. In the context of this report, the water balance equals the ground water and other diffuse inflows to the stream, the stream outflow to the soil and aquifer, and the total storage in the stream.

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Appendix A. Original Wasteload Allocations

Tables 46 and 47 from pages 186 and 187 of the South Fork Clearwater River Total Maximum Daily Load, duplicated below, identify the effluent discharge limits that would not increase criteria stream temperatures more than 0.3 °C during the critical periods for salmonid spawning and cold water aquatic life (DEQ and EPA 2003).

Table 46. Grangeville wastewater treatment plant (WWTP) maximum daily effluent temperatures (°C) [a] which would not increase temperatures in Threemile Creek by more than 0.3 °C between April 1 and May 31 when the salmonid spawning criteria is applicable.

Threemile Creek Flow Above WWTP Outfall (cfs) [b]	WWTP Effluent Discharge (cfs)				
	0.4	**1.0**	**1.5**	**2.0**	**2.5**
0.1	9.3	9.3	9.3	9.3	9.3
1	9.5	9.4	9.4	9.3	9.3
3	9.9	9.5	9.5	9.4	9.4
5	10.2	9.7	9.6	9.5	9.5
7	10.6	9.8	9.7	9.6	9.5
9	11.0	10.0	9.8	9.6	9.6
10	11.2	10.1	9.8	9.7	9.6

[a] Applicable between April 1 and May 31 when salmonid spawning temperature criteria apply

[b] cubic feet per second

Table 47. Grangeville wastewater treatment plant (WWTP) maximum daily effluent temperature (°C) that would not increase Threemile Creek temperature more than 0.3 °C between July 15 and September 15 when coldwater aquatic life temperature criteria apply.

Threemile Creek Flow Above WWTP Outfall (cfs)	WWTP Effluent Discharge (cfs)				
	0.3	**0.5**	**1.0**	**1.5**	**2.0**
0.1	19.3	19.3	19.3	19.3	19.3
1.0	19.6	19.5	19.4	19.4	19.3
2.0	19.8	19.6	19.5	19.4	19.4
3.0	20.1	19.8	19.5	19.5	19.4

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Appendix B. Flow, Channel, and Shade Measurements

The text below is from memoranda issued to Don Essig, Idaho DEQ surface water program, from Mark Shumar, Idaho DEQ technical services program, and Daniel Stewart, DEQ Lewiston Regional Office. These memoranda were edited for format but not for content.

Flow and Channel Measurements on Threemile Creek in May 2010

We measured flow and channels at nine sites along Threemile Creek from Site #2 at the mid-forest location to Site #9 just above the WWTP outfall. Site #8 is on the 'west fork' tributary to Threemile Creek just above the confluence. We added a new site, called #8b, on Threemile Creek at a location just downstream from the confluence with the 'west fork' tributary. Site #1 the upper forest site was not sampled as it is still inaccessible due to snow. The following is a description of the various channel measurements and photographs for each site sampled.

Site #2 Mid-forest (45.87904, -116.11437)
Flow: 2.1 cfs
Gradient: 10.5%
Bankfull Width: 6.4ft
Wetted Width: 4.0ft
Max. Wetted Depth: 0.4ft
Ave. Wetted Depth: 0.29ft
Bank Height: 0.33ft
Max. BF Depth: 0.73ft
Left Bank Angle: 60°
Right Bank Angle: 78°
Incision Depth: none
NSDZ: =BFW

Site #2 is located in the City of Grangeville watershed protection zone. This location had timber harvest activity 10-20 years ago. The east side of the stream (left side in Photo 1) is exposed as a result of that activity. Two temperature loggers were placed in the stream one below each log seen in Photo 2. An air temperature logger was attached to a tree approximately 1m above the ground on the west side of the stream (Photo 3). Photo 4 shows the location for channel measurements.

Photo 1. Site #2 looking upstream.

Photo 2. Site #2 looking downstream.

Photo 3. Site #2 air temperature logger with heat shield. Photo 4. Site #2 location for channel measurements.

Site #3 Lower Forest (45.88811, -116.11191)
Flow: 4.0 cfs
Gradient: 6%
Bankfull Width: 7.5ft
Wetted Width: 4.9ft
Max. Wetted Depth: 0.5ft
Ave. Wetted Depth: 0.39ft
Bank Height: 0.46ft
Max. BF Depth: 0.96ft
Left Bank Angle: 42°
Right Bank Angle: 75°
Incision Depth: none
NSDZ: =BFW

Site #3 is the lower forest site near the forest/meadow boundary. The site is within a local archery range which has clearings formed within the forest for target stations. Site #3 is approximately 20m from the nearest clearing. The water temperature logger (Photo 7) is located below the location of channel measurement (Photo 8) by about 5m. Approximately 50m below Site #3 is an instream pond (Photo 9) that has been constructed by the adjacent landowner.

Photo 5. Site #3 looking upstream.

Photo 6. Site #3 looking downstream.

Photo 7. Site #3 water temperature logger location.

Photo 8. Site #3 channel measurement location.

Photo 9. Small instream pond below Site #3.

Site #4 Upper Meadow (45.89594, -116.11478)
Flow: 5.4 cfs
Gradient: 4%
Bankfull Width: 16ft
Wetted Width: 9ft
Max. Wetted Depth: 0.5ft
Ave. Wetted Depth: 0.31ft
Bank Height: 0.79ft
Max. BF Depth: 1.29ft
Left Bank Angle: 63°
Right Bank Angle: 65°
Incision Depth: none
NSDZ: =BFW

Site #4 is located in a relatively naturalized meadow setting just below a road crossing with principle riparian shrubs including black hawthorn, mountain alder and red-osier dogwood (see Photos 10 and 11). The location is private pasture and some livestock grazing does take place. There are occasional ponderosa pine trees in this lot (Photo 14); however, they are likely a result of dispersal from the nearby forest rather than indicative of past forest on this site. The water temperature logger is located directly below the road crossing culvert (Photo 13).

Photo 10. Site #4 looking upstream.

Photo 11. Site #4 looking downstream

Photo 12. Site #4 channel measurement location. location.

Photo 13. Site #4 water temperature

Photo 14. Site #4 air temperature logger location.

Site #5 lower Meadow (45.91997, -116.11751)
Flow: 4.7 cfs
Gradient: 2.2%
Bankfull Width: 8ft
Wetted Width: 5.4ft
Max. Wetted Depth: 0.75ft
Ave. Wetted Depth: 0.6ft
Bank Height: 0.66ft

Max. BF Depth: 1.41ft
Left Bank Angle: 35°
Right Bank Angle: 24°
Incision Depth: none
NSDZ: =BFW

Site #5 is the lower meadow location and is located on private ground that may be currently or in the past used for livestock grazing pasture. There is no native riparian vegetation, but shade is provided by large golden willow trees (*Salix alba* var. *vitellina*) an introduced species from Eurasia and planted widely for windrow and riparian protection in and around farms in the western U.S. Golden willow is the principle riparian community along Threemile Creek from Grangeville to the canyon. At Site #5 pasture grasses (Photo 18) are the only other riparian plants. The water temperature logger is located downstream of the property owner's driveway bridge (Photo 17).

Photo 15. Site #5 looking upstream.

Photo 16. Site #5 looking downstream.

Photo 17. Site #5 water temperature location.
location.

Photo 18. Site #5 channel measurement

Site #6 Upper Town site, South 1st Street (45.92334, -116.11691)
Flow: 4.0 cfs
Gradient: 2%
Bankfull Width: 15ft
Wetted Width: 6ft
Max. Wetted Depth: 1.0ft

Ave. Wetted Depth: 0.66ft
Bank Height: 1.4ft
Max. BF Depth: 2.4ft
Left Bank Angle: 45°
Right Bank Angle: 15°
Incision Depth: none
NSDZ: =BFW

Site #6 is the upper most town site within the City of Grangeville. Threemile Creek essentially runs between yards and houses at this point. The dominant vegetation is golden willow, although there could be occasional horticultural or weedy species. The house on the east side of the creek is on ground several feet higher than the stream (Photo 22). There is little or no terraces on the west side allowing the stream to flood the adjacent yard for some distance, hence a wider bankfull width in this location. The water temperature logger is located in a small cascade below Photo 20.

Photo 19. Site #6 looking upstream.

Photo 20. Site #6 looking downstream.

Photo 21. Site #6 water temperature location.

Photo 22. Site #6 channel measurement location.

Site #7 Mid-Town site, Liquor Store on Main Street (45.92546, -116.117)
Flow: 4.7 cfs
Gradient: 3%
Bankfull Width: 9.5ft
Wetted Width: 5.4ft

Max. Wetted Depth: 0.75ft
Ave. Wetted Depth: 0.52ft
Bank Height: 1.7ft
Max. BF Depth: 2.5ft
Left Bank Angle: 27°
Right Bank Angle: 20°
Incision Depth: 2.95ft
Left Incision Angle: 20°
Right Incision Angle: 20°
NSDZ: =BFW

Site #7 is located in the center part of town adjacent to the liquor store parking lot. Main Street can be seen just upstream of the sampling location (Photo 23). The site is incised and somewhat armored on the banks typical of urban settings. The channel is narrow and confined (Photos 26 and 26). Golden willow continues to be the principle riparian species although other shrub species are present.

Photo 23. Site #7 looking upstream.

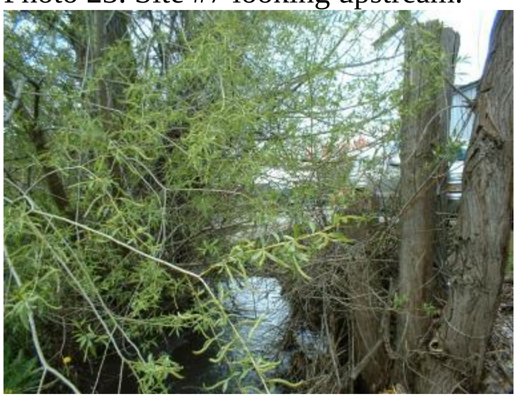

Photo 24. Site #7 looking downstream.

Photo 25. Site #7 water temperature location.

Photo 26. Site #7 channel measurement location.

Site #8 Tributary Stream, 'West Fork' (45.9285, -116.1186)
Flow: 0.8 cfs
Gradient: 2%
Bankfull Width: 8ft

Wetted Width: 3.5ft
Max. Wetted Depth: 0.4ft
Ave. Wetted Depth: 0.235ft
Bank Height: 1.8ft
Max. BF Depth: 2.2ft
Left Bank Angle: 45°
Right Bank Angle: 30°
Incision Depth: 5.3ft
Left Incision Angle: 35°
Right Incision Angle: 55°
NSDZ: =BFW

Site #8 is on the tributary stream locally known as the 'west fork' just above the confluence with Threemile Creek. The west fork tributary has been underground below the city but emerges from the road culvert seen in Photo 27. The channel is small but incised and well armored typical of urban settings. The confluence with Threemile Creek occurs just before the road bridge seen in Photo 28. There are some small golden willows on the east side; however, the west side above the incised channel is asphalt.

Photo 27. Site #8 looking upstream.

Photo 28. Site #8 looking downstream.

