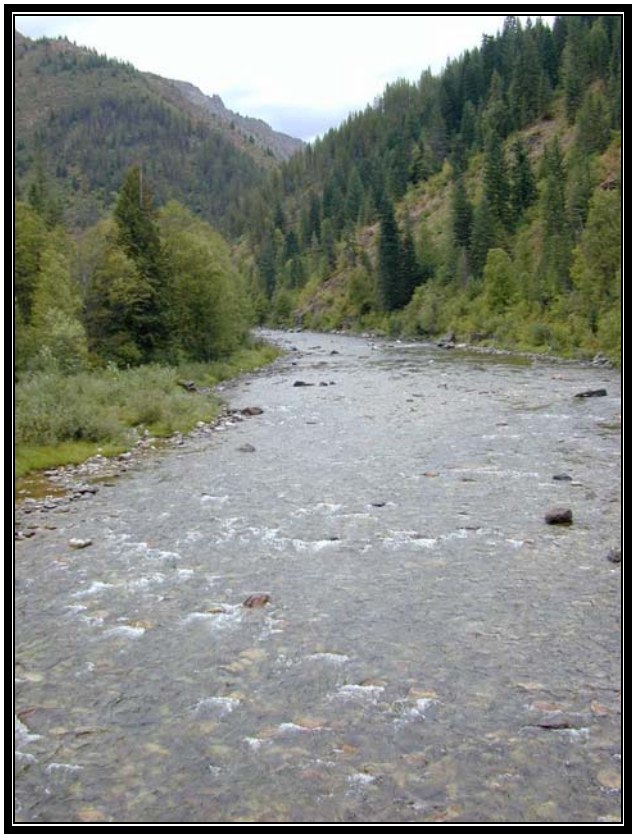
Upper North Fork Clearwater River Subbasin Assessment and Total Maximum Daily Loads



Department of Environmental Quality
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Prepared by:

Lewiston Regional Office
Department of Environmental Quality
1118 F Street
Lewiston, Idaho 83501

Executive Summary

The federal Clean Water Act (CWA) requires that states and tribes restore and maintain the chemical, physical, and biological integrity of the nation's waters. States and tribes, pursuant to Section 303 of the CWA, are to adopt water quality standards necessary to protect fish, shellfish, and wildlife while providing for recreation in and on the waters whenever possible. Section 303(d) of the CWA establishes requirements for states and tribes to identify and prioritize water bodies that are water quality limited (i.e., water bodies that do not meet water quality standards). States and tribes must periodically publish a priority list of impaired waters, currently every two years. For waters identified on this list, states and tribes must develop a total maximum daily load (TMDL) for the pollutants, set at a level to achieve water quality standards. This document addresses the water bodies in the Upper North Fork Clearwater River Subbasin that have been placed on what is known as the "303(d) list."

This subbasin assessment and TMDL analysis has been developed to comply with Idaho's TMDL schedule. This assessment describes the physical, biological, and cultural setting; water quality status; pollutant sources; and recent pollution control actions in the Upper North Fork Clearwater River Subbasin located in north-central Idaho. The first part of this document, the subbasin assessment, is an important first step in leading to the TMDL. The starting point for this assessment was Idaho's 1998 303(d) list of water quality limited water bodies. Nineteen segments of the Upper North Fork Clearwater River Subbasin were listed on this list. The subbasin assessment portion of this document examines the current status of 303(d) listed waters, and defines the extent of impairment and causes of water quality limitation throughout the subbasin. The loading analysis quantifies pollutant sources and allocates responsibility for load reductions needed to return listed waters to a condition of meeting water quality standards.

Subbasin at a Glance

	Water Quality at a Glance
Hydrologic Unit Code	17060307 Subbasin (Upper North Fork Clearwater River)
Subbasin Area	1,294 Square Miles (828,000 Acres)
303(d) Listed Water Bodies	Sneak Creek, Tumble Creek, Orogrande Creek, Tamarack Creek, Sylvan Creek, Hem Creek, Middle Creek, Marten Creek, Gravey Creek, China Creek, Sugar Creek, Swamp Creek, Osier Creek, Laundry Creek, Deception Gulch, Cold Springs Creek, Cool Creek, Grizzly Creek, Cougar Creek
Beneficial Uses Affected	Cold Water Aquatic Life, Salmonid Spawning (Federal Bull Trout Protection)
Pollutants of Concern	Sediment and Temperature as Non-Point Sources (No Point Source Pollutants)
Land Uses	Forestry, Roads, Recreation

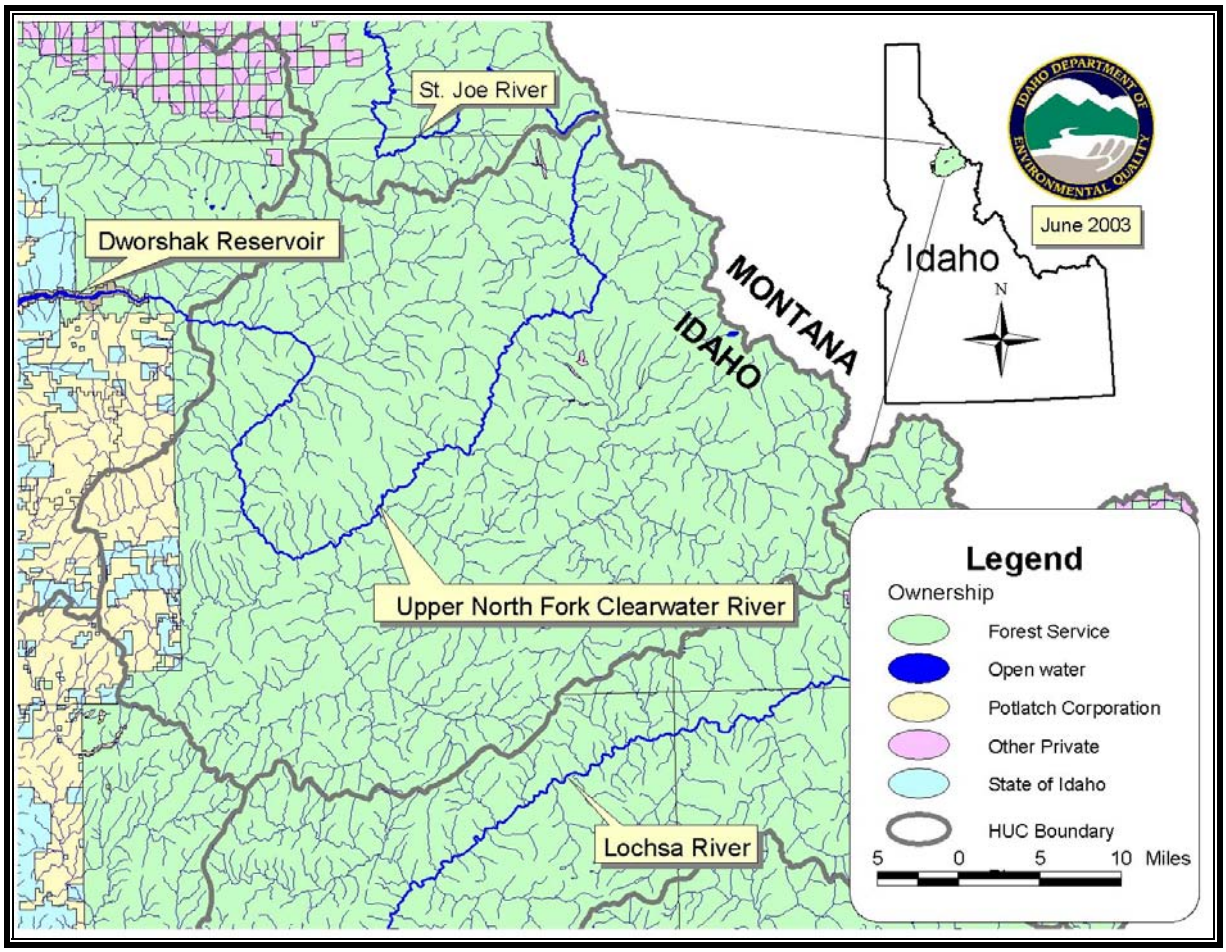

Figure A. Location in Idaho and Ownership of the Upper North Clearwater River Subbasin

The subbasin assessment evaluates the occurrence and effects of pollutants in each of the 303(d) listed water bodies, both in the context of the subbasin and with respect to the water quality of the individual streams. The Department of Environmental Quality *1996 Water Body Assessment Guidance* (WBAG) (DEQ 1996) is the primary tool used to assist in the evaluation of water quality. Water temperature is evaluated using results from continuous temperature recording stations established by the Clearwater National Forest. Such data are available for all of the 303(d) listed streams in this subbasin except Tumble, Sugar, and Marten Creeks. Water temperature is evaluated against the appropriate federal or state standard, depending on federal designation for bull trout protection, presence of cutthroat trout, presence of rainbow trout, and presence of brook trout. Sediment is evaluated using standardized data sets and procedures within the WBAG to determine whether beneficial uses are being supported. The designated beneficial uses for all the listed water bodies are cold water aquatic life and salmonid spawning. Finally, the results of the specific procedural analyses for both temperature and sediment are weighed against other data and information about the subbasin and a conclusion is reached whether or not a water body is impaired and, if so, by which pollutant.

Table A. 303(d) listed water bodies in the Upper North Fork Clearwater River Subbasin.

Stream Name	Boundaries[1]	WQL Seg. No.[2]	Channel Type[3]	Stream Miles	Listed Pollutant[4]
Sneak Creek	HW to NF Clearwater River	5178	B	3.5	Channel Stability
Tumble Creek	HW to Washington Creek	5200	B	4.6	Sed
Orogrande Creek	HW to NF Clearwater River	3215	B	19.5	Sed
Tamarack Creek	HW to Orogrande Creek	5193	B	3.9	Sed
Sylvan Creek	HW to French Creek	5192	B	4.3	Sed
Hem Creek	HW to Sylvan Creek	5093	B	5.0	Sed
Middle Creek	HW to Weitas Creek	5123	B	13.3	Sed
Marten Creek	HW to Gravey Creek	5119	B	4.5	Sed
Gravey Creek	HW to Cayuse Creek	3229	A	9.0	Sed
China Creek	HW to Osier Creek	5040	A	4.9	Sed
Sugar Creek	HW to Swamp Creek	5189	B	4.0	Sed
Swamp Creek	HW to Osier Creek	5190	B	5.4	Sed
Osier Creek	HW to Moose Creek	3225	A&B	8.1	Sed, Temp
Laundry Creek	HW to Osier Creek	5104	A	4.4	Sed
Deception Gulch	HW to NF Clearwater River	5059	B	4.7	Sed
Cold Springs Creek	HW to NF Clearwater River	5045	A	4.8	Sed
Cool Creek	HW to Cold Springs Creek	5047	A	3.3	Sed
Grizzly Creek	HW to Quartz Creek	5088	A	4.5	Sed
Cougar Creek	HW to Quartz Creek	5049	A	3.7	Sed

[1] HW = Headwaters, NF = North Fork
[2]WQL Seq No. = Water Quality Limited Segment Number
[3]A and B are Rosgen channel types (Rosgen 1994)
[4]Sed=Sediment; Temp=Temperature

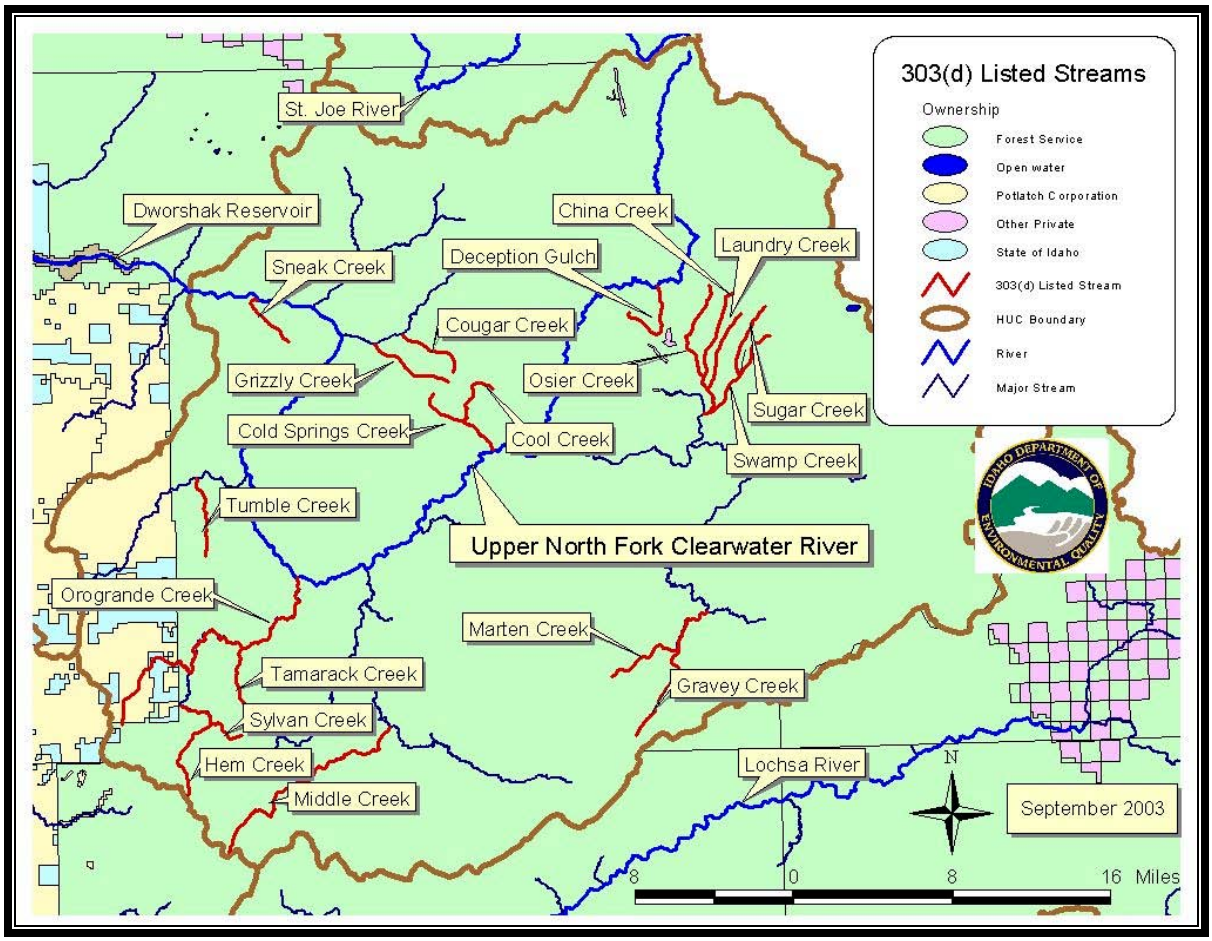

Figure B. 303(d) Listed Streams of the Upper North Fork Clearwater River Subbasin

Eleven of the water bodies (Cold Springs and Cool, Cougar, Grizzly, Gravey, Marten, Middle, Laundry, Osier, Sugar, and Swamp Creeks) are federally protected as bull trout watersheds. Based on the available data, none of these water bodies meets the federal bull trout water temperature standard. Orogrande, Tamarack, Hem, Sylvan, Sneak, and China Creeks have populations of cutthroat trout but do not meet the state's water temperature standard for this species. Hem Creek, however, is in near pristine condition and it is concluded that the temperature regime in this creek is natural. Deception Gulch has rainbow trout but does not meet the state's water temperature standard for rainbow trout. Tumble Creek has a population of brook trout and it is concluded that the state's water temperature standard for salmonid spawning is being met during the brook trout spawning season. Temperature TMDLs are written for every 303(d) listed water body except Hem Creek and Tumble Creek.

Key Findings

All the water bodies are 303(d) listed for sediment (only Osier Creek is listed for temperature). However, analysis of the data indicates that only one of the listed water

bodies, Deception Gulch, is water quality limited as the result of sediment. Except for Deception Gulch, we recommend that all the water bodies be removed from the 303(d) list for sediment. A sediment TMDL is written for Deception Gulch.

Temperature TMDLs are developed for 18 water bodies using percent stream canopy closure increase by stream segment as the target, based on the appropriate water temperature standard as the load capacity. The TMDL section discusses how the percent canopy closure target relates to heat as a pollutant. In order to meet the stream temperature targets in the various water bodies, 75-100 percent of the stream miles require increased stream canopy closure.