Photo 29. Site #8 water temperature location. location

Photo 30. Site #8 channel measurement

Site #8b Threemile Creek below the 'West Fork' confluence (45.92899, -116.11846)
Flow: 4.6 cfs

Gradient: 2%
Bankfull Width: 10ft
Wetted Width: 7ft
Max. Wetted Depth: 1.1ft
Ave. Wetted Depth: 0.74ft
Bank Height: 0.7ft
Max. BF Depth: 1.8ft
Left Bank Angle: 42°
Right Bank Angle: 45°
Incision Depth: 4ft
Left Incision Angle: 30°
Right Incision Angle: 45°
NSDZ: =BFW

A new site (#8b) was located just downstream of the confluence with the 'west fork' tributary (above the bridge in Photo 31). This location is similar to Sites 7 and 8 with an incised channel near a road with golden willow trees dominating the riparian. The 'west fork's' flow contribution appears to be negligible compared to the variation within the limits of the measurement technique.

Photo 31. Site #8b looking upstream.

Photo 32. Site #8b looking downstream.

Photo 33. Site #8b channel measurement location.

Site #9 Threemile Creek above the WWTP outfall (45.9392, -116.11243)
Flow: gage height = 0.68ft

Gradient: 1%
Bankfull Width: 10.8ft
Wetted Width: 6.8ft
Max. Wetted Depth: 1.2ft
Ave. Wetted Depth: 0.33ft
Bank Height: 0.9ft
Max. BF Depth: 2.1ft
Left Bank Angle: 80°
Right Bank Angle: 32°
Incision Depth: 2.8ft
Left Incision Angle: 24°
Right Incision Angle: 29°
NSDZ: =BFW

Site 9 is located in a pasture just below the City of Grangeville, and directly above the WWTP outfall (below far tree in Photo 35). The riparian community consists of golden willow trees and pasture grasses that are routinely grazed by horses. The channel is slightly incised here with active bank erosion (see Photo 36). An air temperature logger (photo 38) has been placed adjacent to the water temperature logger location. Flow was not measured at Site 9 as there is a stage gage just upstream from this site.

Photo 34. Site #9 looking upstream.

Photo 35. Site #9 looking downstream.

Photo 36. Site #9 water temperature location.

Photo 37. Site #9 channel measurement location.

Photo 38. Site #9 air temperature logger location.

Flow and Solar Pathfinder Shade Measurements on Threemile Creek, July 2010

We measured flow and shade at nine sites along Threemile Creek from Site #1 at the upper-forest location to Site #9 just above the WWTP outfall. Site #8 is on the ‘west fork’ tributary to Threemile Creek just above the confluence. We continued the new site, called #8b, on Threemile Creek at a location just downstream from the confluence with the ‘west fork’ tributary. We also downloaded temperature data from the loggers and found several out of the water. All loggers were placed back into the stream after data retrieval. The following is a description of the flow and shade for each site sampled.

Site #1 Upper Forest (45.86434, -116.11654)
This was my first visit to this upper-most site. It is located on a steep hillside that had been logged in the past, part of the City of Grangeville watershed protection zone. Most of the near stream vegetation was mountain shrub and herbaceous vegetation with an occasional young conifer (see Photos # 1-3). Flow was measured via a temporary weir and a five-gallon bucket. Time to fill the bucket was recorded three times and then averaged. Average time to fill was 10.07 seconds which is equivalent to 0.4965 gallons/second or 0.066 cfs.

Average shade measured with a solar pathfinder at ten locations above Site #1 resulted in a six-month average shade of 73.3% (range 32.7% to 100%). The original aerial photo interpretation conducted by us back in February 2010 had placed this section of stream in the 70% existing shade class, which was a correct interpretation.

Photo 1. Site #1 looking upstream above through
shade measurement reach. (July 2010).

Photo 2. Site #1 looking downstream

shade measurement reach. (July 2010).

Photo 3. Landscape view below Site #1. (July 2010).

Site #2 Mid-forest (45.87904, -116.11437)
Site #2 is also located in the City of Grangeville watershed protection zone. This location also had timber harvest activity 10-20 years ago. Flow measured at this location was 1.1 cfs with a wetted width of 4 ft and an average wetted depth of 0.25 ft. Although these wetted channel dimensions have changed little since the May 2010 flow measurements, flow is about half of what it was in May.

Average shade measured at 10 locations, 5 above and 5 below the temperature logger location, was only 60.1% (range 25.7% to 89.4%) and is considerably less than the 80% existing shade class that we had originally interpreted for this site. The logging activity and the current recreational trail on the east side of this stream have left it more exposed than anticipated.

Photo 4. Site #2 looking upstream. (May 2010).

Site #3 Lower Forest (45.88811, -116.11191)
Site #3 is the lower forest site near the forest/meadow boundary. The site is within a local archery range which has clearings formed within the forest for target stations. Site #3 is approximately 20m from the nearest clearing. Flow measured at this location in July was 1.7 cfs, less than half of the 4 cfs measured in May. Wetted width was 2 ft and average wetted depth was 0.37 ft.

Shade was measured at 10 locations above and below Site #3 and the average was 81.8% with a range of 56.6% to 100%. The original aerial photo interpretation had split this area up into a 70% class zone and a 90% class section. The pathfinder data did not show a real separation in shade classes, thus the area should have been interpreted as all 80% class.

Photo 5. Site #3 looking upstream. (May 2010).

Site #4 Upper Meadow (45.89594, -116.11478)
Site #4 is located in a relatively naturalized meadow setting just below a road crossing with principle riparian shrubs including black hawthorn, mountain alder and red-osier dogwood (see Photo 6). The location is private pasture and some livestock grazing does take place. Flow measured in July was 1.8 cfs with a wetted width of 8.5 ft and an average wetted depth of 0.24 ft. Flow at this location in July was one third of the flow in May 2010.

Shade was measured near Site #4 at 10 pathfinder locations below the temperature logger. Average shade was 81.5% with a range of 56.9% to 100%. The majority of this reach was placed into the 80% existing shade class during aerial interpretation, which was a correct assumption. A small portion of this reach was placed in the 40% class, which was not correct.

Photo 6. Site #4 looking upstream. (May 2010).

Site #5 lower Meadow (45.91997, -116.11751)
Site #5 is the lower meadow location and is located on private ground that may be currently or in the past used for livestock grazing pasture. There is no native riparian vegetation, but shade is provided by large golden willow trees (*Salix alba* var. *vitellina*) an introduced species from Eurasia (Photo 7). Flow measured at Site #5 in July 2010 was 2 cfs, again less than half of May 2010 flow of 4.7 cfs. Wetted width was 5.5 ft and average wetted depth was 0.34 ft in July.

Shade was measured at 10 pathfinder locations, 5 above and 5 below the logger location. Average shade was 73.8% with a range from 25.8% to 94.9%. This location was placed into the 70% existing shade class, which was a correct interpretation.

Photo 7. Site #5 looking downstream. (May 2010).

Site #6 Upper Town site, South 1st Street (45.92334, -116.11691)

Site #6 is the upper most town site within the City of Grangeville. Threemile Creek essentially runs between yards and houses at this point. The dominant vegetation is golden willow, although there could be occasional horticultural or weedy species (Photo 8). Flow at Site #6 was measured at 1.8 cfs in July 2010, with a wetted width of 6 ft and an average wetted depth of 0.4 ft.

Shade was measured at six locations above the temperature logger. The lower number of pathfinder locations was due to property boundary issues. Average shade was 87.3% with a range from 76.3% to 94.5%. This location was originally interpreted as a 90% existing shade class, and although measured shade is only a few percentage points away from 90%, technically the location belongs in the 80% shade class.

Photo 8. Site #6 looking downstream. (May 2010).

Site #7 Mid-Town site, Liquor Store on Main Street (45.92546, -116.117)

Site #7 is located in the center part of town adjacent to the liquor store parking lot. The site is incised and somewhat armored on the banks typical of urban settings. The channel is narrow and confined. Golden willow continues to be the principle riparian species although other shrub

species are present (Photo 9). Flow was measured at this location to be 1.7 cfs in July 2010. Wetted width was 4.5 ft and average wetted depth was 0.46 ft.
Average shade at this location, although originally interpreted to be in the 90% existing shade class, was in fact only 84.5% (range 63.4% to 91% at 5 locations).

Photo 9. Site #7 looking downstream. (May 2010).

Site #8 Tributary Stream, 'West Fork' (45.9285, -116.1186)
Site #8 is on the tributary stream locally known as the 'west fork' just above the confluence with Threemile Creek. The west fork tributary has been underground below the city but emerges from a road culvert. The channel is small but incised and well armored typical of urban settings. The confluence with Threemile Creek occurs just before the road bridge seen in Photo 10. There are some small golden willows on the east side; however, the west side above the incised channel is asphalt.

Flow measured on the 'west fork' in July was essentially negligible (~0.01 cfs). There were pools of water in the channel but water was not moving much. Wetted width was 4.6 ft and average wetted depth was 0.2 ft.

Shade was measured at six locations, two in the short reach between the road culvert and the confluence and four in the reach above the road culvert. Average shade was 83.8% with a range from 67.1% to 96%. There was no original aerial interpretation performed for the 'west fork.'

Photo 10. Site #8 looking downstream. (May 2010).

Site #8b Threemile Creek below the 'West Fork' confluence (45.92899, -116.11846)

The new site (#8b) was located just downstream of the confluence with the 'west fork' tributary. This location is similar to Sites 7 and 8 with an incised channel near a road with golden willow trees dominating the riparian (Photo 11). Flow at Site #8b was measured at 1.9 cfs consistent with many of the sites above. Wetted width was 4.5 ft and average wetted depth was 0.41 ft.

Shade was measured at 10 locations below this logger site with four locations being behind the armory where willows had not been trimmed, and six locations were behind the rodeo grounds where willows had been trimmed several months ago. The overall average shade for the 10 locations was 60.9%; however, the four sites behind the armory had an average shade of 78% whereas average shade dropped to 49% for the six locations behind the rodeo ground. The original aerial photo interpretation had placed this entire reach into the 90% existing shade class which was incorrect. Based on pathfinder results, this reach should be split into a 70% class and a 40% class.

Photo 11. Site #8b looking downstream. (May 2010).

Site #9 Threemile Creek above the WWTP outfall (45.9392, -116.11243)

Site 9 is located in a pasture just below the City of Grangeville, and directly above the WWTP outfall. The riparian community consists of golden willow trees and pasture grasses that are routinely grazed by horses (Photo 12). Flow was measured at Site 9 on July 21, 2010 and found to be at 1.56 cfs. Gage height was recorded at 0.69 ft on July 13, 2010, which incidentally was almost the same height as was recorded in our May 2010 visit. The height of 0.69 ft translates to a flow of 6.3 cfs, considerably more than what was measured in the stream at the site. Measured flow at Site 9 (1.56 cfs) is consistent with measured flow at Site 8b a week earlier (1.9 cfs). The gage appears to be out of commission at this time. Flow measured at Site 9 on June 1, 2010 showed the gage was consistent with its calibration at that time. Therefore, something has happened to the channel or the gage between June 1st and July 21st to render it out of commission.

Shade was measured at 10 locations above and below the logger location at Site #9. Average shade was 55.5% with a range from 3.9% to 91.5%. The original aerial interpretation had described this location as in the 70% existing shade class, which is incorrect. The location should be placed into the 50% shade class.

Photo 12. Site #9 looking upstream. (May 2010).