A sediment TMDL is developed for Deception Gulch based on sediment mass balance. Most of the excess sediment is coming from roads on high hazard landtypes and mass failures associated with these roads – the total required load reduction is assigned to these nonpoint sources. A sediment target is set at 390 tons/year, while total loading to the stream is on the order of 770 tons/year. The load reduction target is 380 tons/year, or about a 50 percent sediment loading reduction. To achieve this target, we recommend that the Clearwater National Forest obliterate approximately 50 percent of the roads in the watershed, especially those on high hazard landtypes.

Table B. Summary of conclusions and recommended actions.

Stream Name	Boundaries[1]	Listed Pollutant	TMDLs Completed	Recommend-ations
China Creek	HW to Osier Creek	Sediment	Temperature	Delist for Sediment
Cold Springs Creek	HW to NF Clearwater River	Sediment	Temperature	Delist for Sediment
Cool Creek	HW to Cold Springs Creek	Sediment	Temperature	Delist for Sediment
Cougar Creek	HW to Quartz Creek	Sediment	Temperature	Delist for Sediment
Deception Gulch	HW to NF Clearwater River	Sediment	Temperature Sediment	None
Gravey Creek	HW to Cayuse Creek	Sediment	Temperature	Delist for Sediment
Grizzly Creek	HW to Quartz Creek	Sediment	Temperature	Delist for Sediment
Hem Creek	HW to Sylvan Creek	Sediment	None	Delist for Sediment
Laundry Creek	HW to Osier Creek	Sediment	Temperature	Delist for Sediment
Marten Creek	HW to Gravey Creek	Sediment	Temperature	Delist for Sediment
Middle Creek	HW to Weitas Creek	Sediment	Temperature	Delist for Sediment
Upper Orogrande Creek	HW to French Creek	Sediment	Temperature	Delist for Sediment
Lower Orogrande Creek	French Creek to NF Clearwater River	Sediment	Temperature	Delist for Sediment
Osier Creek	HW to Moose Creek	Sediment Temperature	Temperature	Delist for Sediment
Sneak Creek	HW to NF Clearwater River	Channel Stability	Temperature	Delist for Channel Stability
Sugar Creek	HW to Swamp Creek	Sediment	Temperature	Delist for Sediment
Swamp Creek	HW to Osier Creek	Sediment	Temperature	Delist for Sediment
Sylvan Creek	HW to French Creek	Sediment	Temperature	Delist for Sediment
Tamarack Creek	HW to Orogrande Creek	Sediment	Temperature	Delist for Sediment
Tumble Creek	HW to Washington Creek	Sediment	None	Delist for Sediment

[1] HW = Headwaters, NF = North Fork

Appendix 1 presents a table that correlates the 303(d) listed streams addressed in this TMDL to the "assessment units" being developed by the state and the U.S. Environmental Protection Agency for the purposes of tracking water quality status.

6. Total Maximum Daily Loads

A TMDL prescribes an upper limit on discharge of a pollutant from all sources so as to assure water quality standards are met. It further allocates this load capacity among the various sources of the pollutant. Pollutant sources fall into two broad classes: point sources, each of which receives a wasteload allocation; and nonpoint sources, which receive a load allocation. Natural background, when present, is considered part of the load allocation, but is often broken out on its own because it represents a part of the load not subject to control. Because of uncertainties regarding quantification of loads and the relation of specific loads to attainment of water quality standards, the rules regarding TMDLs (Water Quality Planning and Management, 40 CFR 130) require a margin of safety be a part of the TMDL.

Practically, the margin of safety is a reduction in the load capacity that is available for allocation to pollutant sources. The natural background load is also effectively a reduction in the load capacity available for allocation to humanmade pollutant sources. This can be summarized symbolically as the equation: Load Capacity = (Margin of Safety) + (Natural Background) + (Load Allocations) + (Wasteload Allocations) = TMDL. The equation is written in this order because it represents the logical order in which a loading analysis is conducted. First the load capacity is determined. Then the load capacity is broken down into its components: the necessary margin of safety is determined and subtracted; then natural background, if relevant, is quantified and subtracted; and then the remainder is allocated among pollutant sources. When the breakdown and allocation is completed we have a TMDL, which must equal the load capacity.

Another step in a loading analysis is the quantification of current pollutant loads by source. This allows the specification of load reductions as percentages from current conditions, considers equities in load reduction responsibility, and is necessary in order for pollutant trading to occur. Also a required part of the loading analysis is that the load capacity be based on critical conditions – the conditions when water quality standards are most likely to be violated. If protective under critical conditions, a TMDL will be more than protective under other conditions. Because both load capacity and pollutant source loads vary, and not necessarily in concert, determination of critical conditions can be more complicated than it may appear on the surface.

A load is fundamentally a quantity of a pollutant discharged over some period of time and is the product of concentration and flow. Due to the diverse nature of various pollutants, and the difficulty of strictly dealing with loads, the federal rules allow for “other appropriate measures” to be used when necessary. These “other measures” must still be quantifiable, and relate to water quality standards, but they allow flexibility to deal with pollutant loading in more practical and tangible ways. The rules also recognize the particular difficulty of quantifying nonpoint loads and allow “gross allotment” as a load allocation where available data or appropriate predictive techniques limit more accurate estimates. For certain pollutants whose effects are long term, such as sediment and nutrients, USEPA allows for seasonal or annual loads.

Chapter 5 identifies 18 water bodies in the UNFRCS that are water quality limited. Of the 303(d) listed water bodies, only Hem and Tumble Creeks are identified as fully supporting their beneficial uses. Each of the other 18 water bodies must have a TMDL developed for its particular pollutant. All of the 18 water bodies require a TMDL for temperature, and Deception Gulch also requires a TMDL for sediment. A TMDL includes targets for the pollutant being reduced, a loading analyses for each pollutant in each water body, and a load allocation.

6.1 Temperature TMDLs

Eighteen water bodies were identified in Chapter 5 (Table 10) as water quality limited due to temperature.

Heat Loading

Generally, we conclude that increased temperature in the UNFCRS is primarily the result of increased heat loading from solar radiation to the water body as a result of removal of riparian shading. Logging and road building are the two primary anthropogenic causes of shade reduction over the last half century. Mining in the late 19th and early 20th centuries undoubtedly had some effects. In some cases, lack of shade beyond that which will maintain stream temperatures within the applicable standard is natural, and/or may be the result of forest fires. In addition, solar radiation and resultant heat loading may have been increased by widening of the stream channel (an increase in the width-to-depth ratio). In most cases, this would have been the result of deterioration and/or removal of the streamside vegetation and its ability to hold the stream in a more confined and sinuous channel. In a few cases, stream widening could have resulted from sediment accumulation and stream aggradation.

For the sake of the discussions to follow, we assume that heat loading is directly related to stream temperature. We discuss stream temperature in degrees centigrade and heat loading in watts per square meter. Increasing net heat loading to the surface of a stream segment increases the stream temperature. Heat loading to a stream surface, however, has both temporal and spatial variability within the 18 water bodies for which TMDLs are being developed. Predicting stream temperature at any location and time in a water body requires an understanding of how heat loading is distributed through space and time. In fact, for the purposes of a TMDL, we are less interested in knowing the stream temperature at any given location and time, and more interested in knowing that heat loading is such that stream temperatures throughout a water body are not exceeding water quality standards at any time.

In terms of timing, heat loading in the UNFCRS is at its greatest during late July and early August and is reflected in the higher stream temperatures at this time (see temperature plots in Appendix 3, which also show the temperature standards). July and August are the critical months for temperature exceedances. Water temperatures begin to increase through May and June, but are consistently at their peaks during late July and early August. Water temperatures decrease rapidly after the first wet cold fronts of late August or early September. We analyze heat loading and stream temperature for the critical period of late July through early August, and assume that if stream temperatures are in compliance with the

water quality standards during this period, they will be in compliance throughout the rest of the year.

The stream temperature data in Appendix 3 show the stream temperatures for one location in a water body. These data are usually collected near the mouth where temperatures are likely to be the highest. However, since water quality standards apply throughout a water body, it is necessary to understand heat loading distribution throughout a water body. Solar insolation at some reference elevation over the whole of a water body can be assumed to be constant at any given moment; that is, there is no spatial variation to solar insolation at the scale of a water body. Spatial variation of heat loading is largely a function of how solar insolation interacts with a stream and its immediate surroundings.

The six modes of heat transfer important in stream temperature analyses are (Adams and Sullivan 1990):

Solar radiation (short wave)
Radiation between the stream and the adjacent vegetation and sky (long wave)
Evaporation from the stream
Convection between the stream and the air
Conduction between the stream and the streambed
Ground water and tributary inflow to the stream

There are process-based stream temperature models such as *Heat Source* (Boyd 1996) or SSTEMP (Theurer et al. 1984; Bartholow 1997) for analyzing stream temperatures by quantifying the heat transfer processes. However, these models tend to require extensive inputs, many of which are not easily available or reliable for remote, mountain streams (See Appendix 13 for lists of variables required by SSTEMP and *Heat Source*). The relative importance of each mode of heat transfer varies according to the specific environmental conditions present from reach to reach.

Analyses have established that the primary environmental factors affecting stream temperature are local air temperature, stream depth, ground water inflow, and the extent to which riparian canopy and topography shade the stream (Sullivan and Adams 1990; Theurer et al. 1984; Beschta and Weatherred 1984). In forested environments, stream shading and local air temperature are widely recognized as the major environmental determinants of stream temperature, accounting for up to 90 percent of stream temperature variability (Brown 1971; IDL 2000). Of these two primary factors, canopy cover or shade is the one most modified by human use. Ideally, one would like a stream temperature prediction model based on easily measurable and understandable parameters, but one that could also be translated to describe the physics of the heat loading process.

The Idaho Forest Practices Act Coordinating Committee has developed an empirical model (the CWE model) of stream temperature based on continuous water temperature measurements, elevation, and percent canopy cover data collected throughout north Idaho:

$$MWMT = 29.1 - 0.00262\ E - 0.0849\ C$$

where MWMT = maximum weekly maximum temperature (^{o}C)
E = stream reach elevation (feet)
C = riparian canopy cover (%)

This model utilizes percent stream canopy shading and elevation to predict the maximum weekly mean maximum stream temperature (the MWMT of the hottest week of the year) for forestlands. Elevation and percent shading are easy to acquire: elevation from topographic maps or digital elevation models and percent shading from aerial photography correlated to canopy cover collected using a densiometer. In mountainous terrain such as the UNFCRS, increases in elevation result in reductions in ambient air temperature, thus reducing heat loading in a predictable manner. In addition, increases in shading decrease heat loading by reducing solar insolation impinging on the water surface and by lowering the local air temperature under the canopy. The utility of the CWE model is that it can be solved for percent canopy cover, the one major environmental factor that can be managed to affect stream temperature. It satisfies the need for ease of use and for being reasonable and understandable.

However, since the CWE model is not process based, it does not result in the type of numbers that USEPA prefers for TMDL loading analyses. Further, USEPA has expressed concern as to the accuracy of the CWE temperature predictions. To answer the latter point, DEQ contracted with Western Watershed Analysts of Lewiston, Idaho, to determine the accuracy by comparing the CWE model with other stream temperature models. The report of their short study, *Comparison Between Stream Temperature Prediction Models: SSTEMP, Heat Source, and Idaho Cumulative Watershed Effects,* appears as Appendix 13. Their results, however limited, show that CWE is a better predictor of stream temperature than either SSTEMP or *Heat Source* – the root mean square (RMS) error of the CWE prediction is about 1 degree centigrade, while the RMS errors for SSTEMP and *Heat Source* are between 1 and 2 degrees centigrade. Further analyses would be needed to bring these results up to statistical significance.

To address the concern regarding conversion of CWE results to heat loading per unit time, we take an approach of separating the effects of insolation from the other heat flux processes. The two primary environmental variables that determine stream temperature are air temperature and stream shading. Air temperature enters into the heat transfer relationships for many of the heat transfer processes associated with streams (e.g., convection, evaporation, long wave radiation), and is the primary driver of average water temperature. The CWE model accounts for the variation in air temperature in the elevation variable. Stream shading affects the amount of solar radiation impinging on the water surface and is the primary driver of the diurnal fluctuations in water temperature. The CWE results are, in effect, the change in heat loading associated with changes in stream shading.

In order to quantify heat loading to a stream surface due to insolation, we used SSTEMP-(Bartholow 1997) derived data for August 1 (median hottest day) for insolation rates and calculated the heat loading for different levels of percent shade. The amounts of solar

radiation incident on the stream and its immediate surroundings at different shadings for two stream orientations are presented in Table 11. Fixed conditions used in SSTEMP to develop the solar radiation numbers are 47 degrees latitude, 5,000 feet elevation, a stream width of 10 feet, a buffer height of 60 feet, a buffer width of 30 feet, and topographic shade of 30 degrees. These are generalized standard conditions for streams of the UNFCRS. Under these conditions, incident solar radiation decreases regularly by 21 watts per square meter for every 10 percent increase in canopy density for north-south oriented streams and 26 watts per square meter for east-west oriented streams.

Table 11. Average daily solar radiation incident on a stream related to canopy closure.

	Stream Orientation	
Canopy Density (percent)	**North-South (watts per square meter)**	**East-West (watts per square meter)**
0	226	274
10	205	248
20	185	223
30	164	197
40	143	172
50	122	146
60	101	120
70	80	95
80	59	69
90	38	43
100	17	18

These heat flux amounts do not represent the total heat flux, but just the heat flux directly from the sun (insolation). This is the portion of heat flux this TMDL addresses because it is readily increased by human activity in reducing stream shading and can be managed to decrease stream temperatures. Insolation flux rates decrease linearly with increases in shading (Table 11). Considering the CWE model above, the decrease in stream temperature due to increased percent canopy closure at a given elevation is also linear. Assuming the CWE model is correct, as verified by the study cited above comparing the three models, the linear decrease in temperature implies that the change in heat flux is constant and directly related to shading. These results indicate that the total heat flux is linearly related to the insolation rates, such that the percentage heat reduction required by the TMDL will be the same whether its calculated from total heat flux, or simply that associated with insolation rates. In this TMDL, we use the CWE model with percent canopy closure as the dependent variable directly related to insolation rates.

In summary, we approach heat loading and stream temperature by addressing the primary environmental factors of concern. We address the temporal and spatial variability of heat

loading. Within that framework, we address percent canopy closure as it varies in time and space as the major environmental variable affecting heat loading of any given stream reach. And, we quantify the changes in heat loading as they occur throughout the water bodies as the result of changes in stream shading.

Heat Loading Capacity

All 18 of the water bodies have designated beneficial uses of cold water aquatic life and salmonid spawning. In addition, the USEPA has designated 11 of the water bodies as protected for bull trout, and these must meet the federally promulgated bull trout temperature standard of 10 ^{o}C (50 ^{o}F) MWMT. The remaining creeks, upper Orogrande, lower Orogrande, Sylvan, Tamarack, Sneak, Deception, and China, must meet the applicable standards presented in Table 5 (i.e., a daily average water temperature no greater than 9 ^{o}C [48.2 ^{o}F] and a daily maximum water temperature no greater than 13 ^{o}C [55.4^{o}F] for the time periods when salmonids are spawning). Using a conversion factor developed by Sugden et al. (1998) for northern Idaho and western Montana, a 9 ^{o}C (48.2 ^{o}F) daily average temperature is equivalent to a 9.7 ^{o}C (49.5 ^{o}F) MWMT, such that the federal bull trout temperature standard and Idaho's salmonid standard are roughly equivalent in terms of mean weekly maximum temperatures. We assume they are equivalent and use 10 ^{o}C (50 ^{o}F) MWMT for both standards in our calculations below.

The time periods for which the standards apply are dependent on the salmonid species present in the particular water body. The numeric standards from the Idaho administrative rules (IDAPA 58.01.02.250.02.e.ii) for the applicable time periods are the loading capacities for the upper Orogrande, lower Orogrande, Sylvan, Tamarack, Sneak, Deception, and China water bodies. The remaining 11 water bodies (Cold Springs, Cool, Cougar, Grizzly, Middle, Gravey, Marten, Osier, Laundry, Sugar, and Swamp Creeks) must meet the USEPA promulgated 10 ^{o}C (50 ^{o}F) MWMT for the months of June through September for bull trout. The 10 ^{o}C (50 ^{o}F) MWMT numeric standard from 40 CFR Part 131.33(a) is the loading capacity for the water bodies protected for bull trout.

The heat loading capacity applicable to the UNFCRS in relation to state and federal temperature standards is primarily a consideration during the months of July and August when heat loading is the greatest. Because of the regular seasonal progression in stream temperature, if we target a stream's annual peak in temperature, and bring the temperature down to within criteria limits, then we can safely assume criteria will also be met at cooler times of the year. This is the basis of using metrics like MWMT for criteria and makes CWE particularly relevant to the problem at hand.

The specifics for each 303(d) listed water body are discussed in their respective parts of Chapter 5 and shown graphically on charts in Appendix 3. The charts in Appendix 3 clearly show the time periods when, and degrees to which, the stream temperatures exceed the state and federal water quality standards. The heat loading capacity is exceeded when stream temperatures exceed the temperature standards, but we do not define this capacity in terms of watts per meter squared. The data shown are for one point in the water body; that point where the temperature data are collected. We think it is more appropriate to understand how

the heat loading is distributed throughout the water body and use percent shading as a surrogate measure to develop this understanding.

Heat Loading Capacity Surrogate Measure

In order to understand how heat loading capacity is distributed throughout a water body, we use the CWE temperature model developed for north Idaho under the auspices of the Idaho FPA (IDL 2000). The modeled relationship was developed from data collected in north Idaho whereby the maximum weekly mean maximum stream temperature (the maximum MWMT of the year) is predicted by elevation and percent shading. The CWE model is an empirical, reach-based model that predicts the amount of stream canopy shading required in a given 200-foot elevational range to be able to maintain a given mean weekly maximum stream temperature (usually a given temperature standard such as 10 ^{o}C [50 ^{o}F] MWMT). Each elevational reach has a predicted shading requirement, and shade requirements increase with decreasing elevation as would be expected to account for increasing air temperatures. The model assumes that water temperature has been protected upstream. It accounts for the two primary environmental factors affecting stream temperature – local air temperature as it varies by elevation and microclimatic modification by the canopy and shade of the stream surface by the riparian canopy.

Using the CWE model, we convert the heat loading capacity in terms of stream temperature to a surrogate measure of percent canopy closure. Table 12 shows the percent canopy closure required to maintain a heat loading capacity to attain the temperature standard of 10 ^{o}C MWMT by 200-foot elevation reaches. This is the shading required to maintain stream temperatures during the period of the year with highest ambient air temperatures (late July and early August). Thus, the CWE model predicts the percent canopy closure required at a given elevation to maintain stream temperatures within the water quality standards. The heat loading capacity in terms of the surrogate measure of required percent canopy closure to maintain stream temperatures is distributed throughout the water body, depending on the elevation of the reach.

Using the CWE process, we analyzed the current shade condition of 860 stream reaches in the 18 watersheds for which TMDLs are being developed and compared the results to the surrogate loading capacities (percent stream canopy closure) in Table 12. A stream reach break was defined by a maximum of 200 feet elevation difference from bottom to top (based on the elevation zones in Table 12), an intersection of two perennial streams, or a major change in canopy closure. All of the perennial tributaries were analyzed as contributing to the heat loading process. While we are aware of research by Zwieniecki and Newton (1999) and others indicating that downstream temperature is essentially independent of upstream conditions as long as the stream has sufficient time to equilibrate, we do not proceed with this level of analysis, but rely exclusively on the CWE predictions and their consequent processes under Idaho's FPA.

Table 12. The heat loading capacities for the UNFCRS in terms of CWE-derived percent stream canopy closure by elevation and associated insolation rates for the 10 ^{o}C MWMT code and regulation defined heat loading capacity.

Elevation Zones	Percent Stream Canopy Closure	Insolation Rate North-South Oriented Stream	Insolation Rate East-West Oriented Stream
(feet)	(%)	(watts/m^2)	(watts/m^2)
5,400-5,599	58	105	125
5,200-5,399	64	93	110
5,000-5,199	71	78	92
4,800-4,999	77	65	77
4,600-4,799	83	53	61
4,400-4,599	89	40	46
4,200-4,399	95	28	31
4,000-4,199	100	17	18
3,800-3,999	100 *	**	**
3,600-3,799	100 *	**	**
3,400-3,599	100 *	**	**
3,200-3,399	100 *	**	**
3,000-3,199	100 *	**	**
2,800-2,999	100 *	**	**
2,600-2,799	100 *	**	**
2,400-2,599	100 *	**	**
2,200-2,399	100 *	**	**
2,000-2,199	100 *	**	**
1,800-1,999	100 *	**	**
1,600-1,799	100 *	**	**
1,400-1,599	100 *	**	**
1,200-1,399	100 *	**	**
1,000-1,199	100 *	**	**
800-999	100 *	**	**

* Below about 4,000 feet elevation, the CWE model predicts a need for greater than 100% canopy closure to protect a maximum stream temperature of 10 ^{o}C MWMT. Since this is not possible, 100% canopy closure is set as the surrogate heat loading capacity. In some cases, 100% canopy closure may not be achievable because of the canopy type, in which case it should be noted in the implementation plan.

** SSTEMP predicts insolation rates of 17 or 18 watts per square meter, depending on aspect, for 100% canopy closure

In summary, the heat loading capacity is defined here for the critical time of the year and for various reaches throughout the water body. The heat loading capacity is 10 ^{o}C MWMT as defined by the water quality standards, but is measured by a surrogate environmental variable, percent canopy closure X elevation. Using SSTEMP, we identify the heat loading associated with solar insolation as that portion of heat loading affected by stream shading, the environmental variable that can be managed for heat flux control. We show that the heat loading due to solar insolation is distributed over the water body in a predictable manner and that, further, heat loading capacities for different stream reaches can be translated to surrogate percent canopy cover targets.

Excess Heat Load

Excess heat loading is the heat increase in net heat flux that causes temperatures at any given time and location to exceed the applicable water quality standards (loading capacity). While the excess heat loading is variable over time as a function of weather and spawning periods for the species in question, the data presented here are considered representative of the general pattern over time in the UNFCRS. As shown in Appendix 3 and discussed water body by water body in Chapter 5, 18 water bodies in the UNFCRS regularly exceed the applicable water quality temperature standards during July and August of every year. This exceedance extends into June and September for some water bodies and some years. Based on the data presented in this report, there is no particular reason to think that the years when data were collected are anomalous in relation to the long-term climate of the subbasin.

The spatial distribution of excess heat loading over a water body is more complicated, but largely predictable using the CWE model. The temperature data presented in Appendix 3 are collected near the mouths of the water bodies. They give some idea of the overall magnitude of excess heat loading to a water body, but provide little information about where in the water body heat is gained such that temperatures exceed the water quality standards.

Based on our analysis of water bodies in the UNFCRS, we conclude that the manageable part of any excess heat loading is the result of reduction of canopy shading over a water body. We use the CWE relationship to show the distribution of locations throughout the water body where excess heat is being gained. In addition, the CWE relationship shows the degree to which excess heat is gained based on the percent canopy closure lacking for each particular reach in relation to the percent canopy closure of the heat loading capacity.

Whereas in the Heat Loading section above we do not quantify the total heat loading distributed across the landscape as it results in ambient stream temperatures, we do quantify in general terms the portion of heat loading coming from solar insolation. We establish a framework for calculating the heat loading capacity for a given stream reach based on knowledge of the elevation, orientation, and existing percent canopy shading. From Table 12, one can identify the percent shading at a given elevation needed to protect the stream temperature. Within this framework, excess heat loading occurs during the critical time periods wherever existing percent canopy closure over a stream is less than that identified as needed to protect stream temperatures within the state's standards.

Excess Heat Load Allocation

The only known source of human-caused heat to increase the heat load to excess is increased insolation largely as a result of reduced shading over streams. Therefore, the excess heat load is grossly allocated to nonpoint sources. One hundred percent of the excess heat load is allocated to activities and processes that have reduced percent canopy closure over the streams. Primary among these activities and processes are roading, timber harvesting, mining, natural fires, and storm events. At many locations on the landscape these activities and processes have been intermixed. Because virtually all of the land is managed by the CNF, and they are implementing the federal Inland Native Fish Strategy (INFISH) (USFS 1995) to address excess heat loading regardless of original cause, we do not make any effort to allocate excess heat load to the various causes. In the case of upper Orogrande Creek, it is assumed that Potlatch Corporation and IDL will implement FPA standards and some site-specific BMPs to address excess heat load, also regardless of original cause.

The heat load reduction allocations presented are specific to the 303(d) listed water quality limited streams and are defined in terms of the temperature exceedances and heat capacity temperatures for each water body (Appendix 3). In those situations where the effects of heat loading from non-303(d) listed streams are contributing to water standard exceedances in a 303(d) listed water body, the load reduction allocation is assigned to the 303(d) listed water body, even though corrective action may be recommended further upstream. The assigned load reduction allocation has been distributed appropriately throughout the watersheds wherever stream shading is inadequate according to the CWE model.

Heat Load Reduction Targets

The heat load reduction targets are the state's water quality temperature standards for salmonid spawning for the most limiting salmonid species or the federally promulgated temperature standards for bull trout. The critical time period has been determined to be the months of July and August; therefore, the targets are set for those months. If the targets are attained during July and August, when water flows are low and air temperatures are high, it is assured the water quality temperature standards will be met throughout the rest of the year. For federally protected bull trout watersheds, the target shall be 10 ^{o}C (50 ^{o}F) MWMT during the months of July and August. For other streams that support cutthroat trout, the target shall be 9 ^{o}C (48.2 ^{o}F) mean daily temperature for the month of July. For water bodies that support only rainbow trout, the target shall be 9 ^{o}C (48.2 ^{o}F) mean daily temperature from July 1 through July 15.

Surrogate Water Temperature Targets

Stream temperature, per se, is of limited use in guiding activities that will reduce nonpoint source heat loading to a water body. Instead, for the UNFCRS temperature TMDLs, we have chosen to use a surrogate target as provided under USEPA regulations [40 CFR §130.2(I)]. The surrogate target we use is percent canopy closure by stream reach elevation. Stream shading is the most important controlling factor of heat loading in forested environments.

Stream reaches can be located on the ground and their canopy cover producing shade can be managed.

The surrogate loading capacities are the surrogate targets set for the temperature TMDLs. To develop the surrogate targets for the 18 temperature impaired streams, we converted the 10 ^{o}C MWMT loading capacity water quality standard to the percent canopy closure X elevation required to attain that target using the CWE relationship. The surrogate percent canopy closure targets are calculated for individual segments based on 200-foot elevational ranges. The insolation heat load targets are calculated for each elevational range and four classes of stream orientation – east/west, north/south, northeast/southwest, and northwest/southeast.

Based on the conclusions by Zwieniecki and Newton (1999) that downstream temperature is essentially independent of upstream conditions as long as the stream has sufficient time to equilibrate, we believe that a reach by reach allocation is appropriate. Stream temperatures continuously tend towards equilibration with their environment such that any extra cooling upstream from a given reach is unlikely to have much effect further down a stream network if temperature protection is not maintained. The conditions controlling stream temperatures are relatively local and should be controlled at a localized scale.

However, EPA has expressed concerns that the CWE model "is not a precise or accurate tool for predicting stream temperature response" and its use in setting shade targets "could result in on the ground reductions in shade below levels that are currently present, particularly at higher elevations in the watershed" (Psyk 2001). We have adopted EPA recommendations for setting percent canopy closure targets as follows:

- If existing percent canopy closure is less than what CWE predicts is necessary to achieve the state's water quality standards, then the CWE temperature model estimate of necessary percent canopy closure is set as the target.
- If the existing percent canopy closure is greater than what the CWE temperature model predicts is necessary to achieve the state's water quality standards, the target percent canopy closure is set at current percent canopy closure. This ensures that CWE derived estimations will not result in a reduction of shade below current levels in impaired water bodies.

Percent canopy closure surrogate targets are set for 303(d) listed water bodies on a watershed-wide basis. The water bodies for which targets are set are:

- Orogrande Creek watershed (Appendix 4)
  Includes upper Orogrande, lower Orogrande, Tamarack, and Sylvan Creeks

- Osier Creek watershed (Appendix 5)
  Includes Osier, China, Laundry, Swamp, and Sugar Creeks

- Cold Springs and Cool Creeks (Appendix 6)

- Cougar and Grizzly Creeks (Appendix 7)

- Gravey and Marten Creeks (Appendix 8)
- Middle Creek (Appendix 9)
- Sneak Creek (Appendix 10)
- Deception Gulch (Appendix 11)

For each stream segment in a watershed, existing percent canopy closure determined by aerial photo interpretation is subtracted from the CWE model prediction of necessary percent canopy closure to protect stream temperatures. As noted above, if the existing percent canopy closure is less that what the CWE temperature model predicts as necessary, the CWE model prediction is set as the target. If the existing percent canopy closure is equal to or greater than what the CWE model predicts is necessary, then the existing percent canopy closure is set as the target. The targets by stream segment are presented in graphic form on a map and in a table in an appendix for each water body. An ArcView shapefile containing the graphics and target allocation data are on the diskette included with this document. It will be necessary to use the ArcView shapefile to identify the target for a specific stream reach.

The upper Orogrande, lower Orogrande, and French Creek watersheds were analyzed as a whole (the Orogrande Creek watershed). The upper Orogrande watershed is made up of Orogrande Creek above the confluence with French Creek, including all of Elk Creek, Silver Creek, Crystal Creek, Breakfast Creek, South Fork Creek, and numerous smaller perennial streams. Lower Orogrande Creek is fed not only by all of the upper Orogrande Creek, but also by French Creek and its major tributaries of Sylvan, Hem, and Joy Creeks. Lower Orogrande Creek also has tributaries of Pine Creek, Tamarack Creek, Cache Creek, Grand Creek, Shake Creek, and numerous smaller perennial streams.

The watershed map in Appendix 4 shows the perennial streams and water bodies that were analyzed in the Orogrande Creek watershed. In all, 130 miles of stream, divided into 330 segments, were analyzed. The results are shown in Table 13, in Appendix 4, and on the included diskette.

These results and those in Appendix 4 and in the ArcView shapefile are the temperature TMDLs for the 303(d) listed water bodies upper Orogrande Creek, lower Orogrande Creek, Sylvan Creek, and Tamarack Creek. For the upper Orogrande Creek watershed, the majority of stream segments require in the range of a 26-50 percent increase in percent canopy closure to meet the targets. For the lower Orogrande Creek watershed, the majority of the stream segments require greater than a 50 percent increase in percent canopy closure. For Tamarack Creek too, as a subwatershed within the lower Orogrande Creek watershed, the majority of the stream segments require greater than a 50 percent increase in percent canopy closure. For Sylvan Creek, the majority of the stream segments require in the range of a 26-50 percent increase in percent canopy closure.

Table 13. Stream segments and shading status for the Orogrande Creek watershed.

Stream Name	Total Number of Stream Segments	Total Miles of Stream	Number of Segments Requiring a Given Range of Percent Canopy Closure Increase to Meet the Temperature TMDL Targets				
			0%	1-10%	11-25%	26-50%	>50%
Upper Orogrande	45	28.4	0	0	10	26	12
Elk	12	9.2	0	0	0	2	11
Total U. Orogrande	57	37.6	0	0	10	28	23
French	48	18.4	0	1	13	22	12
Hem/Joy	15	7.0	0	6	3	6	0
Sylvan	23	8.5	0	0	10	16	6
Total French	86	33.9	0	7	26	44	18
Lower Orogrande	108	34.1	0	2	8	42	56
Pine/Fir	21	6.3	0	0	3	2	16
Tamarack	24	6.9	0	0	3	0	21
Cache	12	4.0	2	2	2	0	6
Shake	8	3.1	0	0	0	0	8
Grand	10	3.3	0	1	2	0	7
Total L. Orogrande	183	57.7	2	5	18	44	114
Total Watershed	326	129.2	2	12	54	116	155

For the Osier Creek watershed temperature loading analysis, analyses were also conducted on Swamp Creek, Pollack Creek, Sugar Creek, Laundry Creek, China Creek, West Fork Osier Creek, and Pioneer Gulch. Osier, Swamp, Sugar, and Laundry Creeks are listed by the USEPA as protected for bull trout, so shading targets for bull trout temperatures were applied to these streams. The watershed map in Appendix 5 shows the perennial streams that were analyzed. Surrogate targets were developed for the 67 stream segments that were analyzed (Table 14) (see Appendix 5 and included diskette). These results, therefore, are the temperature TMDLs for the 303(d) listed water bodies Osier Creek, China Creek, Laundry Creek, Sugar Creek, and Swamp Creek.