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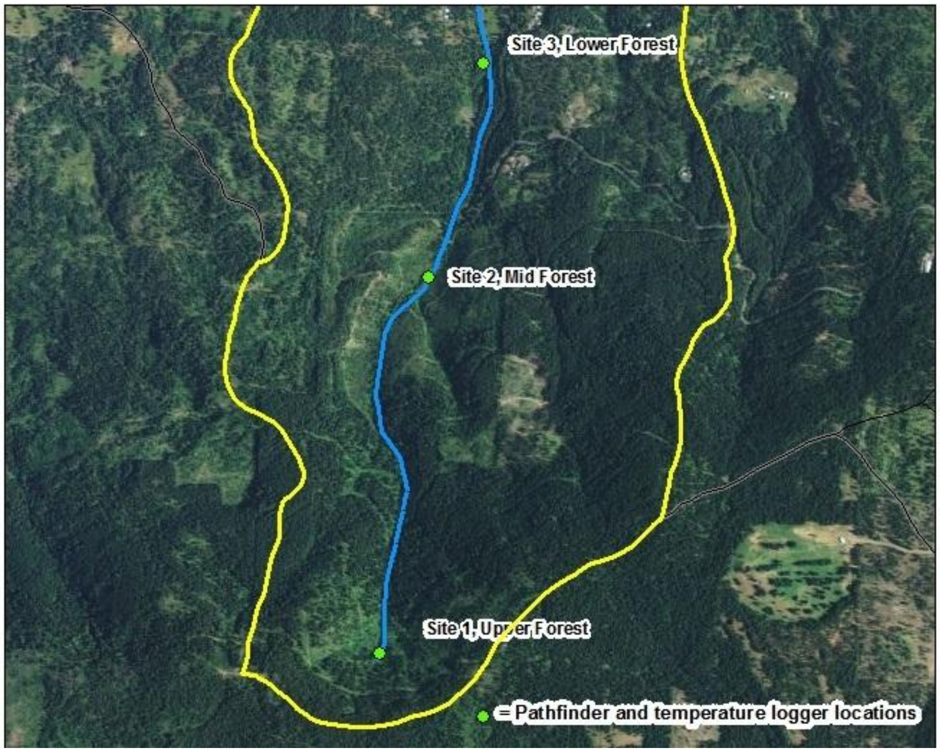
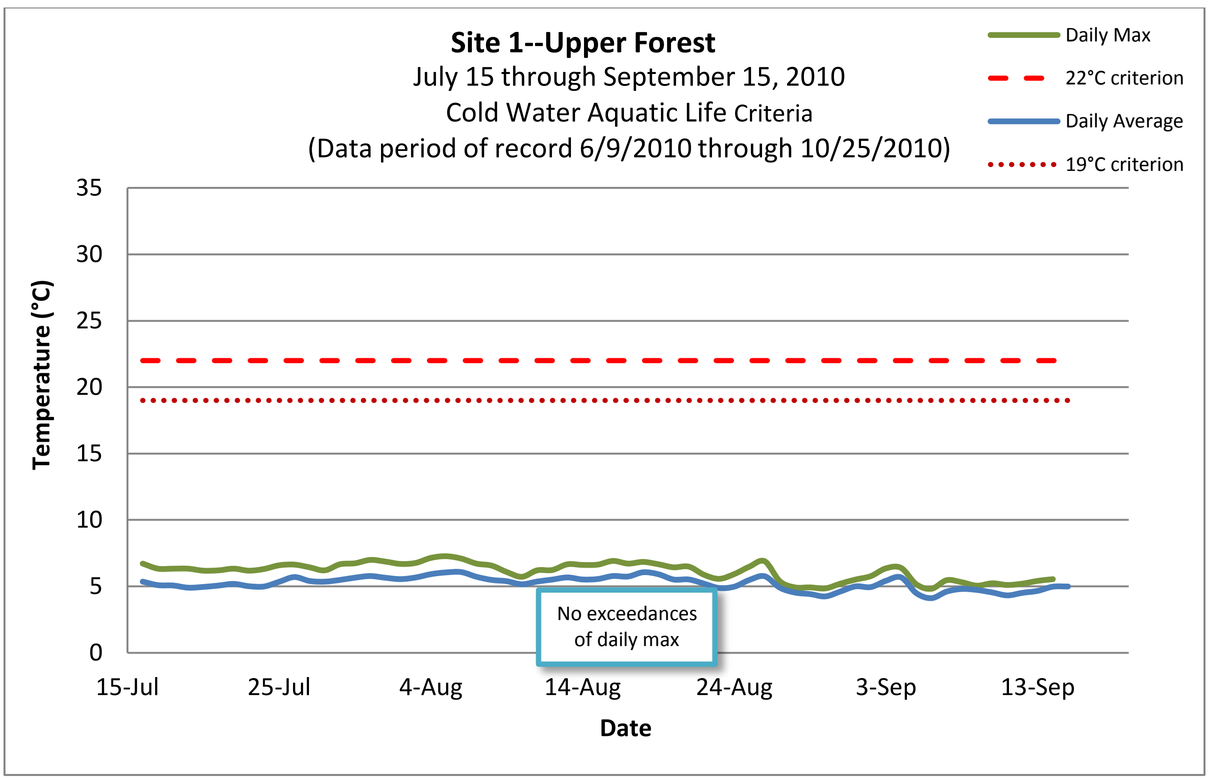
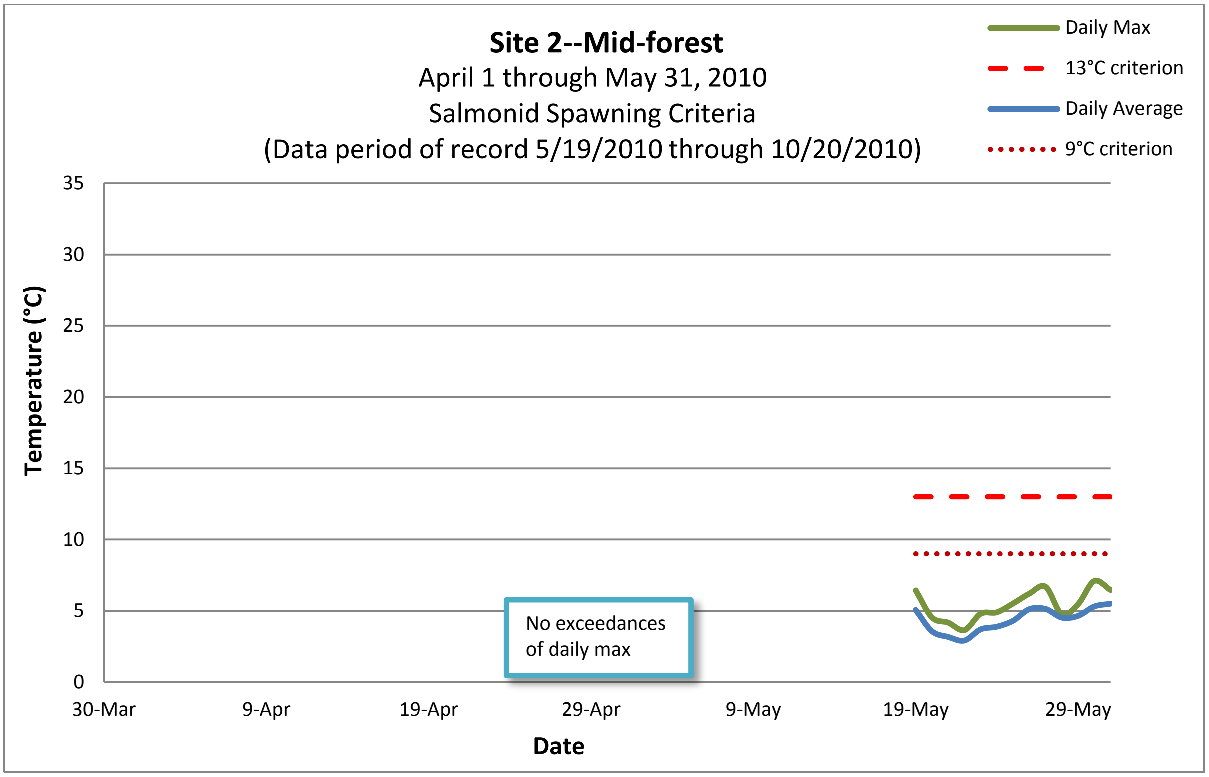
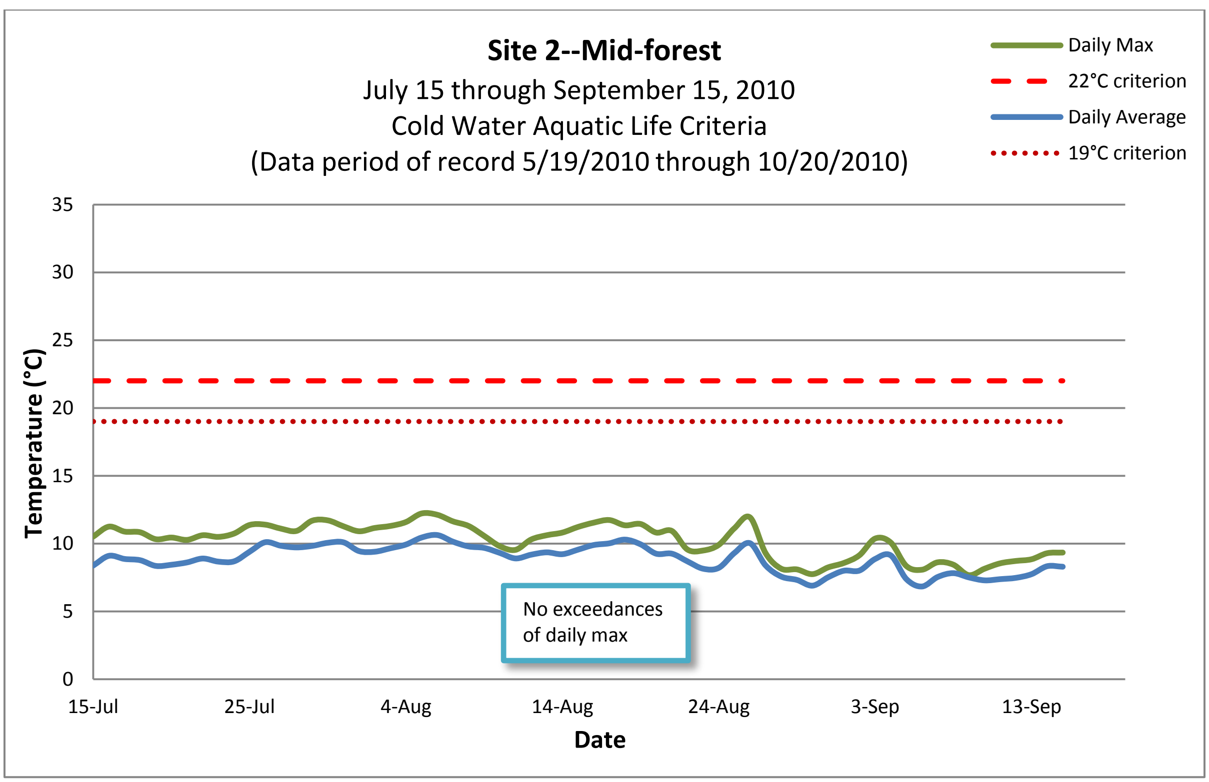
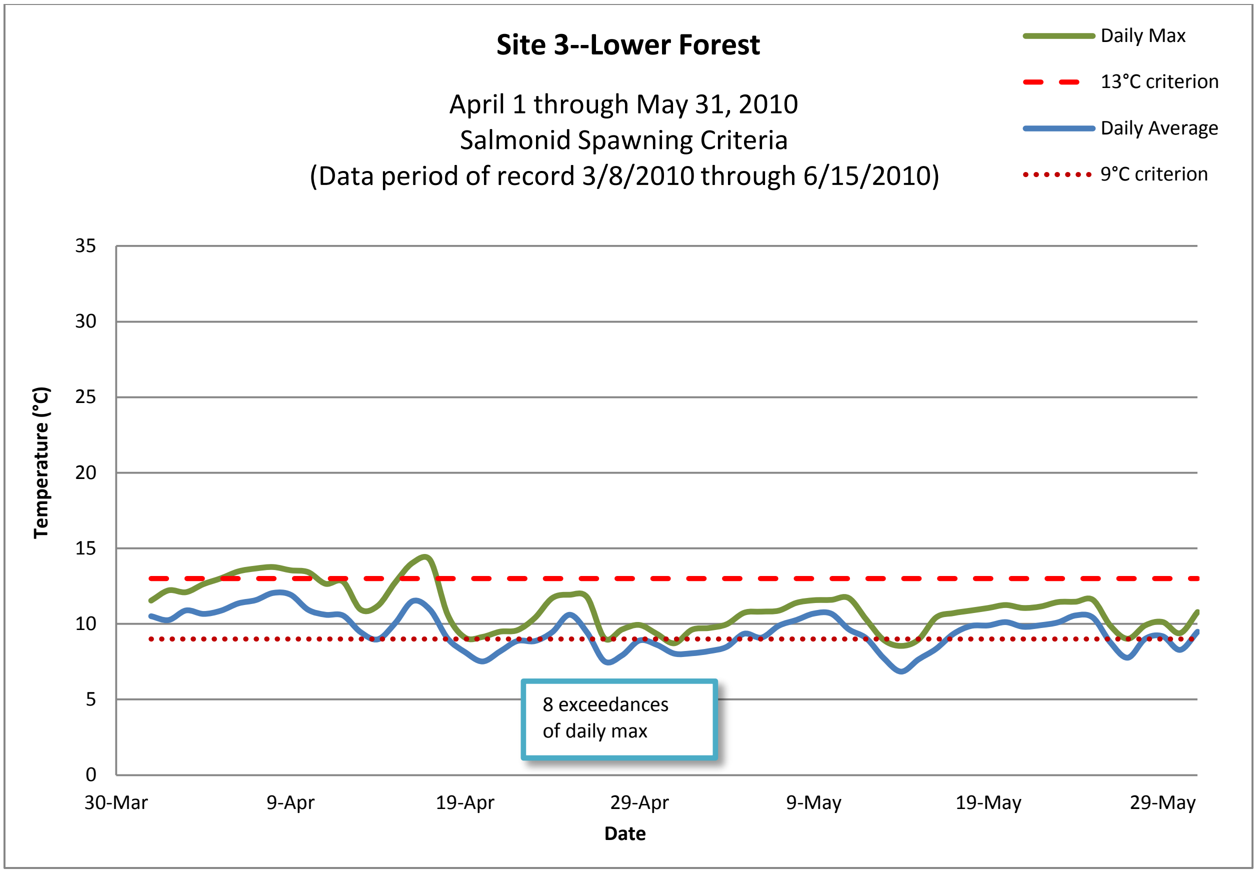
Appendix C. DEQ Stream Temperature Data Summaries