Over 50 percent of the stream segments in the Osier Creek watershed require greater than a 50 percent canopy closure increase to meet the temperature TMDL targets.

Similar to the Orogrande and Osier watersheds, we have grouped the temperature TMDLs for the other 303(d) listed streams by watershed. Cold Springs Creek and Cool Creek are calculated together. Gravey and Marten Creeks are calculated together. Cougar and Grizzly Creeks are calculated together because they are adjacent with nearly identical landforms and

land uses, even though they don't actually come together to form one watershed. For Middle Creek, we include analyses of numerous important tributaries. Calculations for the Sneak Creek and Deception Gulch watersheds also include all the perennial tributaries. Results of each of the TMDL calculations are presented in their respective appendices, and the ArcView shapefile data are on the included diskette. Table 15 presents summary results by watershed. All streams were analyzed using the 10 ^{o}C MWMT temperature standard.

Table 14. Stream segments and shading status for the Osier Creek watershed.

Stream Name	Total Number of Stream Segments	Total Miles of Stream	Number of Segments Requiring a Given Range of Percent Canopy Closure Increase to Meet the Temperature TMDL Targets				
			0%	1-10%	11-25%	26-50%	>50%
Osier/WF Osier	16	10.6	0	0	1	4	11
China	11	6.2	0	0	1	1	9
Laundry	9	4.6	0	0	2	6	1
Sugar	9	3.9	0	1	5	1	2
Swamp/Pollack	22	10.2	0	2	4	7	9
Total Watershed	67	35.5	0	3	13	19	32

The maps and tables in Appendices 6 through 11 are the TMDLs for the water bodies listed in Table 15. The data for all the temperature TMDLs are available in ArcView format to those reviewing this document or implementing this TMDL. The ArcView shapefiles are on the included diskette. The surrogate water temperature targets are the segment by segment percent stream shading targets determined from the CWE analysis.

For Cold Springs Creek, Cougar Creek, Grizzly Creek, Gravey Creek, Middle Creek, Sneak Creek, and Deception Gulch, the majority of the stream segments require in the range of a 11-50% canopy closure increase to meet the temperature targets. For Cool Creek and Marten Creek, the majority of the stream segments require in the range of a 1-25% increase in canopy closure to meet the temperature targets.

Stream Temperature Reduction Margin of Safety

The CWA requires a margin of safety to ensure that load allocations will result in water quality attainment. In the case of the load allocations for heat in the UNFCRS, there are two levels of margin of safety. As reported in Chapter 3, Temperature Issue Analysis, of Idaho's 1998 303(d) list (DEQ 1999), stream temperature criteria for Idaho do not comport well with support of beneficial uses. In all the temperature TMDLs developed herein for salmonids other than bull trout, reasonable populations already exist in these water bodies. The temperature TMDLs were developed because of numeric exceedances even though the water quality is evidently supporting salmonid spawning as its beneficial use. Further reduction of stream temperatures can only enhance existing conditions that already appear adequate according to the state's metrics. Improving already adequate conditions is the ultimate in

Table 15. Stream segments and shading status for the Cold Springs/Cool, Cougar/Grizzly, Gravey/Marten, Middle, Sneak, and Deception Gulch watersheds.

Stream Name	Total Number of Stream Segments	Total Miles of Stream	Number of Segments Requiring a Given Range of Percent Canopy Closure Increase to Meet the Temperature TMDL Targets				
			0%	1-10%	11-25%	26-50%	>50%
Cold Springs	53	9.2	6	6	19	20	2
Cool	47	7.2	15	9	16	6	1
Total Watershed	100	16.4	21	15	35	26	3
Cougar	56	7.8	4	0	21	24	7
Grizzly	35	6.2	3	1	9	14	8
Total Watershed	91	14.0	7	1	30	38	15
Gravey	80	29.1	10	13	19	31	7
Marten	24	7.8	7	6	8	3	0
Total Watershed	104	36.9	17	19	27	34	7
Middle	73	27.9	2	7	24	24	16
Sneak	76	9.3	10	13	16	23	14
Deception Gulch	18	6.7	0	7	5	4	2

margins of safety. In the case of streams protected for bull trout, the USEPA has set a conservative standard, especially when compared to the standard thought by the state of Idaho to be adequate. The final measure in any case will be the attainment of the applicable water quality temperature standards.

Seasonal Variation

Surrogate targets are set for percent canopy closure, which is largely a year-round feature in coniferous forests. The critical time of the year for stream heating is July and August when percent canopy closure would be at it greatest because the vegetation will be fully leafed out.

Reasonable Assurance

Since no point sources of temperature loading are known to exist in the UNFCRS, reasonable assurance is not a requirement for nonpoint source loadings. However, it is reasonably clear that under the CNF INFISH policy and the FPA CWE project results, there is a large degree of institutionalized commitment to meet the targets set in these temperature TMDLs.

Background

Background stream heating is recognized in these TMDLs as that part of stream heat loading that would occur under a more-or-less natural vegetative canopy. For the most part, this degree of heat loading is not quantified in these TMDLs. The effort of the TMDLs is to identify the human-caused portion of heat loading, and the TMDLs targets are set at removing all human-caused heat loading. Natural background heat loading is assumed to exist more or less independent of human intervention and, as such, is not subject to reduction through any reasonable human management activity.

6.2 Sediment TMDL

Deception Gulch is the only water body in the UNFCRS for which it was concluded that water quality is impaired by sediment such that beneficial uses are impaired. The actual degree of impairment is unknown. Impairment from sediment is primarily the result of several large mass failures that delivered massive amounts of sediment to the stream, most recently during the 1995-96 rain-on-snow event, but also during the 1975-76 rain-on-snow events, and most likely in previous events. The watershed has a history of human use since the mid- to late-1800s when it was a transportation corridor to Moose City and its associated mining district. Since 1996, the delivery of human-caused sediment has been significantly reduced, but not stopped. Potential mass failure sites have not been adequately addressed.

The analysis of sediment loading for Deception Gulch is complicated by the fact that no specific data or standards exist defining the level of sediment beyond which salmonids cannot successfully spawn in this stream. Almost certainly, given the turbidity data from other watersheds in the UNFCRS (Appendix 2, Tables 16-20), Deception Gulch does not exceed the turbidity standard except during rain-on-snow events that cause significant mass failures. These events have occurred on an average of once every 15 years over the last century.

Our decision to develop a TMDL for Deception Gulch is based on the assessment of available data, observations, and other reliable information. Table 11 present a comparison of data from several water bodies similar to Deception Gulch. Swamp, Osier, China, Sugar, and Laundry Creeks are in the same general area as Deception Gulch (Figure 9); all have the same bedrock type (Lower Wallace Formation); all are in the same general elevation range and have similar stream gradients; all exhibit the same suite of landtypes (Moderate Relief Uplands, Mountain Slopelands, Rounded Mountain Slopelands, Dissected Stream Breaklands); and all are Rosgen B type channels. They all exhibit on the order of 1-10 cubic feet per second flow in the summer months, except Swamp Creek, which has on the order of 50 cubic feet per second flow. They are all associated with the Moose Creek mining district, which is interpreted to be an old, highly weathered surface being actively downcut, resulting in a relatively highly erodible surface with an abundance of fine-textured material. Swamp Creek is totally unroaded and not impacted by human activity. Only the headwaters of Sugar Creek have been roaded. Both, however, were severely burned in the early part of the 20th century.

Table 16. Data comparing Deception Gulch to similar water bodies.

	Deception Gulch	Swamp Creek	Sugar Creek	Osier Creek	Laundry Creek	China Creek
Elevation Range (feet)	3,480-5,700	3,350-6,000	3,700-6,100	3,320-5,600	3,480-5,400	3,600-6,000
WBAG Assessment						
MBI[1] Score	5.86	4.48	4.04	4.59	4.83	3.81
HI[2] Score	84	107	107	102	121	106
Salmonids	4+juveniles	3+juveniles	2+juveniles	3+juveniles	3+juveniles	4+juveniles
CNF[3] Stream Habitat Data						
CNF CE[4] (%)	48.6	43.8	64.3	56.1	53.2	48.3
CE Threshold (%)	30-35	30-35	30-35	25-30	25-30	25-30
Gradient (%)	4.7	3.9	3.8	3.5	5.5	3.1
Bank Stability Index	4.8	4.9	5	4.4	4.9	4.8
Raw Banks (m/km)	41.9	nd	nd	62	37	64
Percent Pools	28.5	10.5	20.6	nd	30.8	43.1
Percent Riffles	49	37.6	33.1	nd	67.5	32.6
Fish Density	Mod (?)	Mod	Mod	Mod-Low	Widespread	Widespread
Sediment Source Data						
Equivalent Clearcut Acres (%)	30	0	10	45-50	50	20-30
Road Density (mi/mi^2)	9	0.1	2.4	6.7	7.6	6.1
Roads <100 ft. from Stream (%)	13	0	7	13	11	10
Roads in High Risk Landtypes (%)	50	0	0	13	8	5
Mass Failures (No.)	24	0	0	5	3	1
Mass Failure Density (MF/mi^2)	4.9	0	0	0.6	1	0.2
CWE[5] Erosion Delivery Rating	Moderate	Low	Low	Moderate	Moderate	Moderate

	Deception Gulch	Swamp Creek	Sugar Creek	Osier Creek	Laundry Creek	China Creek
CWE Mass Failure Score	180	0	0	50	30	12
% Sediment over Background	28	0	15	5	12	8
Geomorphic Threshold (%)	163	223	207	196	212	212
Water Quality Objective (%)	150	55	55	110	110	110

[1] Macroinvertebrate biotic index
[2] Habitat index
[3] Clearwater National Forest
[4] Cobble embeddedness
[5] Cumulative watershed effects

When one examines the BURP/WBAG results and the CNF stream habitat data, Deception Gulch exhibits the same relatively good qualities as all the others. The WBAG results by themselves would indicate full support of beneficial uses by Deception Gulch, with a very good MBI score and good fish class distribution. The HI score for Deception Gulch is the weakest of the scores, but still well above the threshold of 73. Similarly, for stream habitat data from the CNF intensive bio-physical studies, Deception Gulch compares favorably with the unentered Swamp Creek and all the others. Cobble embeddedness is high by most standards for good quality spawning, but this is true for all the water bodies in this area, including Swamp Creek, and appears to be a function of the fine-textured, highly weathered nature of the bedrock and the lingering effects of early 20th century fires.

The real concern for Deception Gulch comes from the sediment source data and information which indicate the sediment loading poses a real threat to water quality. Road density in Deception Gulch is about twice of what the CNF considers acceptable for water quality. Of these roads, some 50 percent are on high-risk landtypes, which is a very high percentage. The result is that Deception Gulch has a very high mass failure rate, and most of the mass failures are associated with the roads. While sediment loading from road erosion is somewhat elevated, it is still in the moderate range using the CWE index. The real threat in terms of sediment loading is sediment from the mass failures, most of which have occurred in the past during rain-on-snow events.

All of this together indicates that the sediment problems in Deception Gulch are of a nature and magnitude that reductions in event-based loading should and can be reduced. Analysis of the roads and geology of the watershed indicates that mass failures will continue to occur and degrade the stream. The road system on the west side of the drainage is built on geologic dip slopes that will continue to fail. Forest Service Road 734 shows numerous signs of fill slope slipping. Forest Service Roads 255 and 730 cross the contact between Wallace gneiss and the Revett quartzite where most of the large mass failures have occurred. It is likely that this unstable area will continue to fail. In the final analysis, unlike all the other water bodies listed for sediment in the UNFCRS, the situation here appears to be likely to continue to degrade.

We included sediment from natural background sources and recent management activities when calculating the sediment being delivered to the stream. We relied on data from the landslide inventory and a CWE type road assessment conducted in September 2000 by DEQ personnel. We then compared these data to CNF WATBAL-derived predictions for the levels of sediment over background that would adversely affect channel stability or fish populations.

Sediment Loading and Loading Capacity

There are three major sources of sediment being delivered to Deception Gulch – natural background erosion, roads, and road-related mass failures. Wilson et al. (1982) calculated a natural background sediment rate of 25 tons per square mile per year for most of the CNF. Other research we have seen leads us to think this is a conservative estimate for this particular watershed. The area of the Deception Gulch watershed is approximately 4.7

square miles, resulting in a background sediment rate of approximately 120 tons per year for the watershed.

Twenty-four mass failures have been identified in the watershed, and all of these have an estimated volume range and percent delivery to a stream. These data and the calculations are in an ArcView shapefile named "DecepMF" located on the diskette in the pouch with this document. For each volume range and percent delivery range, we used the midpoint of the range for each mass failure and calculated the total amount of sediment delivered to the stream. For all the mass failures, we calculated the volume delivered to be 3,800 cubic yards. Using a conversion of 1.6 tons per cubic yard, this converts to 6,080 tons of sediment delivered from mass failures.

This amount of material is not delivered every year. Data from McClelland et al. (1997) show that rain-on-snow mass failure events occur on average every 15 years. Converting the 6,080 tons to a yearly basis results in an estimate of approximately 400 tons per year of sediment delivered from mass failures. This is another conservative estimate in-so-far-as it's based on data for all of north-central Idaho, with such massive results unlikely to occur throughout the area. In other words, assuming significant rain-on-snow events occur every 15 years, it is unlikely that the UNFCRS will be hit as hard in every event as it did during the 1996-97 event. Further, this calculation ignores that some percentage of the mass failures would occur naturally – perhaps as much as 100 tons per year, or 25 percent, based on the 120 tons per year background rate. Thirty percent of the mass failures in the larger study area were determined to be natural (McClelland et al. 1997). However, since all the mass failures except one in Deception Gulch were road related, we did not make this adjustment.

However, thinking about these numbers should help establish a loading capacity for sediment from mass failures. If the loading capacity for mass failure produced sediment should be somewhere close to background, or about 100 tons per year, then the target load reduction for mass failure sediment in Deception Gulch should be somewhere around 75 percent. This comports well with the reference watershed data in Table 11 wherein indications are that mass failure density needs to be reduced from about five per square mile to at most one per square mile, or an 80 percent reduction.

We conducted an assessment of road erosion in the Deception Gulch watershed using the FPA CWE methodology (IDL 2000). The results of this assessment are in Appendix 12 and the ArcView shapefile included on the diskette. We then converted the CWE scores to tons per year using a conversion developed by McGreer wherein he conducted both the Washington state watershed analysis and the CWE analysis on three watersheds and correlated the results (McGreer and Schult 1998). About 1.5 miles of USFS Road 255 have significant problems, with a CWE road score of 36. Another 6 miles of roads close to streams received CWE road scores of 20-30 because of delivery potential (Figure 11). The remaining 35 miles of road were each assigned a score of 15. Using the McGreer-developed conversion rates of 20, 10, and 5 tons per mile, respectively, roads in the watershed are delivering approximately 250 tons of sediment per year.

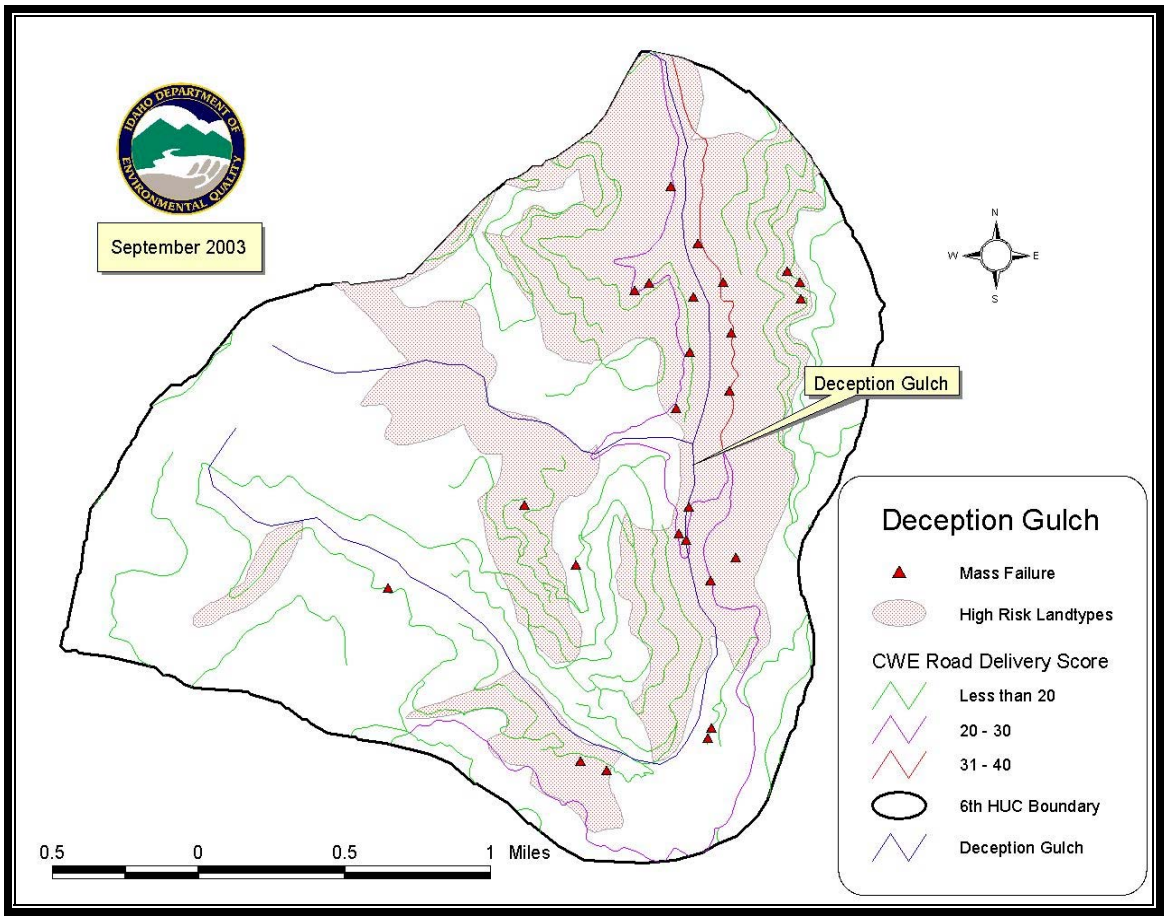

Figure 11. Mass Failures, CWE Roads, and High Risk Landtypes of Deception Gulch

The calculation for sediment from the roads is probably conservative in that other evidence indicates that the sediment from roads is less than 250 tons per year. A CNF WATBAL-generated a figure of 120 tons per year from 31 miles of the roads in this watershed (compared to 42 miles in the GIS database) indicates that McGreer-derived figure may be 50 percent too high. For the CWE assessment, we assigned a minimum CWE score of 15 to a large number of roads that probably in reality have scores no higher than 10-15, as we were unable to field verify their conditions. And, more recent work by McGreer, that is as yet unavailable for use, indicates that sediment production scores for watersheds dominated by metasedimentary rock types are less than for granitics, for which the original relation was developed.

Our conclusion, therefore, is that Deception Gulch has the following major sediment sources:

Background	120 tons/year
Mass Failures	400 tons/year
Road Erosion	250 tons/year
Total Sediment Loading	770 tons/year

We have not found any other sources of sediment of these magnitudes in Deception Gulch. Based on the reference watersheds in Table 11, and as discussed above, it appears that sediment from mass failures would need to be reduced by about 75 percent and from roads by about 50 percent to reduce the threat to water quality to tolerable levels. This would translate into a load capacity of about 340 tons per year.

Excess Sediment Load

The excess sediment load for Deception Gulch depends on a decision about what level of sediment above background is acceptable to be able to maintain beneficial uses of salmonid spawning. The CNF has derived three measures of sediment load over background for this watershed that are instructive (Jones and Murphy 1997; Jones et al. 1997). At 163 percent over background (Table 11, Geomorphic Threshold) (about 300 tons per year loading), one expects adverse conditions in the stream channel. Undoubtedly, Deception Gulch has surpassed this level.

In addition, the CNF uses a fish status classification system in its forest plan (USFS 1987) that relates channel type and threshold percent sediment over background to the viability of fish populations. The classes are as follows (assuming a B channel type for Deception Gulch and its comparable water bodies):

No Effect: No sustained, measurable adverse changes over time due to management-caused effects on turbidity, temperature, substrate composition, and chemical quality; or physical loss or degradation of existing fish habitat potential. The approximate maximum sediment loadings, expressed as increases (%) over natural sediment yields, that generally support this criteria are:

Channel type B – Threshold – 45% over natural background

High Fishable: Maximum short-term reduction of water quality that is still likely to maintain a fish habitat potential that can support an excellent fishery relative to the stream's natural potential and that will provide the capability for essentially full habitat recovery over time….

Channel type B – Threshold for cutthroat – 55% over background

Mod Fishable: Maximum short-term reduction of water quality that is still likely to maintain a fish habitat potential that can support at least a moderate harvestable surplus relative to the streams system's natural potential and that will provide the capability for significant habitat recovery over time.

Channel type B –Threshold for cutthroat – 150% over background

Low Fishable: Maximum short-term reduction of water quality that is still likely to maintain a fish habitat potential that can support at least a minimal harvestable surplus relative to the streams potential and that will provide the capability for some significant recovery over time.

Channel type B – Threshold for cutthroat – 225% over background

Min Viable: Maximum short-term reduction of water quality that is still likely to maintain a fish habitat potential that can support at least a viable fish population and that will provide the capability for some significant habitat recovery over time.

Channel type B – Threshold for cutthroat – 450% over background

We consider that for a population to be "viable," it must have enough individuals and enough interconnected, suitable habitats to have a high probability of long-term persistence. Thus, if a population is indeed "viable" as defined by the CNF, then the waters in which the population occurs would also meet the following definition of waters protected for "salmonid spawning" in Idaho's water quality standards: "waters that provide or could provide a habitat for active, self-propagating populations of salmonid fishes." Therefore, the CNF goal of "minimum viable," if met, would support salmonid spawning. The CNF goal of "low fishable," which is defined as water providing a harvestable surplus in addition to maintaining viability, would exceed the minimum standard of salmonid spawning as defined by Idaho's water quality standards, subsection 100.01(b). Idaho's water quality standards are silent on harvest goals, since Idaho considers that to be a fisheries management issue, not an issue of meeting water quality standards.

Based on our analyses of data from all the 303(d) listed streams in the UNFCRS, we recognize that these streams have a considerable capacity for sediment loading above background and still support salmonid spawning. Assuming similar sediment production and delivery in Deception Gulch compared to the other streams listed in Table 11, it would require about a 50 percent reduction (125 tons per year) in roads and an 80 percent (320 tons per year) reduction in mass failures, or about 445 tons per year total, for Deception Gulch to have similar conditions. A 445 tons per year sediment reduction would result in about 325 tons per year sediment loading, which translates to 171 percent over background. This would bring Deception Gulch well below the range of the CNF's "low fishable" sediment loading of 225 percent over background. So we think we're in the right ballpark and well within what might be called a reasonable definition of support of beneficial uses.

After considering this information, we established the conservative target of 225 percent (390 tons per year) over background sediment load as the level beyond which the sediment load would be excessive. This target is a level where our data and predictions by the CNF WATBAL procedure say that beneficial uses will be supported. Already, the BURP/WBAG assessment, the CNF stream habitat data, and the fish population indicate that current water quality of Deception Gulch is not seriously limited in relation to the state standard. A 50 percent reduction in the number of miles of roads and an 80 percent reduction in the number of mass failures for this watershed, as called for in the surrogate targets below, would bring road and mass failure densities well down into the range of other watersheds in this subbasin where we know salmonid spawning is being fully supported.

Excess Sediment Load Allocation

The only major sources of sediment that create the excess load are roads and mass failures associated with roads. Sediment resulting from road erosion is truly a nonpoint source.

Mass failures occur at particular points, but since their location cannot be predicted, they are considered nonpoint sources as well. There are no known point sources of sediment in the watershed. Therefore, 100 percent of the load is allocated to nonpoint sources affecting the water quality limited stream. One hundred percent of the excess load is allocated to road construction and road maintenance activities.

Excess Sediment Load Reduction Targets

Based on the reasoning above, we use 225 percent over background, or 390 tons per year, as a target for sediment loading. Since the total loading is 770 tons per year, the load reduction target is 380 tons per year. This converts to about a 50 percent sediment loading reduction.

Surrogate Sediment Load Reduction Targets

If our analysis of the situation is correct, then it is clear that a 390 tons per year target cannot be attained if mass failures are not largely contained. If only road erosion and background sedimentation are considered, then sediment loading is only 370 tons per year. However, since the occurrence of mass failures is episodic depending on weather and, therefore, is not predictable, surrogate targets of mass failures *per se* really aren't measurable. But virtually all the mass failures are associated with roads, and even more are associated with roads on high hazard landtypes (Figure 11). In order to reduce the potential for mass failures during the next major rain-on-snow event, the number miles of roads with high potential for mass failure should be reduced. Reducing the number of miles of roads on high-risk landtypes will, over the long term, reduce sediment from both roads and mass failures.

Of the 42 miles of roads in the Deception Gulch watershed, about half are on high hazard landtypes, and 20 of the 24 mass failures occurred on high hazard landtypes (Figure 11). The CNF has the objective of obliterating approximately one-third of the roads on the forest. In the case of Deception Gulch, in order to reduce the potential of sediment from mass failures as a function of this TMDL, we recommend obliteration of half the 42 miles of roads, concentrating on the roads on hazardous landtypes. In addition, we recommend reducing the mass wasting hazard on roads that will not be obliterated. We recognize that the CNF may need five or more years to accomplish these tasks, which will be dependent on securing funding for the work. Reducing roads by half would reduce road-generated sediment to about 120 tons per year. Based on the fact that about 80 percent of the current mass failures are associated with roads on high hazard landtypes, eliminating roads in high hazard areas should reduce mass failures by 80 percent, or to around 80 tons per year. This would result in a sediment load from background, roads, and mass failures of around 325 tons per year, somewhat under the 390 tons per year TMDL target.

Sediment Reduction Margin of Safety

Throughout this section on sediment loading analysis and reduction targets, we have pointed out where we have made conservative calls. Most conservative of all, we chose a loading target of 225 percent over background, which is almost a 60 percent margin of safety over the CNF's 450 percent over background loading for minimum viable fishery. There are no particular data to suggest that the 450 percent over background loading is not the correct

target. Even at the current loading level of 770 tons per year, BURP/WBAG stream habitat and fish data seem to indicate that beneficial uses are being supported. We chose a lower loading level target specifically to reduce the threat of sediment to water quality and build in a margin of safety based on our knowledge of the subbasin. The background sediment delivery rate used in our calculations is low such that the percentages over background targets are also low. Calculations for mass failure-produced sediment are based on what is probably a worst-case scenario – it is unlikely that the North Fork Clearwater River will be the center of worst occurrence of mass failures in the next rain-on-snow event. Our loading figure from roads is probably high, perhaps by as much as 50 percent. Adherence to our recommendations of obliterating at least half the roads, focusing on roads on high hazard landtypes, and reducing the potential for mass failures on the remaining roads, will reduce sediment delivery potential in the watershed to well below the target.

Seasonal Variation

Sediment loading in Deception Gulch occurs primarily in late winter and early spring during snow melt, rain events, and rain-on-snow events. Some loading may occur during high-intensity rain events in the summer and fall. The management of roads to reduce the risk of mass failures and runoff should account for the situations that occur during these few times out of the year.

Reasonable Assurance

Since all of the load allocation is to nonpoint sources, no reasonable assurance is required for this TMDL. However, the CNF has set itself the goal of reducing roads in Deception Gulch by as much as 60 percent. They are well focused on the roads on the high hazard landtypes. Appendix 15 shows the results of those activities to date.

Background

Wilson et al. (1982) calculated a natural background sediment rate of 25 tons per square mile per year for most of the CNF. Other research we have seen leads us to think this is a conservative estimate for this particular watershed, given the highly weathered and erosive nature of the bedrock. In addition, the watershed is highly susceptible to natural mass failures as a result of dip slopes greater than 100 percent and the bedrock contact between the Wallace and Revett Formations. The area of the Deception Gulch watershed is approximately 4.7 square miles, resulting in a background rate of approximately 120 tons per year for the watershed, using the 25 tons per square mile per year estimate of Wilson et al. (1982).

6.3 Implementation Strategy

"An implementation plan identifies and describes the specific pollution controls or management measures to be undertaken, the mechanisms by which the selected pollution control and management measures will be put into action, and describes the authorities, regulations, permits, contracts, commitments, or other evidence sufficient to ensure that

implementation will take place. The plan also describes when implementation will take place, identifies when various tasks or action items will begin and end, when mid-term and final objectives will be met, and establishes dates for meeting water quality targets," (Dailey et al. 1999, p 67).

Development of the UNFCRS implementation plan will occur through a collaborative process involving a number of entities and interested parties, including landowners, land managers, and resource agencies. Further details on the parties involved, contents, and the timeframe for development of the plan are included in later sections of this strategy. DEQ recognizes that implementation strategies for TMDLs may need to be modified if monitoring shows that the TMDL goals are not being met or significant progress is not being made toward achieving the goals.

Implementation of the TMDLs presented in this document should occur in an integrated fashion to address the pollutants in a cost effective manner. The major human-caused sediment sources that have been identified in the Deception Gulch include roads, forestry, eroding stream banks, and mass failures. Temperature problems are widespread and occur in many of the same areas with many of the same causes.

Application of effective BMPs is crucial to achieving the pollutant load reductions and targets of the TMDLs. Consequently, the implementation plan, to the extent practicable, must be explicit about which BMPs or systems of BMPs will be employed to achieve the targets, where and when the BMPs will be employed, and how application of the BMPs will achieve the stated targets. The USEPA (1991) guidance specifically identifies several criteria by which BMPs will be judged:

- A data-based analysis showing that the selected BMPs have been demonstrated to be effective in addressing the issue or pollutant in question (i.e., a history of successful application in similar situations);
- An explanation of the mechanisms by which application of the BMPs will be assured; and
- A plan for tracking the implementation and effectiveness of the BMPs.

As implementation progresses, pollutant reductions may be accomplished in a variety of ways at the discretion of the implementing landowners, managers, and agencies.

Over time, implementation strategies for the TMDLs may need to be modified if monitoring shows that the TMDL goals are not being met, or that significant progress is not being made toward achieving the goals.

The following are issues with each one of the TMDL pollutants that should be kept in mind while developing an implementation plan.

Temperature

Implementing this TMDL will be a long-term affair while trees reestablish themselves and grow back along the streams to provide the level of shading required to reduce stream temperatures. In that time frame, it is expected that the CNF, IDL, and Potlatch Corporation will reevaluate the condition of these water bodies many times and regularly monitor their progress towards meeting the temperature targets. This TMDL identifies the general locations and magnitudes of the shading problems and sets the targets for percent canopy closure. The land managers will develop and implement the specific plans to attain the percent canopy closure targets.

Shade targets are established in the TMDLs as surrogate measures necessary to achieve temperature criteria. While specific information and direction regarding how these targets are to be implemented will be established in the implementation plan, certain general considerations accompany these targets.

Riparian areas along streams do not naturally exhibit 100 percent canopy cover for the entire length of the streams. Natural events (fires, landslides, wind events) may affect riparian vegetation along small stream segments or entire streams. In addition, larger streams (i.e., Middle Creek, lower Orogrande Creek) have larger stream widths that do not allow for a high canopy closure. Also, colder habitat types typically found at high elevations or in cold air drainages often do not support 100 percent canopy cover. We have not attempted to sort out these site-specific conditions in relation to the CWE predictions, but leave it for the land managers as they develop their implementation plans.

The overall intent is to meet temperature criteria by increasing shade, or in areas where shade targets are already met, to maintain natural shade levels, which incorporate natural disturbance regimes (e.g., fire, mass wasting, insects, disease, etc.). While these shade targets do not preclude management of the riparian zone, only activities that will result in negligible shade reduction, or through careful evaluation will result in long-term benefits in terms of stream temperature, are consistent with the targets.