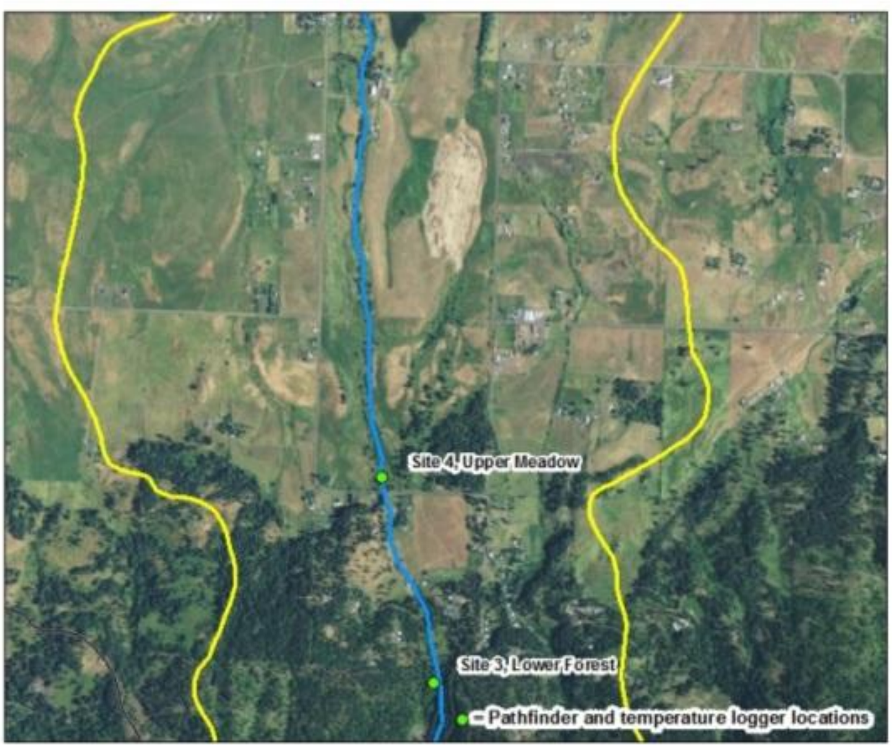

Site 3, Lower Forest
Site 2, Mid Forest
Site 1, Upper Forest
= Pathfinder and temperature logger locations

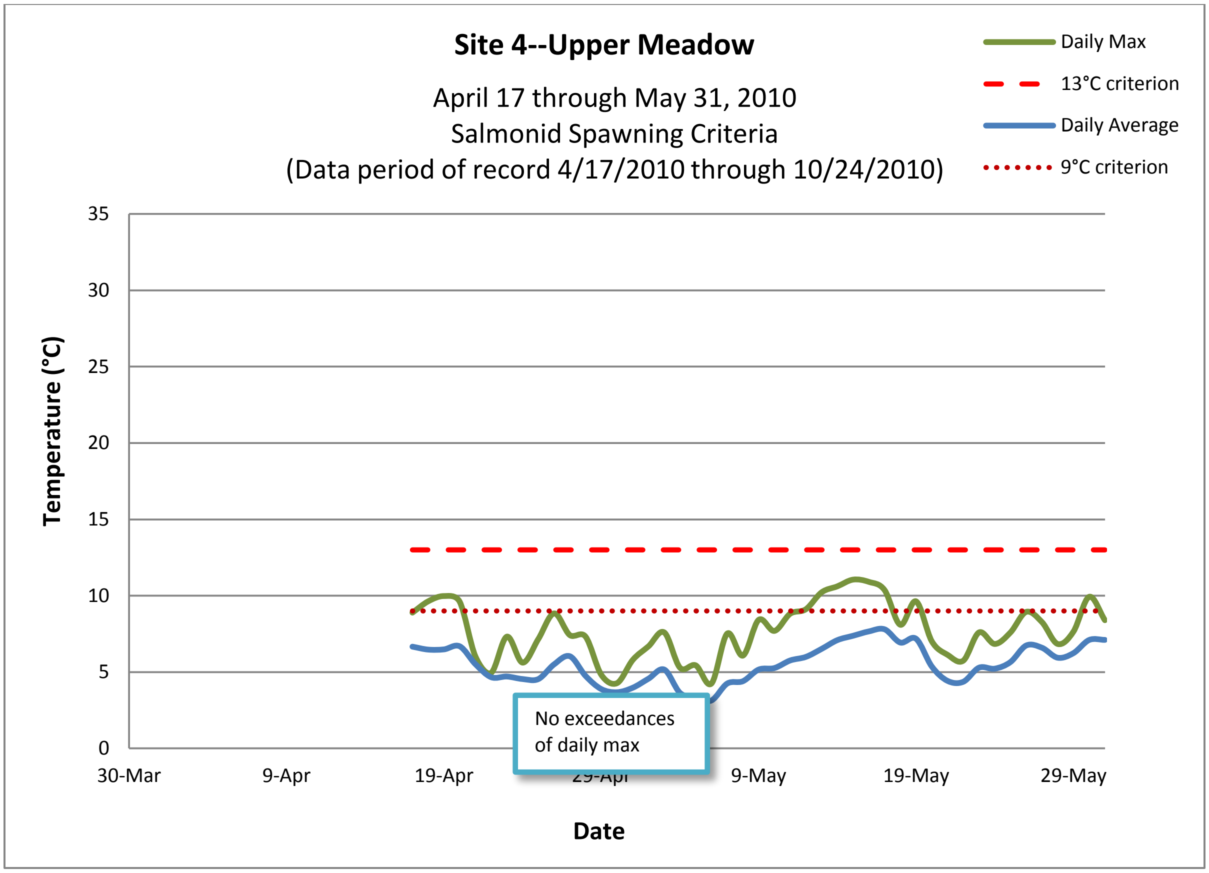

Site 1--Upper Forest
July 15 through September 15, 2010
Cold Water Aquatic Life Criteria
(Data period of record 6/9/2010 through 10/25/2010)
Daily Max
22°C criterion
Daily Average
19°C criterion
Temperature (°C)
35
30
25
20
15
10
5
0
No exceedances of daily max
15-Jul
25-Jul
4-Aug
14-Aug
24-Aug
3-Sep
13-Sep
Date