Application of these targets is expected to be carried out at a stream reach scale. Typically the stream reaches are 0.5 mile in length, but this may vary considerably given the nature and size of the stream. In all cases, a site evaluation will be essential in order to 1) confirm current shade conditions, 2) confirm channel conditions, 3) determine why shade is above or below target values, and 4) establish appropriate BMPs. While the shade targets provide a useful goal for restoration, the key to implementation is to tailor management to the problems unique to each stream reach.

In much of the watershed it is expected that shade targets will be achieved through passive restoration, that is, allowing vegetation to grow to a mature state. In some locations (e.g., dredge mined areas, grazed areas), active restoration through plantings and channel modification may be warranted.

There may be circumstances in which it is necessary to temporarily reduce shade in order to achieve increased shade and ecological health in the long term. For example, active channel restoration or prescribed fire may temporarily reduce existing shade, but lead to long-term temperature benefits. These activities would be consistent with TMDL targets, provided they are carefully evaluated to establish whether or not the long-term temperature benefits outweigh the short-term loss of shade.

In still other areas, it is recognized that it may not be possible to achieve the desired shade due to essentially irreversible human caused changes, such as major roads or railroads adjacent to the stream. In these areas, it is expected that the implementation plan will identify local or other offsetting measures (e.g., plantings along the stream) that would minimize the effects of permanent human-caused shade loss.

Sediment

Specific BMPs for sediment for forestry activities will be identified in the implementation plan. The following are a few examples of the many forest practices that could be implemented to reduce sediment.

- Road improvements including culvert and stream crossing upgrades, sidecast removal or reduction, road removal or closure, stabilizing cut and fill banks, hardening surfaces, and improving maintenance.

- Road decommissioning and obliteration.

- Stabilizing mass failures.

- Land management activities that attenuate water yield, such as wetland and riparian buffer enhancement/development and no-till agriculture.

- Instream habitat restoration in intensively altered areas including reestablishing historic fluvial processes, pool frequency, pool depth etc. through channel reconstruction.

Approach

The implementation plan will be developed jointly through a collaborative process involving landowners, land managers, responsible resource agencies, and other interested parties. Contents of the implementation plan are expected to include:

- A description of how targets are to be attained (e.g., explains details of how to implement CWE targets).
- An identification of BMPs and BMP locations.
- An identification of existing efforts that will help achieve TMDL goals.
- An implementation schedule with milestones based on restoration priorities.
- Provisions to seek funding sources and sponsoring agencies.

Reasonable Assurance

Reasonable assurance of the implementation of nonpoint source control actions is required in a TMDL when point source waste load allocations are made less restrictive as a result of expected reductions from nonpoint source allocations (USEPA 1991). Since no point sources are identified or receive allocations in these TMDLs, reasonable assurance of nonpoint source control actions is not relevant to these TMDLs.

Nonetheless, for forested areas in the UNFCRS, water quality problems caused by nonpoint sources of sediment and heat are improving as a result of work by land managers, federal policies, and the Idaho's FPA. There is no reason to expect that the trend will not continue. The TMDLs identify areas of highest pollutant input and should allow for prioritization of areas for additional work.

Time Frame

Implementation plans are to be developed within 18 months of USEPA approval of the TMDL and are intended to achieve the water quality goals provided in a TMDL package. Implementation of nonpoint source controls has already begun, but is expected to proceed more rapidly once the implementation plan is complete and funds are available. The sources of pollutant loading are nonpoint in origin, and realistically it may take many years if not decades to fully achieve the goals of the TMDL. In order to substantially decrease stream temperatures, mature riparian communities and a stable hydrologic regime and stream channel are needed. In smaller streams and watersheds, significant improvement may be seen in a few years. Realistically though, it is likely to take decades to see such improvement throughout the watershed given the large scale of needed improvements and the time frame needed to for riparian vegetation to grow to maturity.

Participating Parties

Responsible agencies and interest groups are expected to play an important role in developing and implementing restoration measures. The primary responsible agencies are the CNF, Potlatch Corporation, IDL, and DEQ. Other organizations or entities that may be interested in participating are the Clearwater County Soil and Water Conservation District, the Idaho Department of Water Resources, USEPA, Idaho Fish and Game, USFWS, the Nez Perce Tribe, local highway districts, industries, local county government, environmental groups, and local landowners.

Monitoring Strategy

Monitoring needs include continued monitoring of in-stream temperatures and monitoring to establish reach-specific shade targets. Monitoring for stream temperature trends and standards attainment should occur near the mouths of each of the water bodies. A total of 18 monitoring points should be established in the UNFCRS, primarily at the mouths of each of the water bodies for which a TMDL has been written. Stream temperature should be monitored using a device that at a minimum can make hourly recordings over the course of

six months, encompassing the critical months of July and August. Monitoring should occur every summer until such time as the water quality standards are attained, or until this TMDL is revised and another plan established.

As with temperature, improvements in sediment conditions in Deception Gulch should be monitored. One to several types of data should be monitored to see whether control measures are being put in place. The implementation plan will identify how monitoring data will be acquired, organized, and maintained.

Surrogate targets for sediment have been set for percent reduction in road miles and associated percent reduction of road miles on high mass failure hazard landtypes. Documentation of these activities should be acquired and maintained by the CNF.

It is recommended as well that the CNF monitor in-stream habitat in Deception Gulch for an improving trend. It is recommended that the CNF will establish long-term monitoring sites for cobble embeddedness and/or several habitat parameters at two locations in Deception Gulch. In addition to reduced loading as documented by the above surrogate targets, the TMDL will be successful only if a statistically significant improving trend of stream habitat is demonstrated. This trend monitoring is a measure of BMP effectiveness.

6.4 Summary and Conclusions

This subbasin assessment and TMDLs have been developed to comply with Idaho's water quality standards and TMDL schedule. The first part of this document, the subbasin assessment, describes the physical, biological, and cultural setting; water quality status; pollutant sources; and recent pollution control actions in the UNFCRS located in north-central Idaho. The starting point for the assessment was Idaho's 1998 303(d) list of water quality limited water bodies. Nineteen stream segments in the UNFCRS were included on this list. The subbasin assessment portion of this document examines the current status of 303(d) listed waters. It defines the extent of impairment and causes of water quality limitation throughout the subbasin.

Temperature analyses were conducted of all the 303(d) listed streams in light of an extensive database indicating that no stream in the UNFCRS, not even those in relatively pristine condition, meets the Idaho numeric temperature criteria for salmonid spawning. However, the Idaho water quality standards recognize that stream temperatures may naturally exceed numeric criteria and that pollution control measures should only address the human-caused increases in temperature. The nonpoint temperature assessments assumed that the human-caused effects were increased solar insolation, primarily a result of reduced streamside vegetation and, secondarily, a result of increased stream width. Shading analyses were conducted on all 303(d) listed streams in the subbasin. The human-caused stream temperature increase was quantified in terms of the percent decrease in stream shade. Targets were set based on best estimates of natural conditions for stream shade and stream width.

Sediment loading in Deception Gulch was determined to be threatening beneficial uses of the water body. Excessive loading was identified as coming from road erosion and mass failures associated with roads. Loading rates were compared to several very similar watersheds, and targets were set for reducing sediment loading in Deception Gulch to levels that support beneficial uses in all the other water bodies compared.

Implementation of nonpoint source controls has already begun, but is expected to proceed in earnest once the implementation plan is complete and funds are available. The sources of temperature and sediment loading are nonpoint in origin, and realistically it may take many years, if not decades, to fully achieve the goals of the TMDL. In order to improve stream temperature, restored riparian communities and stream channels are needed. In smaller streams and watersheds, for example, significant improvement may be seen in several years. It is likely to take decades to see such improvement throughout the watershed given the large scale of needed improvements and the time needed for riparian vegetation to grow to maturity.

It is expected that implementation of the TMDLs as presented in this document will result in full restoration of the waters of the UNFCRS to meet the Idaho water quality standards. Further, this restoration will contribute substantially to improved habitat for threatened and endangered aquatic species in the subbasin.

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Appendix 4. Orogrande Creek Watershed Temperature TMDLs (includes Upper Orogrande Creek, Lower Orogrande Creek, Tamarack Creek, and Sylvan Creek)

An ArcView shapefile of
these data is on the diskette
located in the back of this document

Appendix 4. Orogrande Creek Watershed Temperature TMDLs (includes Upper Orogrande Creek, Lower Orogrande Creek, Tamarack Creek, and Sylvan Creek)

This appendix, along with ArcView shapefile data included on the enclosed diskette, constitute the temperature TMDLs for upper Orogrande Creek, lower Orogrande Creek, Tamarack Creek, and Sylvan Creek. Figure 4-1 shows the distribution of stream segements needing increased percent canopy closure to meet the TMDLs targets. Table 4-1 presents the loading calculations data on a stream reach by stream reach basis. The location of each stream reach can be ascertained using the ArcView shapefile. The ArcView shapefile contains all the data used to create the percent canopy closure increase targets in Figure 4-1 and the data presented in Table 4-1.

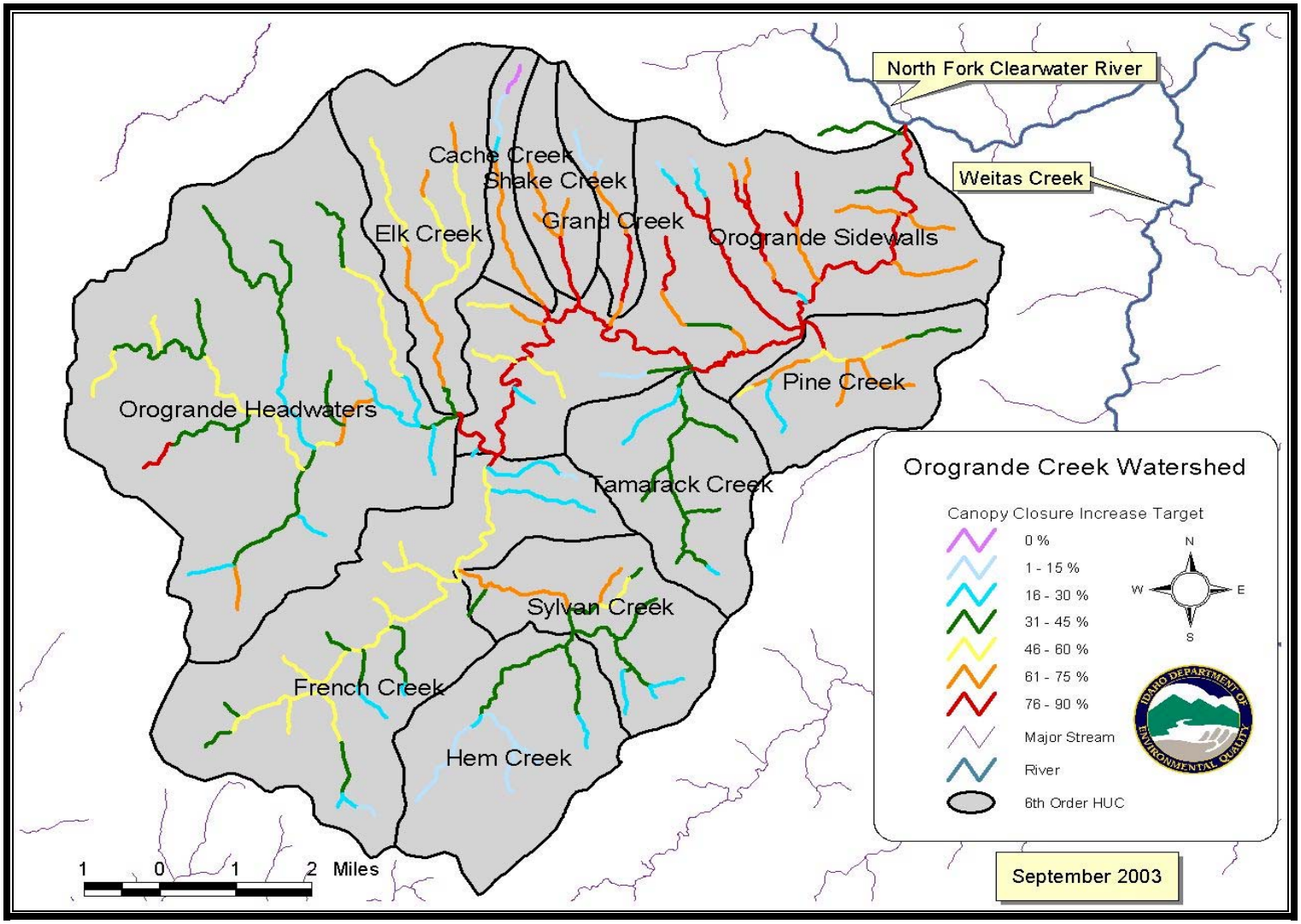

Figure 4-1. Targeted Percent Canopy Closure Increases for the Orogrande Creek Watershed

Table 4-1. Orogrande Creek watershed temperature TMDLs, stream reach by stream reach (includes TMDLs for upper Orogrande Creek, lower Orogrande Creek, Tamarack Creek, and Sylvan Creek).

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Bailey Gulch	1,844	3,400	75	120	100	25	70	17	76
Bailey Gulch	2,146	3,600	50	114	100	50	122	17	86
Bailey Gulch	1,746	3,800	50	108	100	50	122	17	86
Breakfast Creek	1,263	3,400	45	120	100	55	146	18	88
Breakfast Creek	5,674	3,600	45	114	100	55	146	18	88
Breakfast Creek	640	3,800	60	108	100	40	111	18	84
Breakfast Creek	7,078	3,800	45	108	100	55	146	18	88
Breakfast Creek	5,408	3,800	60	108	100	40	111	18	84
Breakfast Creek	1,865	3,800	60	108	100	40	111	18	84
Breakfast Creek	4,787	3,800	60	108	100	40	111	18	84
Breakfast Creek	3,512	4,000	40	101	100	60	157	18	89
Breakfast Creek	2,513	4,000	60	101	100	40	111	18	84
Breakfast Creek	4,312	4,000	40	101	100	60	157	18	89
Cache Creek	1,253	3,000	20	132	100	80	185	17	91
Cache Creek	1,777	3,200	30	126	100	70	164	17	90
Cache Creek	2,454	3,400	30	120	100	70	164	17	90

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Cache Creek	2,704	3,600	30	114	100	70	164	17	90
Cache Creek	2,953	3,800	30	108	100	70	164	17	90
Cache Creek	2,289	4,000	30	101	100	70	164	17	90
Cache Creek	1,840	4,200	75	95	95	20	70	28	60
Cache Creek	1,395	4,400	75	89	89	14	70	40	43
Cache Creek	1,056	4,600	75	83	83	8	70	53	24
Cache Creek	1,123	4,800	75	77	77	2	70	65	7
Cache Creek	1,335	5,000	75	71	75	0	70	78	0
Cache Creek	974	5,200	75	64	75	0	70	93	0
China Gulch	1,625	4,400	45	89	89	44	146	43	71
Copper Creek	1,829	3,600	45	114	100	55	133	17	87
Copper Creek	4,620	3,800	45	108	100	55	133	17	87
Copper Creek	2,019	4,000	30	101	100	70	164	17	90
Cottonwood Creek	2,018	3,000	30	132	100	70	181	18	90
Cottonwood Creek	1,249	3,000	60	132	100	40	111	18	84
Cottonwood Creek	1,973	3,200	60	126	100	40	111	18	84
Cottonwood Creek	1,522	3,400	30	120	100	70	181	18	90
Cottonwood Creek	1,618	3,600	30	114	100	70	181	18	90
Cottonwood Creek	4,794	3,800	20	108	100	80	204	18	91

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Crystal Creek	1,054	3,400	70	120	100	30	80	17	79
Crystal Creek	7,600	3,600	70	114	100	30	80	17	79
Crystal Creek	4,603	3,800	60	108	100	40	101	17	83
Crystal Creek	4,988	4,000	60	101	100	40	101	17	83
Crystal Creek	11,319	4,000	60	101	100	40	101	17	83
E.F. Elk Creek	3,717	3,600	45	114	100	55	133	17	87
E.F. Elk Creek	3,070	3,600	45	114	100	55	133	17	87
E.F. Elk Creek	6,719	3,800	45	108	100	55	133	17	87
E.F. Elk Creek	2,327	4,000	30	101	100	70	164	17	90
E.F. French Creek	4,623	4,000	45	101	100	55	133	17	87
E.F. French Creek	4,109	4,200	60	95	95	35	101	28	72
E.F. French Creek	924	4,400	60	89	89	29	101	40	60
E.F. French Creek	252	4,400	60	89	89	29	101	40	60
E.F. French Creek	1,268	4,400	60	89	89	29	101	40	60
E.F. French Creek	1,562	4,600	80	83	83	3	59	53	10
Elk Creek	2,874	3,200	60	126	100	40	101	17	83
Elk Creek	1,781	3,400	30	120	100	70	164	17	90
Elk Creek	3,367	3,400	30	120	100	70	164	17	90
Elk Creek	1,938	3,600	30	114	100	70	164	17	90