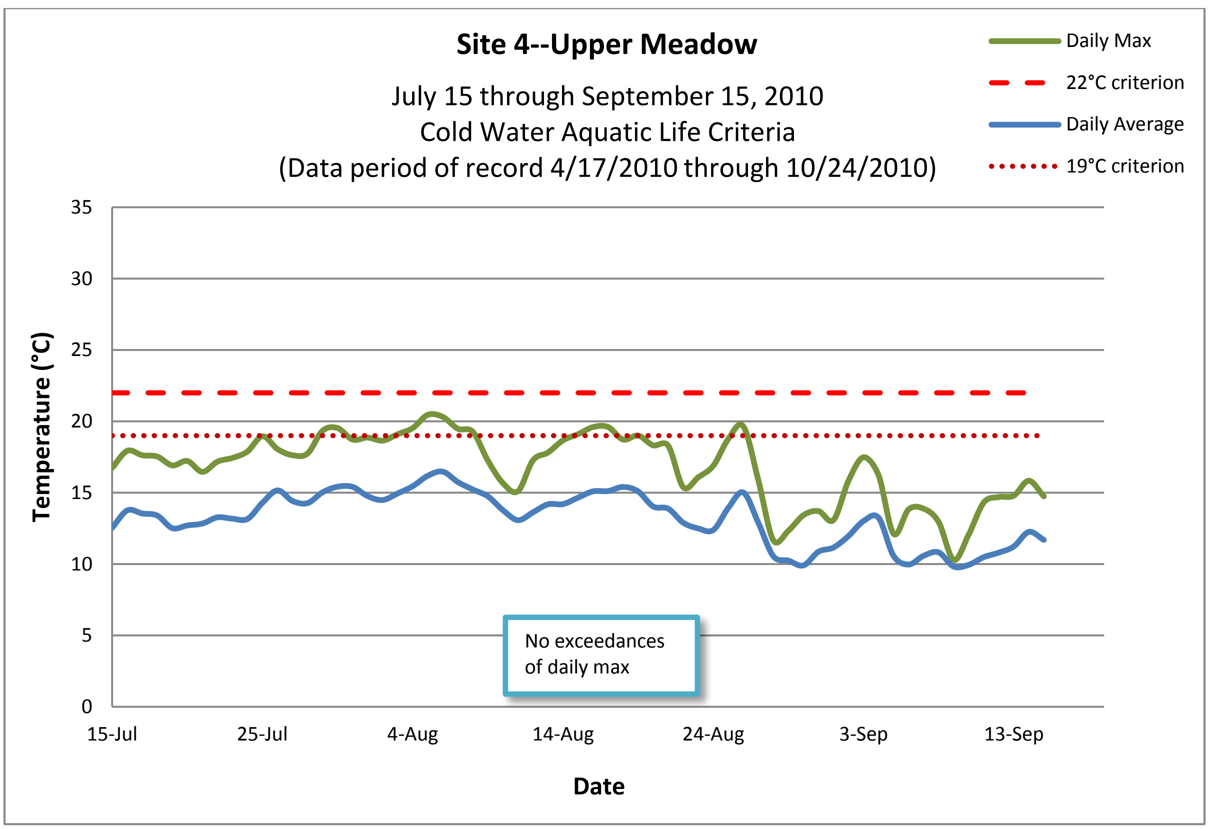

Site 2--Mid-forest
April 1 through May 31, 2010
Salmonid Spawning Criteria
(Data period of record 5/19/2010 through 10/20/2010)
Daily Max
13°C criterion
Daily Average
9°C criterion
Temperature (°C)
35
30
25
20
15
10
5
0
No exceedances of daily max
30-Mar
9-Apr
19-Apr
29-Apr
9-May
19-May
29-May
Date

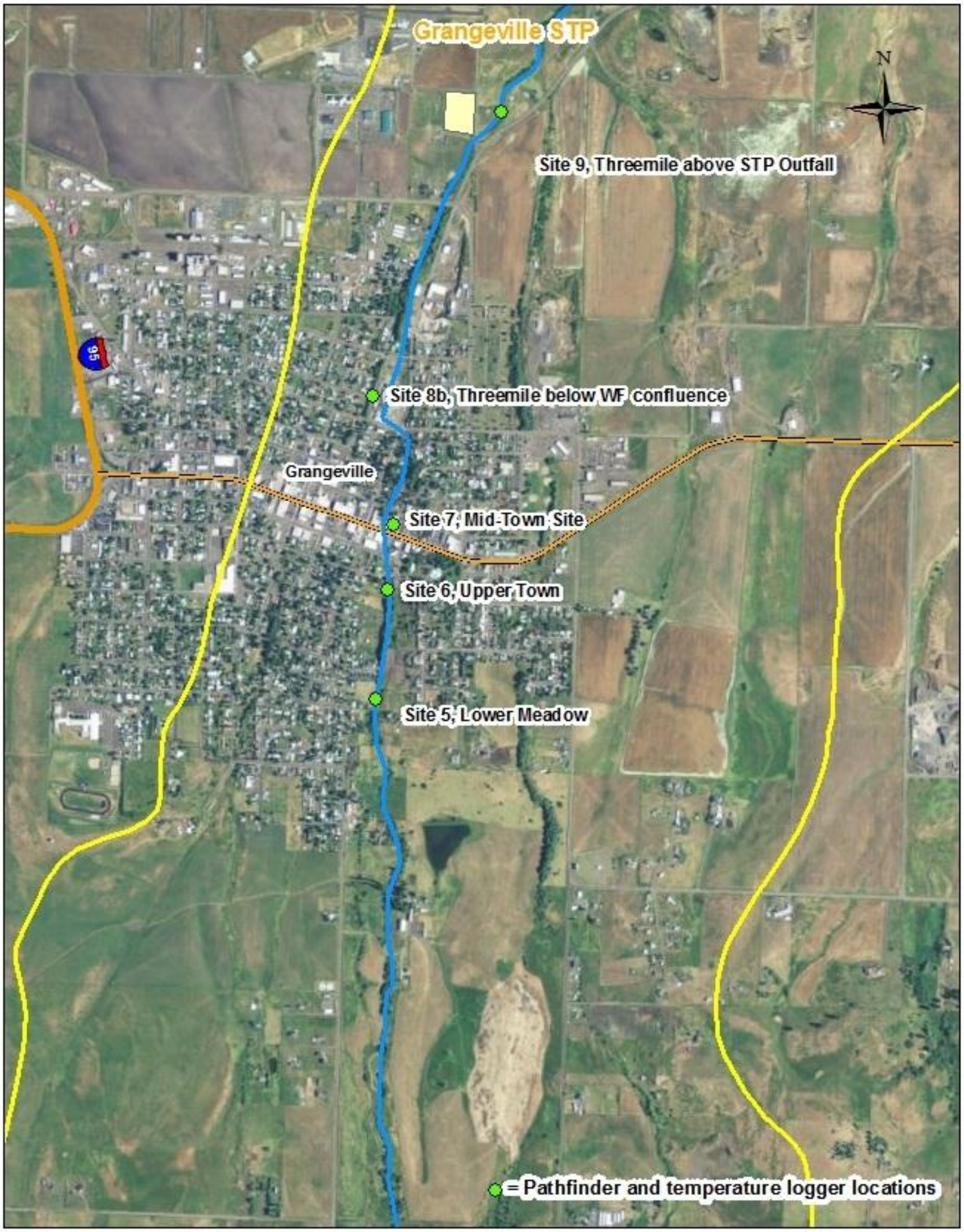

Site 2--Mid-forest
July 15 through September 15, 2010
Cold Water Aquatic Life Criteria
(Data period of record 5/19/2010 through 10/20/2010)
Daily Max
22°C criterion
Daily Average
19°C criterion
Temperature (°C)
35
30
25
20
15
10
5
0
No exceedances of daily max
15-Jul
25-Jul
4-Aug
14-Aug
24-Aug
3-Sep
13-Sep
Date

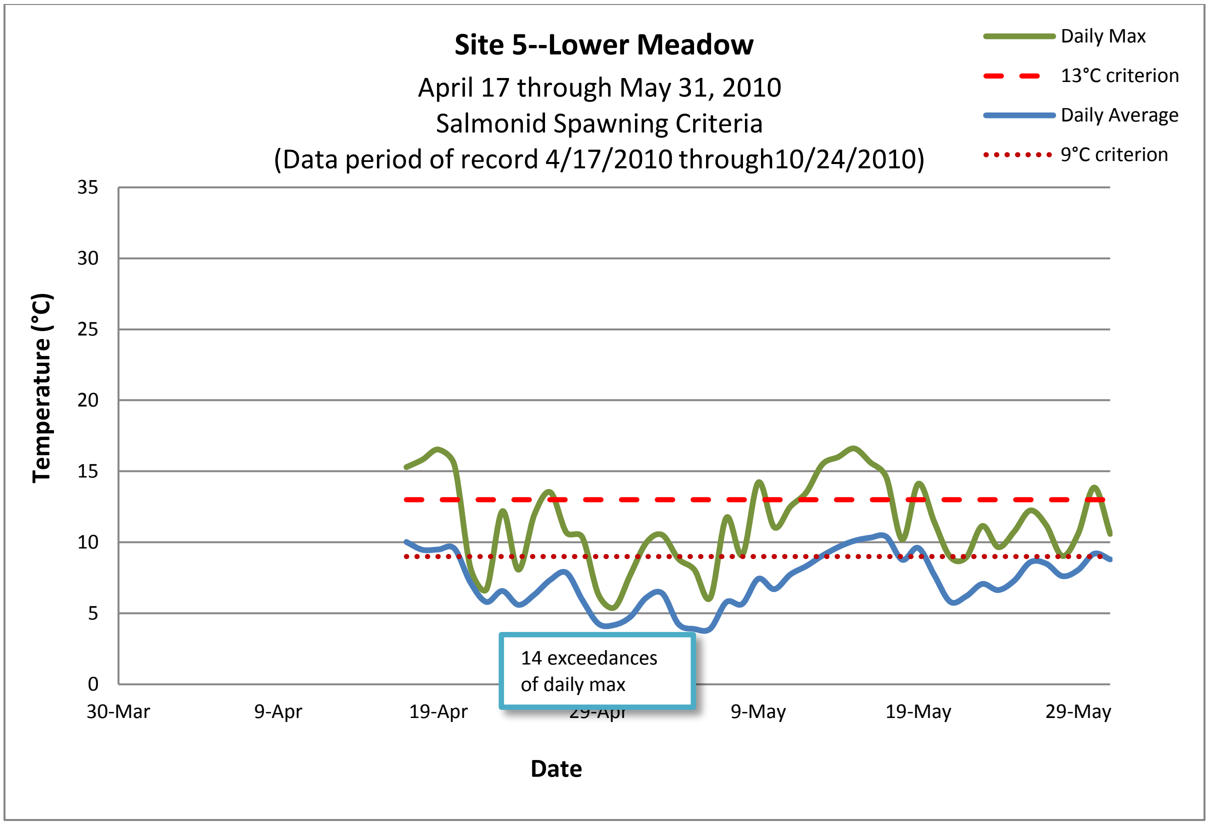

Site 3--Lower Forest
April 1 through May 31, 2010
Salmonid Spawning Criteria
(Data period of record 3/8/2010 through 6/15/2010)
Daily Max
13°C criterion
Daily Average
9°C criterion
Temperature (°C)
35
30
25
20
15
10
5
0
30-Mar
9-Apr
19-Apr
29-Apr
9-May
19-May
29-May
Date
8 exceedances
of daily max