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Fidelity Gulch	3,750	4,000	45	101	100	55	133	17	87
Fir Creek	1,409	2,800	45	139	100	55	146	18	88
Fir Creek	3,248	3,000	30	132	100	70	181	18	90
Fir Creek	1,283	3,200	30	126	100	70	181	18	90
Fir Creek	1,750	3,200	75	126	100	25	76	18	76
Fir Creek	1,270	3,400	45	120	100	55	146	18	88
Fir Creek	1,436	3,400	75	120	100	25	76	18	76
Fir Creek	1,204	3,600	75	114	100	25	76	18	76
French Creek	1,172	3,200	20	126	100	80	204	18	91
French Creek	1,932	3,200	45	126	100	55	146	18	88
French Creek	3,187	3,200	45	126	100	55	146	18	88
French Creek	1,306	3,400	75	120	100	25	76	18	76
French Creek	1,486	3,400	75	120	100	25	76	18	76
French Creek	5,107	3,400	50	120	100	50	134	18	87
French Creek	5,869	3,600	50	114	100	50	134	18	87
French Creek	2,063	3,600	50	114	100	50	134	18	87
French Creek	462	3,600	75	114	100	25	76	18	76
French Creek	625	3,600	75	114	100	25	76	18	76
French Creek	782	3,800	45	108	100	55	146	18	88

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
French Creek	2,915	3,800	45	108	100	55	146	18	88
French Creek	894	3,800	45	108	100	55	146	18	88
French Creek	3,238	3,800	45	108	100	55	146	18	88
French Creek	436	3,800	45	108	100	55	146	18	88
French Creek	2,261	3,800	65	108	100	35	99	18	82
French Creek	2,145	3,800	50	108	100	50	134	18	87
French Creek	957	3,800	75	108	100	25	76	18	76
French Creek	2,013	3,800	75	108	100	25	76	18	76
French Creek	1,138	3,800	60	108	100	40	111	18	84
French Creek	1,193	3,800	50	108	100	50	134	18	87
French Creek	2,634	4,000	45	101	100	55	146	18	88
French Creek	2,001	4,000	50	101	100	50	134	18	87
French Creek	1,934	4,000	50	101	100	50	134	18	87
French Creek	2,249	4,000	45	101	100	55	146	18	88
French Creek	1,790	4,000	75	101	100	25	76	18	76
French Creek	1,611	4,000	75	101	100	25	76	18	76
French Creek	2,465	4,000	60	101	100	40	111	18	84
French Creek	2,899	4,000	65	101	100	35	99	18	82
French Creek	1,611	4,000	50	101	100	50	134	18	87

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
French Creek	4,180	4,200	45	95	95	50	146	29	80
French Creek	1,486	4,200	75	95	95	20	76	29	62
French Creek	2,165	4,200	75	95	95	20	76	29	62
French Creek	1,832	4,200	60	95	95	35	111	29	74
French Creek	1,519	4,200	65	95	95	30	99	29	71
French Creek	1,393	4,200	45	95	95	50	146	29	80
French Creek	1,159	4,400	75	89	89	14	76	43	43
French Creek	2,232	4,400	45	89	89	44	146	43	71
French Creek	940	4,600	60	83	83	23	111	57	49
French Creek	1,734	4,600	65	83	83	18	99	57	42
Fuzzy Creek	911	2,600	30	145	100	70	197	18	91
Fuzzy Creek	841	2,800	30	139	100	70	197	18	91
Fuzzy Creek	1,383	3,000	30	132	100	70	197	18	91
Fuzzy Creek	1,770	3,200	30	126	100	70	197	18	91
Fuzzy Creek	1,596	3,600	30	114	100	70	197	18	91
Grand Creek	656	3,000	30	132	100	70	164	17	90
Grand Creek	1,274	3,200	30	126	100	70	164	17	90
Grand Creek	2,488	3,400	20	120	100	80	185	17	91
Grand Creek	1,687	3,600	20	114	100	80	185	17	91

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Grand Creek	1,372	3,800	20	108	100	80	185	17	91
Grand Creek	1,386	4,000	30	101	100	70	164	17	90
Grand Creek	3,809	4,200	30	95	95	65	164	28	83
Grand Creek	977	4,400	75	89	89	14	70	40	43
Grand Creek	2,036	4,400	75	89	89	14	70	40	43
Grand Creek	1,604	4,600	75	83	83	8	70	53	24
Hem Creek	1,304	3,800	60	108	100	40	111	18	84
Hem Creek	4,087	4,000	60	101	100	40	111	18	84
Hem Creek	5,418	4,200	60	95	95	35	111	29	74
Hem Creek	1,226	4,200	75	95	95	20	76	29	62
Hem Creek	3,146	4,400	75	89	89	14	76	43	43
Hem Creek	4,643	4,400	75	89	89	14	76	43	43
Hem Creek	447	4,600	75	83	83	8	76	57	25
Hem Creek	1,395	4,600	75	83	83	8	76	57	25
Hem Creek	1,805	4,600	75	83	83	8	76	57	25
Hem Creek	2,437	4,600	75	83	83	8	76	57	25
Hem Creek	938	4,800	75	77	77	2	76	71	7
Hem Creek	2,081	4,800	75	77	77	2	76	71	7
Hook Creek	2,808	2,800	20	139	100	80	185	17	91

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Hook Creek	2,402	3,000	10	132	100	90	206	17	92
Hook Creek	1,530	3,200	10	126	100	90	206	17	92
Hook Creek	3,280	3,400	20	120	100	80	185	17	91
Hook Creek	1,634	3,600	10	114	100	90	206	17	92
Hook Creek	1,439	3,800	10	108	100	90	206	17	92
Hook Creek	1,727	3,800	10	108	100	90	206	17	92
Hook Creek	2,117	4,000	10	101	100	90	206	17	92
Hook Creek	1,439	4,000	75	101	100	25	70	17	76
Hook Creek	1,667	4,200	75	95	95	20	70	28	60
Hook Creek	1,104	4,200	75	95	95	20	70	28	60
Hook Creek	763	4,400	75	89	89	14	70	40	43
Hook Creek	618	4,400	75	89	89	14	70	40	43
Irish Creek	1,095	3,400	60	120	100	40	101	17	83
Irish Creek	3,623	3,600	60	114	100	40	101	17	83
Jazz Creek	585	2,800	30	139	100	70	164	17	90
Jazz Creek	1,578	3,000	30	132	100	70	164	17	90
Jazz Creek	1,144	3,200	30	126	100	70	164	17	90
Jazz Creek	1,475	3,400	30	120	100	70	164	17	90
Jazz Creek	1,259	3,600	20	114	100	80	185	17	91

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Jazz Creek	908	3,600	20	114	100	80	185	17	91
Jazz Creek	1,452	3,800	20	108	100	80	185	17	91
Jazz Creek	1,863	4,000	20	101	100	80	185	17	91
Joy Creek	3,168	4,000	60	101	100	40	101	17	83
Joy Creek	2,471	4,200	60	95	95	35	101	28	72
Joy Creek	2,644	4,400	60	89	89	29	101	40	60
Knute Creek	1,063	2,800	75	139	100	25	70	17	76
Knute Creek	1,190	3,000	10	132	100	90	206	17	92
Knute Creek	897	3,200	10	126	100	90	206	17	92
Knute Creek	671	3,400	30	120	100	70	164	17	90
Knute Creek	919	3,600	30	114	100	70	164	17	90
Knute Creek	4,645	3,800	20	108	100	80	185	17	91
Knute Creek	2,711	4,000	20	101	100	80	185	17	91
Knute Creek	1,965	4,000	20	101	100	80	185	17	91
Knute Creek	1,222	4,200	20	95	95	75	185	28	85
Knute Creek	1,966	4,200	20	95	95	75	185	28	85
L. Orogrande Creek	890	2,200	60	157	100	40	111	18	84
L. Orogrande Creek	3,191	2,200	20	157	100	80	204	18	91
L. Orogrande Creek	693	2,200	20	157	100	80	204	18	91

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
L. Orogrande Creek	4,109	2,400	20	151	100	80	204	18	91
L. Orogrande Creek	648	2,400	20	151	100	80	204	18	91
L. Orogrande Creek	2,914	2,400	20	151	100	80	204	18	91
L. Orogrande Creek	1,366	2,400	60	151	100	40	111	18	84
L. Orogrande Creek	2,236	2,400	20	151	100	80	204	18	91
L. Orogrande Creek	447	2,400	60	151	100	40	111	18	84
L. Orogrande Creek	6,748	2,600	20	145	100	80	204	18	91
L. Orogrande Creek	847	2,600	60	145	100	40	111	18	84
L. Orogrande Creek	792	2,600	30	145	100	70	181	18	90
L. Orogrande Creek	546	2,600	60	145	100	40	111	18	84
L. Orogrande Creek	2,101	2,800	20	139	100	80	204	18	91
L. Orogrande Creek	2,225	2,800	20	139	100	80	204	18	91
L. Orogrande Creek	495	2,800	20	139	100	80	204	18	91
L. Orogrande Creek	413	2,800	60	139	100	40	111	18	84
L. Orogrande Creek	963	2,800	20	139	100	80	204	18	91
L. Orogrande Creek	492	2,800	30	139	100	70	181	18	90
L. Orogrande Creek	455	2,800	60	139	100	40	111	18	84
L. Orogrande Creek	918	3,000	10	132	100	90	227	18	92
L. Orogrande Creek	4,056	3,000	10	132	100	90	227	18	92

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
L. Orogrande Creek	374	3,000	10	132	100	90	227	18	92
L. Orogrande Creek	2,996	3,000	10	132	100	90	227	18	92
L. Orogrande Creek	555	3,000	10	132	100	90	227	18	92
L. Orogrande Creek	3,015	3,000	20	132	100	80	204	18	91
L. Orogrande Creek	250	3,000	10	132	100	90	227	18	92
L. Orogrande Creek	5,110	3,000	10	132	100	90	227	18	92
L. Orogrande Creek	10,082	3,000	20	132	100	80	204	18	91
L. Orogrande Creek	6,173	3,000	10	132	100	90	227	18	92
L. Orogrande Creek	6,530	3,000	20	132	100	80	204	18	91
L. Orogrande Creek	351	3,000	60	132	100	40	111	18	84
L. Orogrande Creek	4,099	3,000	10	132	100	90	227	18	92
L. Orogrande Creek	1,952	3,000	60	132	100	40	111	18	84
L. Orogrande Creek	1,072	3,000	60	132	100	40	111	18	84
L. Orogrande Creek	1,252	3,000	30	132	100	70	181	18	90
L. Orogrande Creek	515	3,000	30	132	100	70	181	18	90
L. Orogrande Creek	485	3,000	60	132	100	40	111	18	84
L. Orogrande Creek	1,341	3,200	20	126	100	80	204	18	91
L. Orogrande Creek	419	3,200	60	126	100	40	111	18	84
L. Orogrande Creek	2,133	3,200	90	126	100	10	41	18	56

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
L. Orogrande Creek	2,022	3,200	45	126	100	55	146	18	88
L. Orogrande Creek	1,240	3,200	75	126	100	25	76	18	76
L. Orogrande Creek	1,493	3,200	30	126	100	70	181	18	90
L. Orogrande Creek	963	3,200	30	126	100	70	181	18	90
L. Orogrande Creek	668	3,200	60	126	100	40	111	18	84
L. Orogrande Creek	1,212	3,200	45	126	100	55	146	18	88
L. Orogrande Creek	4,498	3,200	20	126	100	80	204	18	91
L. Orogrande Creek	919	3,400	75	120	100	25	76	18	76
L. Orogrande Creek	639	3,400	60	120	100	40	111	18	84
L. Orogrande Creek	1,360	3,400	90	120	100	10	41	18	56
L. Orogrande Creek	1,090	3,400	45	120	100	55	146	18	88
L. Orogrande Creek	596	3,400	75	120	100	25	76	18	76
L. Orogrande Creek	1,800	3,400	45	120	100	55	146	18	88
L. Orogrande Creek	518	3,400	30	120	100	70	181	18	90
L. Orogrande Creek	228	3,400	60	120	100	40	111	18	84
L. Orogrande Creek	847	3,400	45	120	100	55	146	18	88
L. Orogrande Creek	1,060	3,600	60	114	100	40	111	18	84
L. Orogrande Creek	557	3,600	45	114	100	55	146	18	88
L. Orogrande Creek	1,357	3,600	45	114	100	55	146	18	88

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
L. Orogrande Creek	568	3,600	30	114	100	70	181	18	90
L. Orogrande Creek	1,450	3,600	50	114	100	50	134	18	87
L. Orogrande Creek	675	3,800	60	108	100	40	111	18	84
L. Orogrande Creek	589	3,800	50	108	100	50	134	18	87
L. Orogrande Creek	598	3,800	30	108	100	70	181	18	90
L. Orogrande Creek	317	4,000	30	101	100	70	181	18	90
Mill Creek	1,169	2,600	30	145	100	70	197	18	91
Mill Creek	1,220	2,800	30	139	100	70	197	18	91
Mill Creek	1,287	3,200	30	126	100	70	197	18	91
Pine Creek	2,003	2,800	45	139	100	55	159	18	89
Pine Creek	2,979	2,800	20	139	100	80	223	18	92
Pine Creek	1,733	3,000	45	132	100	55	159	18	89
Pine Creek	947	3,000	30	132	100	70	197	18	91
Pine Creek	154	3,000	30	132	100	70	197	18	91
Pine Creek	1,960	3,000	30	132	100	70	197	18	91
Pine Creek	1,874	3,000	30	132	100	70	197	18	91
Pine Creek	1,652	3,200	30	126	100	70	197	18	91
Pine Creek	662	3,200	30	126	100	70	197	18	91
Pine Creek	998	3,200	30	126	100	70	197	18	91

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Pine Creek	1,709	3,200	30	126	100	70	197	18	91
Pine Creek	1,309	3,400	30	120	100	70	197	18	91
Pine Creek	1,665	3,400	60	120	100	40	120	18	85
Pine Creek	2,212	3,600	60	114	100	40	120	18	85
S.F. Breakfast Creek	1,130	3,800	60	108	100	40	111	18	84
S.F. Breakfast Creek	1,412	3,800	60	108	100	40	111	18	84
S.F. Breakfast Creek	6,047	3,800	60	108	100	40	111	18	84
S.F. Breakfast Creek	3,055	4,000	20	101	100	80	204	18	91
Shake Creek	1,617	3,000	20	132	100	80	185	17	91
Shake Creek	1,551	3,200	20	126	100	80	185	17	91
Shake Creek	897	3,400	30	120	100	70	164	17	90
Shake Creek	2,241	3,400	20	120	100	80	185	17	91
Shake Creek	1,722	3,600	30	114	100	70	164	17	90
Shake Creek	3,041	3,600	30	114	100	70	164	17	90
Shake Creek	3,439	3,600	30	114	100	70	164	17	90
Shake Creek	1,991	3,800	30	108	100	70	164	17	90
Silver Creek	4,348	3,400	75	120	100	25	70	17	76
Silver Creek	10,656	3,600	50	114	100	50	122	17	86
Silver Creek	6,952	3,800	55	108	100	45	112	17	85