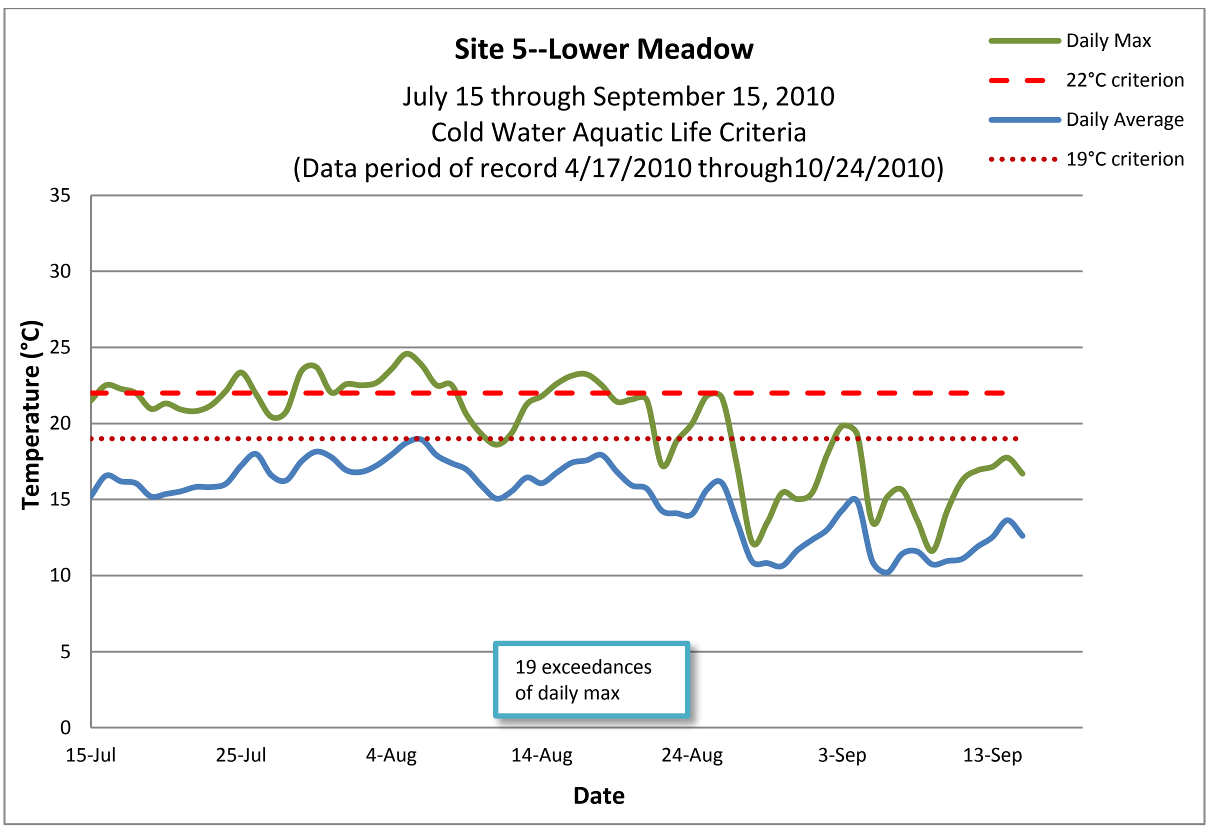

Site 4, Upper Meadow
Site 3, Lower Forest
= Pathfinder and temperature logger locations


Site 4--Upper Meadow
April 17 through May 31, 2010
Salmonid Spawning Criteria
(Data period of record 4/17/2010 through 10/24/2010)
Daily Max
13°C criterion
Daily Average
9°C criterion
Temperature (°C)
35
30
25
20
15
10
5
0
30-Mar
9-Apr
19-Apr
9-May
19-May
29-May
No exceedances of daily max
Date


Site 4--Upper Meadow
July 15 through September 15, 2010
Cold Water Aquatic Life Criteria
(Data period of record 4/17/2010 through 10/24/2010)
Daily Max
22°C criterion
Daily Average
19°C criterion
Temperature (°C)
35
30
25
20
15
10
5
0
15-Jul
25-Jul
4-Aug
14-Aug
24-Aug
3-Sep
13-Sep
No exceedances of daily max
Date


Grangeville STP
N
Site 9, Threemile above STP Outfall
95
Site 8b, Threemile below WF confluence
Grangeville
Site 7, Mid-Town Site
Site 6, Upper Town
Site 5, Lower Meadow
= Pathfinder and temperature logger locations


Site 5--Lower Meadow
April 17 through May 31, 2010
Salmonid Spawning Criteria
(Data period of record 4/17/2010 through10/24/2010)
Daily Max
13°C criterion
Daily Average
9°C criterion
Temperature (°C)
35
30
25
20
15
10
5
0
30-Mar
9-Apr
19-Apr
29-Apr
9-May
19-May
29-May
Date
14 exceedances
of daily max


Site 5--Lower Meadow
July 15 through September 15, 2010
Cold Water Aquatic Life Criteria
(Data period of record 4/17/2010 through10/24/2010)
Daily Max
22°C criterion
Daily Average
19°C criterion
Temperature (°C)
35
30
25
20
15
10
5
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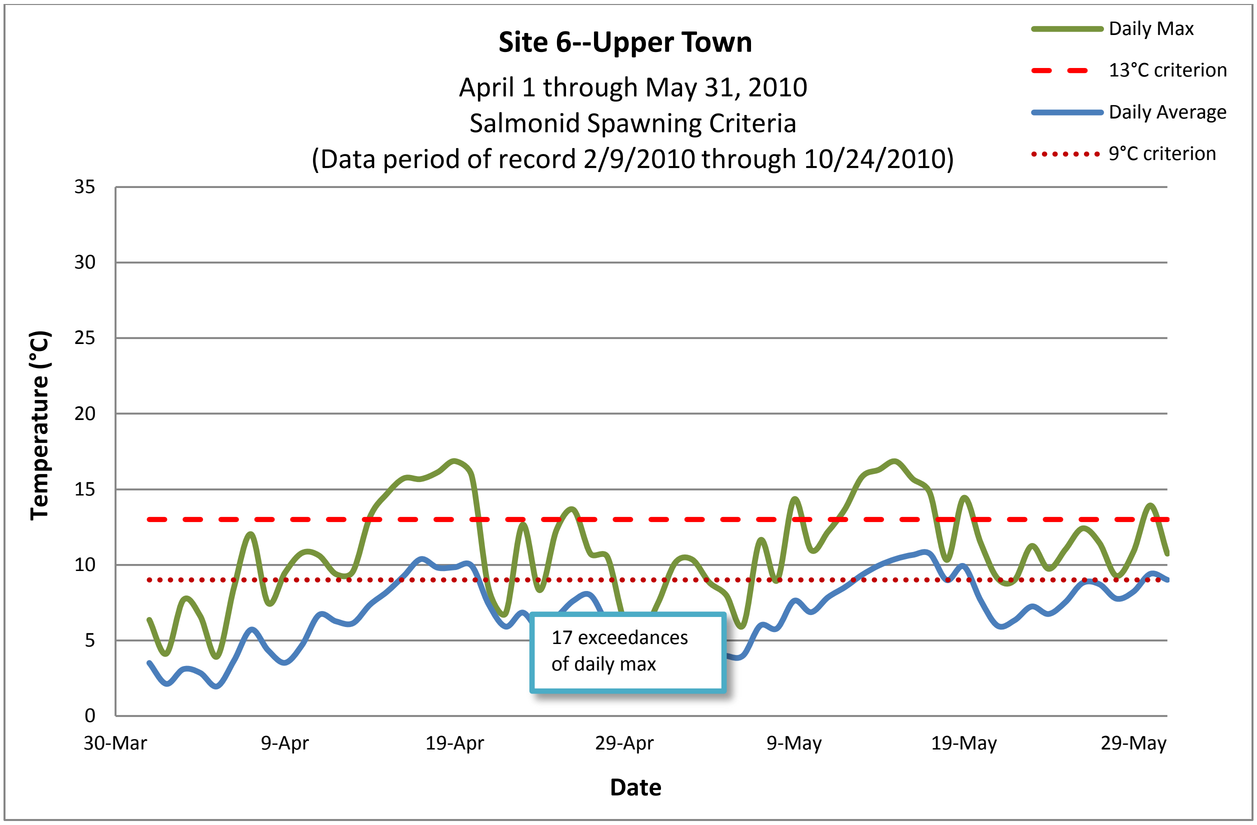
15-Jul
25-Jul
4-Aug
14-Aug
24-Aug
3-Sep
13-Sep
Date
19 exceedances
of daily max


Site 6--Upper Town
April 1 through May 31, 2010
Salmonid Spawning Criteria
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Daily Max
13°C criterion
Daily Average
9°C criterion
Temperature (°C)
35
30
25
20
15
10
5
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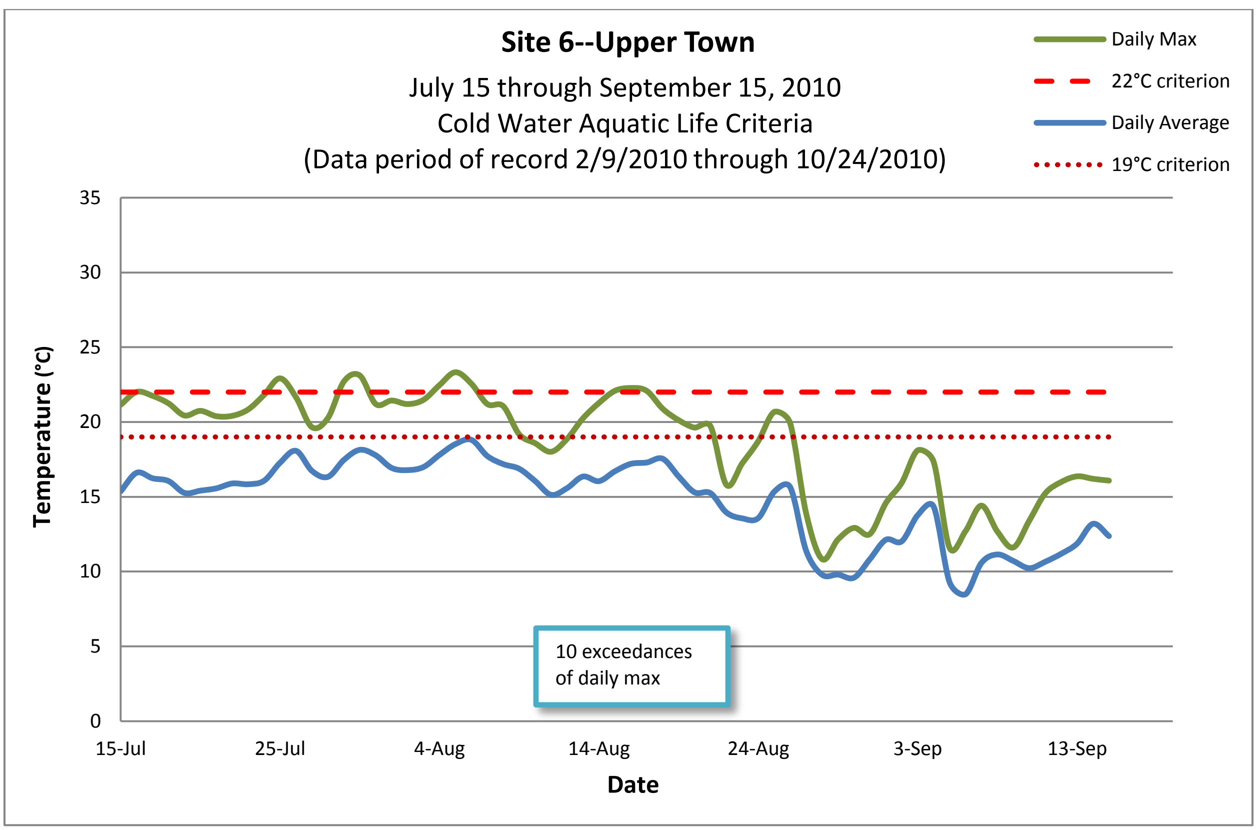
30-Mar
9-Apr
19-Apr
29-Apr
9-May
19-May
29-May
Date
17 exceedances of daily max


Site 6--Upper Town
July 15 through September 15, 2010
Cold Water Aquatic Life Criteria
(Data period of record 2/9/2010 through 10/24/2010)
Daily Max
22°C criterion
Daily Average
19°C criterion
Temperature (°C)
35
30
25
20
15
10
5
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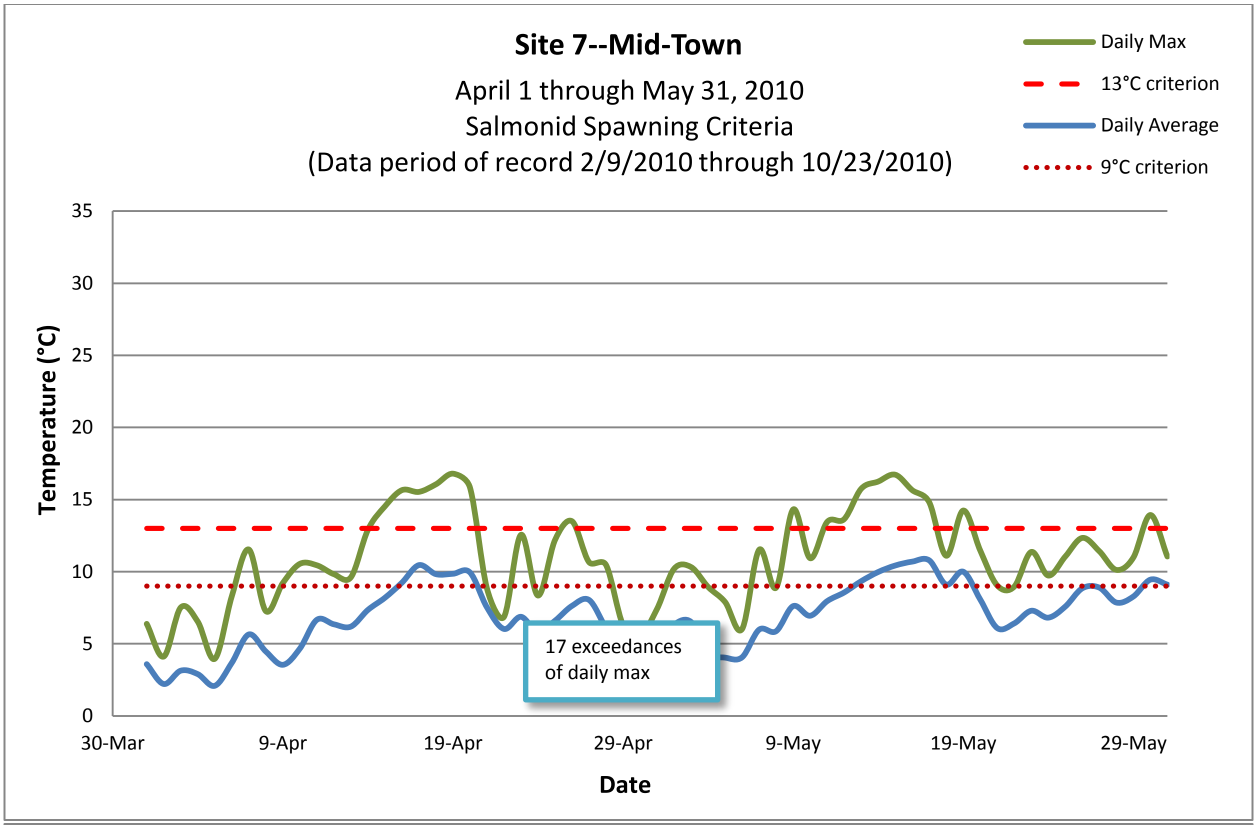
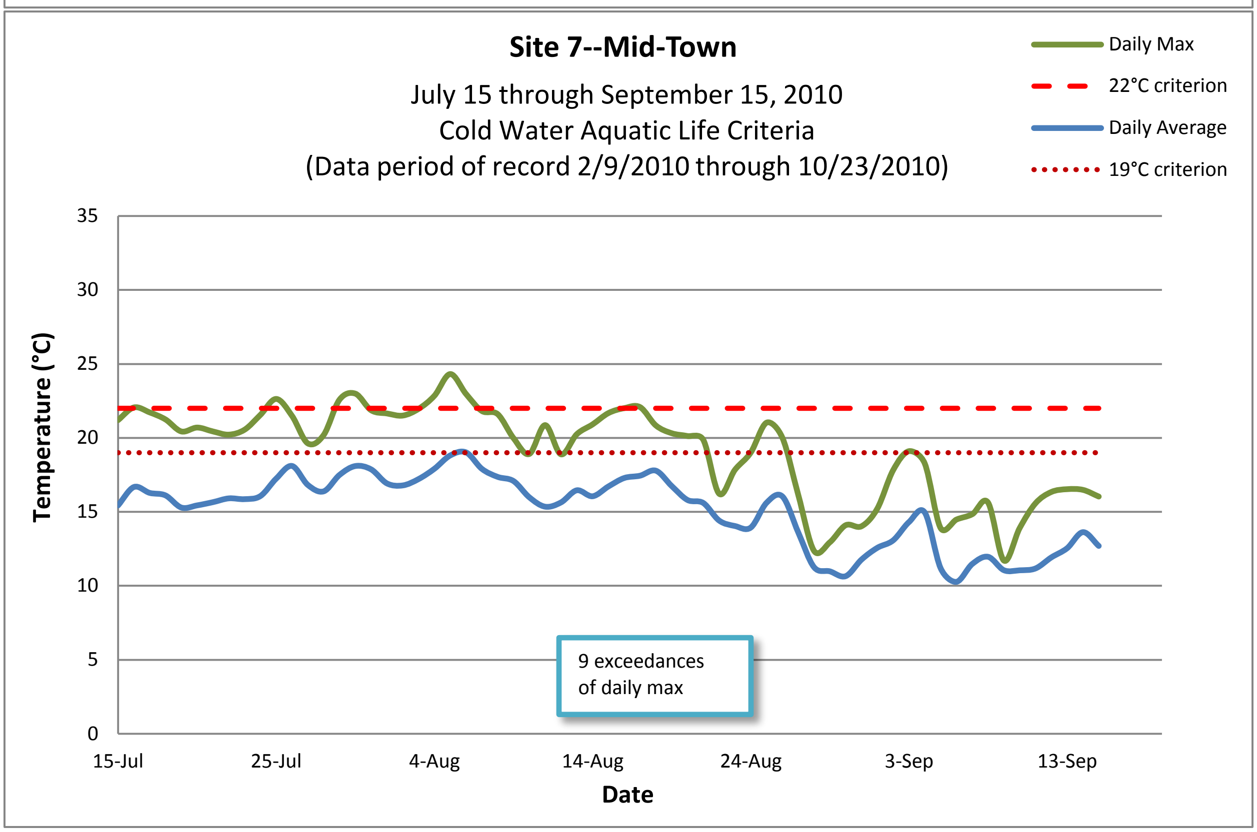
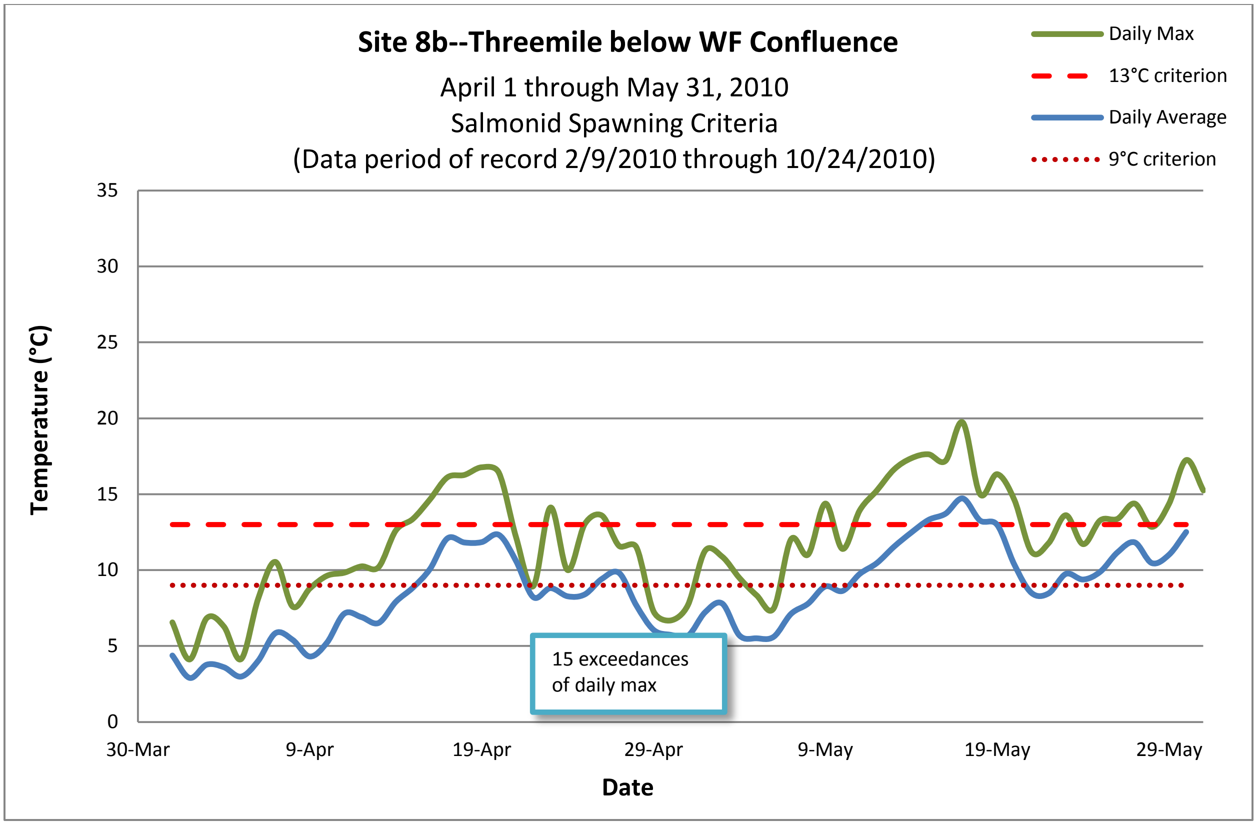
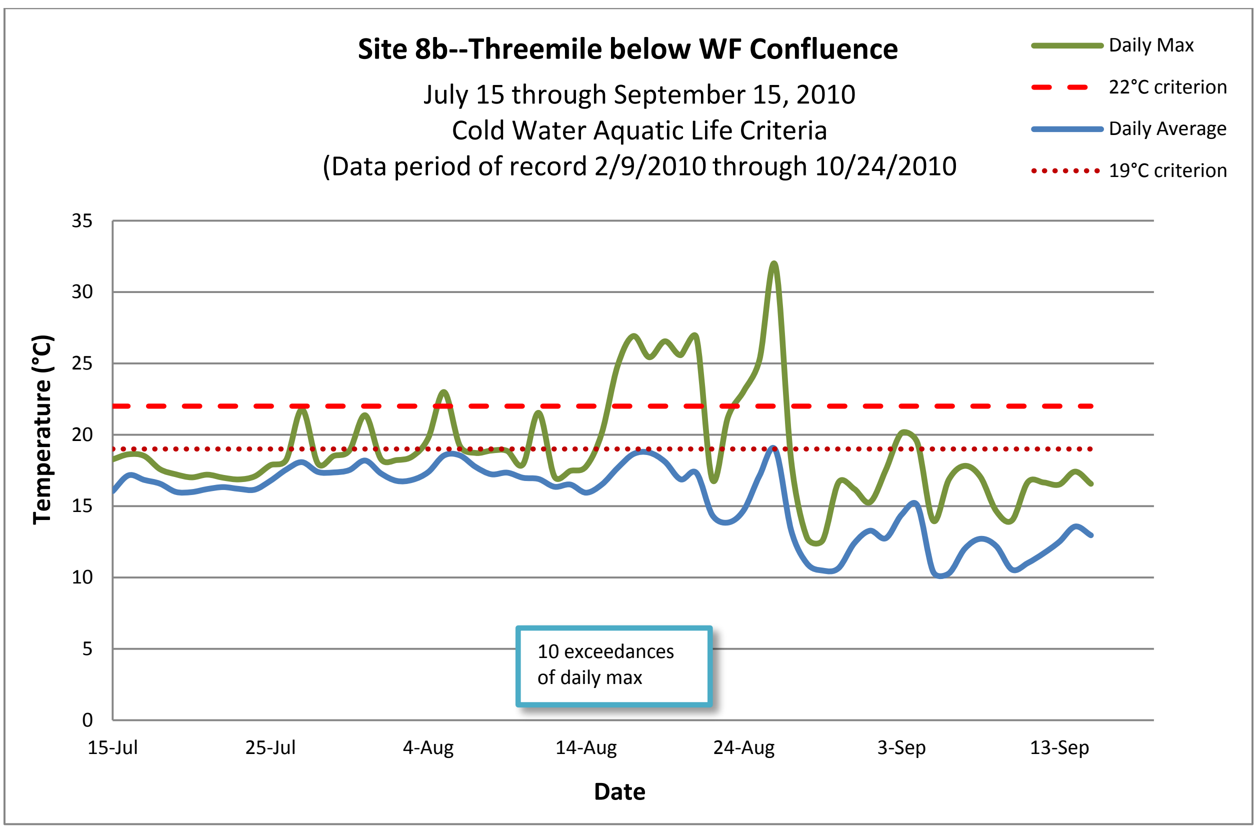
15-Jul
25-Jul
4-Aug
14-Aug
24-Aug
3-Sep
13-Sep
Date
10 exceedances of daily max


Site 7--Mid-Town
April 1 through May 31, 2010
Salmonid Spawning Criteria
(Data period of record 2/9/2010 through 10/23/2010)
Daily Max
13°C criterion
Daily Average
9°C criterion
Temperature (°C)
35
30
25
20
15
10
5
0
17 exceedances of daily max
30-Mar
9-Apr
19-Apr
29-Apr
9-May
19-May
29-May
Date


Site 7--Mid-Town
July 15 through September 15, 2010
Cold Water Aquatic Life Criteria
(Data period of record 2/9/2010 through 10/23/2010)
Daily Max
22°C criterion
Daily Average
19°C criterion
Temperature (°C)
35
30
25
20
15
10
5
0
9 exceedances of daily max
15-Jul
25-Jul
4-Aug
14-Aug
24-Aug
3-Sep
13-Sep
Date


Site 8b--Threemile below WF Confluence
April 1 through May 31, 2010
Salmonid Spawning Criteria
(Data period of record 2/9/2010 through 10/24/2010)
Daily Max
13°C criterion
Daily Average
9°C criterion
Temperature (°C)
35
30
25
20
15
10
5
0
30-Mar
9-Apr
19-Apr
29-Apr
9-May
19-May
29-May
Date
15 exceedances of daily max


Site 8b--Threemile below WF Confluence
July 15 through September 15, 2010
Cold Water Aquatic Life Criteria
(Data period of record 2/9/2010 through 10/24/2010
Daily Max
22°C criterion
Daily Average
19°C criterion
Temperature (°C)
35
30
25
20
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4-Aug
14-Aug
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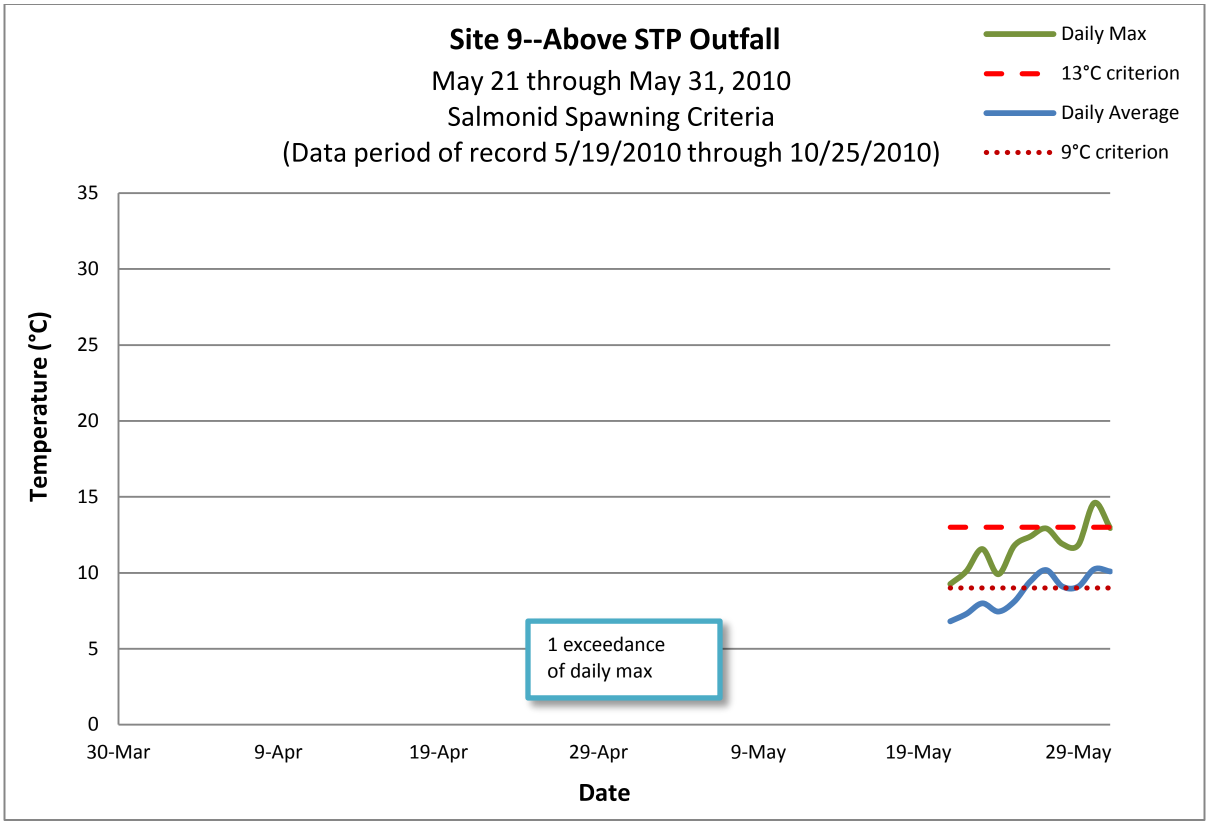
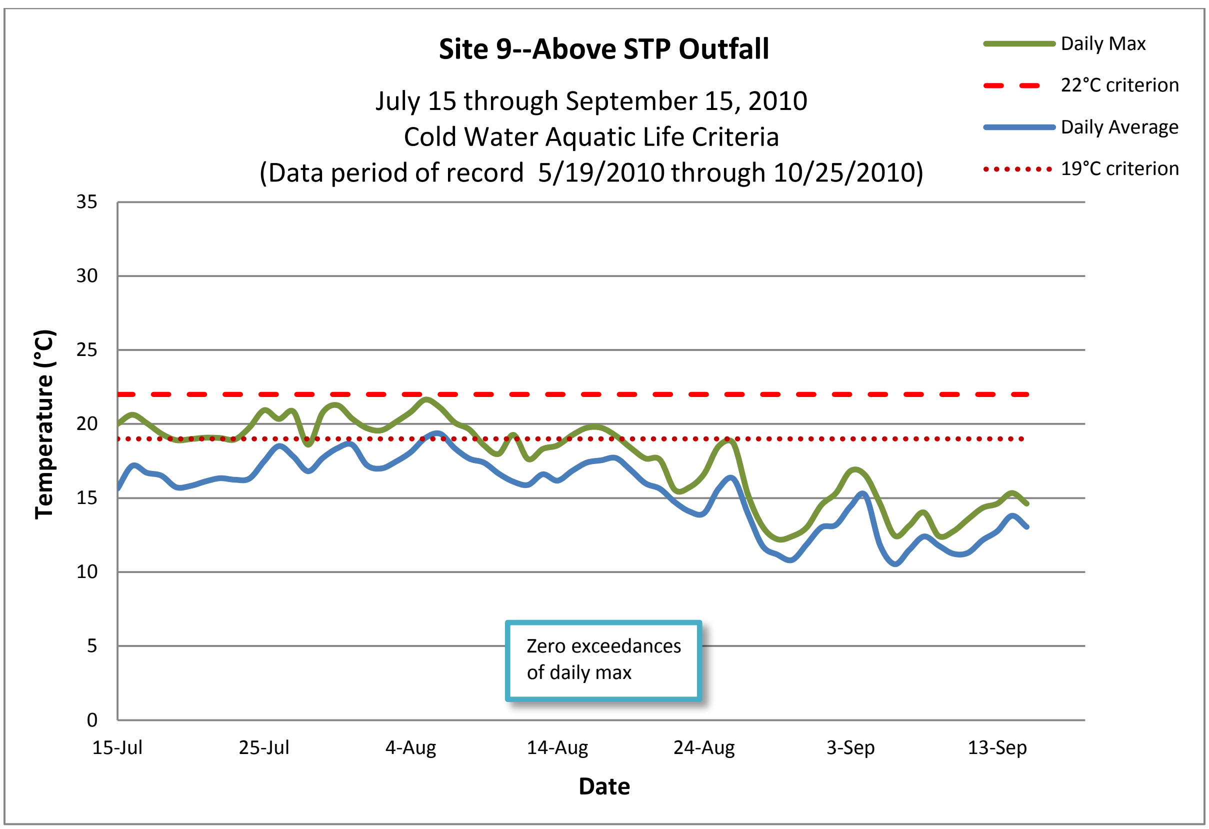
13-Sep
Date
10 exceedances of daily max


Site 9--Above STP Outfall
May 21 through May 31, 2010
Salmonid Spawning Criteria
(Data period of record 5/19/2010 through 10/25/2010)
Daily Max
13°C criterion
Daily Average
9°C criterion
Temperature (°C)
35
30
25
20
15
10
5
0
1 exceedance of daily max
30-Mar
9-Apr
19-Apr
29-Apr
9-May
19-May
29-May
Date


Site 9--Above STP Outfall
July 15 through September 15, 2010
Cold Water Aquatic Life Criteria
(Data period of record 5/19/2010 through 10/25/2010)
Daily Max
22°C criterion
Daily Average
19°C criterion
Temperature (°C)
35
30
25
20
15
10
5
0
Zero exceedances of daily max
15-Jul
25-Jul
4-Aug
14-Aug
24-Aug
3-Sep
13-Sep
Date