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Sylvan Creek	507	3,600	60	114	100	40	111	18	84
Sylvan Creek	2,688	3,600	30	114	100	70	181	18	90
Sylvan Creek	3,063	3,600	30	114	100	70	181	18	90
Sylvan Creek	1,996	3,800	60	108	100	40	111	18	84
Sylvan Creek	1,672	3,800	60	108	100	40	111	18	84
Sylvan Creek	4,230	3,800	30	108	100	70	181	18	90
Sylvan Creek	1,122	3,800	60	108	100	40	111	18	84
Sylvan Creek	3,900	4,000	60	101	100	40	111	18	84
Sylvan Creek	1,386	4,000	60	101	100	40	111	18	84
Sylvan Creek	1,478	4,000	30	101	100	70	181	18	90
Sylvan Creek	1,101	4,000	45	101	100	55	146	18	88
Sylvan Creek	1,568	4,000	60	101	100	40	111	18	84
Sylvan Creek	1,960	4,200	60	95	95	35	111	29	74
Sylvan Creek	4,374	4,200	50	95	95	45	134	29	78
Sylvan Creek	1,742	4,200	30	95	95	65	181	29	84
Sylvan Creek	2,196	4,200	45	95	95	50	146	29	80
Sylvan Creek	1,089	4,200	60	95	95	35	111	29	74
Sylvan Creek	665	4,200	60	95	95	35	111	29	74
Sylvan Creek	2,445	4,400	60	89	89	29	111	43	61

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Sylvan Creek	1,025	4,400	60	89	89	29	111	43	61
Sylvan Creek	1,177	4,400	45	89	89	44	146	43	71
Sylvan Creek	1,743	4,400	60	89	89	29	111	43	61
Sylvan Creek	1,648	4,600	60	83	83	23	111	57	49
Tamarack Creek	2,001	3,000	60	132	100	40	101	17	83
Tamarack Creek	2,711	3,000	60	132	100	40	101	17	83
Tamarack Creek	2,774	3,000	75	132	100	25	70	17	76
Tamarack Creek	1,969	3,200	60	126	100	40	101	17	83
Tamarack Creek	1,757	3,200	60	126	100	40	101	17	83
Tamarack Creek	2,269	3,200	75	126	100	25	70	17	76
Tamarack Creek	2,136	3,400	60	120	100	40	101	17	83
Tamarack Creek	1,208	3,400	60	120	100	40	101	17	83
Tamarack Creek	1,252	3,400	60	120	100	40	101	17	83
Tamarack Creek	2,639	3,400	60	120	100	40	101	17	83
Tamarack Creek	1,135	3,400	60	120	100	40	101	17	83
Tamarack Creek	1,059	3,400	75	120	100	25	70	17	76
Tamarack Creek	1,037	3,600	60	114	100	40	101	17	83
Tamarack Creek	1,048	3,600	60	114	100	40	101	17	83
Tamarack Creek	1,193	3,800	60	108	100	40	101	17	83

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Tamarack Creek	965	3,800	60	108	100	40	101	17	83
Tamarack Creek	2,437	3,800	60	108	100	40	101	17	83
Tamarack Creek	991	4,000	60	101	100	40	101	17	83
Tamarack Creek	857	4,000	60	101	100	40	101	17	83
Tamarack Creek	903	4,000	60	101	100	40	101	17	83
Tamarack Creek	827	4,000	60	101	100	40	101	17	83
Tamarack Creek	830	4,200	60	95	95	35	101	28	72
Tamarack Creek	1,172	4,200	60	95	95	35	101	28	72
Tamarack Creek	1,019	4,400	60	89	89	29	101	40	60
U. Orogrande Creek	1,940	3,200	60	126	100	40	111	18	84
U. Orogrande Creek	3,494	3,400	30	120	100	70	181	18	90
U. Orogrande Creek	1,839	3,400	30	120	100	70	181	18	90
U. Orogrande Creek	4,256	3,400	75	120	100	25	76	18	76
U. Orogrande Creek	1,096	3,400	60	120	100	40	111	18	84
U. Orogrande Creek	1,514	3,400	45	120	100	55	146	18	88
U. Orogrande Creek	1,853	3,400	60	120	100	40	111	18	84
U. Orogrande Creek	1,817	3,400	75	120	100	25	76	18	76
U. Orogrande Creek	1,348	3,400	60	120	100	40	111	18	84
U. Orogrande Creek	94	3,600	75	114	100	25	76	18	76

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
U. Orogrande Creek	1,033	3,600	75	114	100	25	76	18	76
U. Orogrande Creek	2,224	3,600	60	114	100	40	111	18	84
U. Orogrande Creek	2,153	3,600	55	114	100	45	122	18	85
U. Orogrande Creek	2,746	3,800	75	108	100	25	76	18	76
U. Orogrande Creek	866	3,800	75	108	100	25	76	18	76
U. Orogrande Creek	3,918	3,800	65	108	100	35	99	18	82
U. Orogrande Creek	3,474	4,000	35	101	100	65	169	18	89
U. Orogrande Creek	3,407	4,000	80	101	100	20	64	18	72
W.F. Elk Creek	9,081	3,800	50	108	100	50	122	17	86
W.F. Elk Creek	5,231	3,600	30	114	100	70	164	17	90

[1]More than one segment of a named water body may occur in the same 200-foot elevation zone. Generally this is because unnamed perennial tributaries are included in the analysis, a reach is split because of a radical percent canopy closure change, or a reach is split at the confluence of two tributaries (see map). The only way to know which data apply to which reach on the ground is to use the ArcView data set included with this report.
[2]Current Canopy Closure (%) is estimated from recent 1:15,840 stereo aerial photographs.
[3]CWE Modeled Canopy Closure (%) is the percent canopy closure predicted by the CWE temperature model as needed to protect stream temperatures for salmonid spawning and/or bull trout.

Appendix 5. Osier Creek Watershed Temperature TMDLs (includes Swamp Creek, China Creek, Sugar Creek, and Laundry Creek)

An ArcView shapefile of
these data is on the diskette
located in the back of this document

Appendix 5. Osier Creek Watershed Temperature TMDLs (includes Swamp Creek, China Creek, Sugar Creek and Laundry Creek)

This appendix, along with ArcView shapefile data included on the enclosed diskette, constitutes the temperature TMDLs for Osier Creek, Swamp Creek, China Creek, Sugar Creek, and Laundry Creek. Figure 5-1 shows the distribution of stream segements needing increased percent canopy closure to meet the TMDLs targets. Table 5-1 presents the loading calculations data on a stream reach by stream reach basis. The location of each stream reach can be ascertained using the ArcView shapefile. The ArcView shapefile contains all the data used to create the percent canopy closure increase targets in Figure 5-1 and the data presented in Table 5-1.

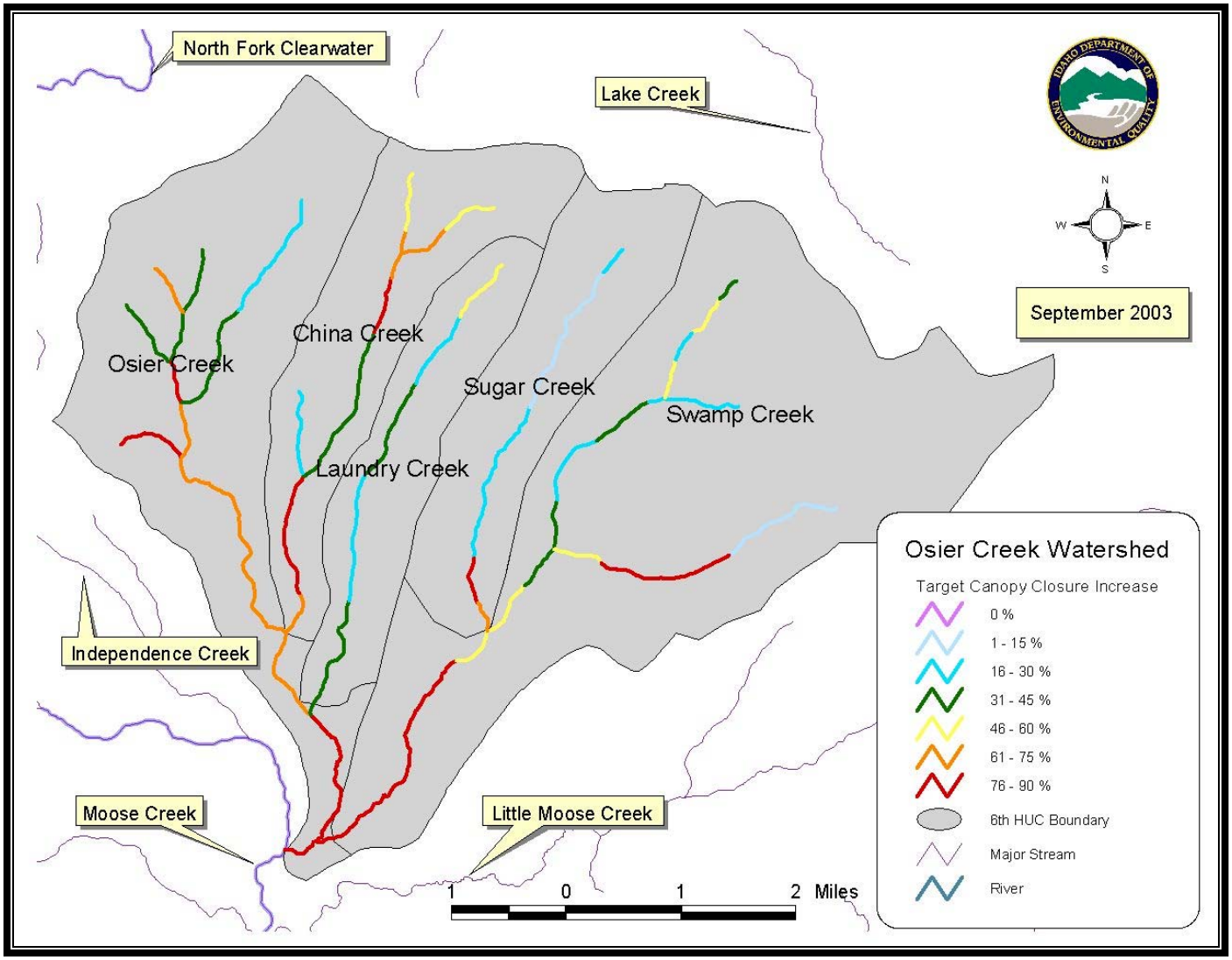

Figure 5-1. Targeted Percent Canopy Closure Increases for the Osier Creek Watershed

Table 5-1. Osier Creek watershed temperature TMDLs, stream reach by stream reach (includes TMDLs for Swamp Creek, China Creek, Sugar Creek, and Laundry Creek).

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
China Creek	2,130	3,600	30	114	100	70	164	17	90
China Creek	1,526	3,600	15	114	100	85	196	17	91
China Creek	4,230	3,800	15	108	100	85	196	17	91
China Creek	4,149	4,000	75	101	100	25	70	17	76
China Creek	7,741	4,000	60	101	100	40	101	17	83
China Creek	2,666	4,200	15	95	95	80	196	28	86
China Creek	1,263	4,200	30	95	95	65	164	28	83
China Creek	1,085	4,200	30	95	95	65	164	28	83
China Creek	2,466	4,200	30	95	95	65	164	28	83
China Creek	2,745	4,400	30	89	89	59	164	40	76
China Creek	2,659	4,400	30	89	89	59	164	40	76
Laundry Creek	3,512	3,600	60	114	100	40	101	17	83
Laundry Creek	2,618	3,800	60	108	100	40	101	17	83
Laundry Creek	3,141	3,800	75	108	100	25	70	17	76
Laundry Creek	2,851	4,000	75	101	100	25	70	17	76
Laundry Creek	2,221	4,000	60	101	100	40	101	17	83
Laundry Creek	2,707	4,200	60	95	95	35	101	28	72

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Laundry Creek	3,740	4,400	60	89	89	29	101	40	60
Laundry Creek	2,199	4,600	30	83	83	53	164	53	68
Laundry Creek	1,059	4,800	30	77	77	47	164	65	60
Osier Creek	1,806	3,200	15	126	100	85	196	17	91
Osier Creek	4,628	3,200	15	126	100	85	196	17	91
Osier Creek	4,624	3,400	30	120	100	70	164	17	90
Osier Creek	2,488	3,400	15	120	100	85	196	17	91
Osier Creek	5,180	3,600	30	114	100	70	164	17	90
Osier Creek	4,141	3,800	30	108	100	70	164	17	90
Osier Creek	2,715	3,800	30	108	100	70	164	17	90
Osier Creek	1,768	3,800	30	108	100	70	164	17	90
Osier Creek	5,524	4,000	60	101	100	40	101	17	83
Osier Creek	6,076	4,200	75	95	95	20	70	28	60
Pioneer Gulch	3,449	4,000	15	101	100	85	196	17	91
Pollock Creek	2,370	3,800	45	108	100	55	146	18	88
Pollock Creek	4,470	4,000	15	101	100	85	216	18	92
Pollock Creek	1,882	4,200	15	95	95	80	216	29	87
Pollock Creek	2,528	4,400	75	89	89	14	76	43	43
Pollock Creek	2,329	4,600	75	83	83	8	76	57	25

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Pollock Creek	1,078	4,800	75	77	77	2	76	71	7
Sugar Creek	1,453	3,600	30	114	100	70	164	17	90
Sugar Creek	1,313	3,800	75	108	100	25	70	17	76
Sugar Creek	2,217	3,800	15	108	100	85	196	17	91
Sugar Creek	2,119	4,000	75	101	100	25	70	17	76
Sugar Creek	842	4,000	75	101	100	25	70	17	76
Sugar Creek	3,550	4,200	75	95	95	20	70	28	60
Sugar Creek	4,031	4,400	75	89	89	14	70	40	43
Sugar Creek	3,411	4,600	75	83	83	8	70	53	24
Sugar Creek	1,414	4,800	50	77	77	27	122	65	47
Swamp Creek	2,385	3,200	15	126	100	85	216	18	92
Swamp Creek	7,814	3,400	15	120	100	85	216	18	92
Swamp Creek	1,687	3,600	15	114	100	85	216	18	92
Swamp Creek	2,267	3,600	45	114	100	55	146	18	88
Swamp Creek	2,856	3,600	45	114	100	55	146	18	88
Swamp Creek	2,200	3,800	60	108	100	40	111	18	84
Swamp Creek	2,351	3,800	60	108	100	40	111	18	84
Swamp Creek	3,678	4,000	75	101	100	25	76	18	76
Swamp Creek	3,073	4,200	60	95	95	35	111	29	74

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Swamp Creek	757	4,400	60	89	89	29	111	43	61
Swamp Creek	1,692	4,400	60	89	89	29	111	43	61
Swamp Creek	1,832	4,400	30	89	89	59	181	43	76
Swamp Creek	1,470	4,600	60	83	83	23	111	57	49
Swamp Creek	1,888	4,800	60	77	77	17	111	71	36
Swamp Creek	2,125	4,800	30	77	77	47	181	71	61
Swamp Creek	1,173	5,000	30	71	71	41	181	85	53
WF Osier Creek	2,442	4,000	60	101	100	40	101	17	83
WF Osier Creek	3,459	4,000	60	101	100	40	101	17	83
WF Osier Creek	2,014	4,000	15	101	100	85	196	17	91
WF Osier Creek	3,105	4,200	60	95	95	35	101	28	72
WF Osier Creek	2,455	4,200	30	95	95	65	164	28	83

[1]More than one segment of a named water body may occur in the same 200-foot elevation zone. Generally this is because unnamed perennial tributaries are included in the analysis, a reach is split at the confluence of two tributaries (see map), or a reach is split because of a radical percent canopy closure change. The only way to know which data apply to which reach on the ground is to use the ArcView data set included with this report.

[2]Current Canopy Closure (%) is estimated from recent 1:15,840 stereo aerial photographs.

[3]CWE Modeled Canopy Closure (%) is the percent canopy closure predicted by the CWE temperature model as needed to protect stream temperatures for salmonid spawning and/or bull trout.

Appendix 6. Cold Springs Creek and Cool Creek Temperature TMDLs

An ArcView shapefile of
these data is on the diskette
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Appendix 6. Cold Springs Creek and Cool Creek Temperature TMDLs

This appendix, along with ArcView shapefile data included on the enclosed diskette, constitutes the temperature TMDLs for Cold Springs Creek and Cool Creek. Figure 6-1 shows the distribution of stream segements needing increased percent canopy closure to meet the TMDLs targets. Tables 6-1 and 6-2 present the loading calculations data on a stream reach by stream reach basis. The location of each stream reach can be ascertained using the ArcView shapefile. The ArcView shapefile contains all the data used to create the percent canopy closure increase targets in Figure 6-1 and the data presented in Tables 6-1 and 6-2.

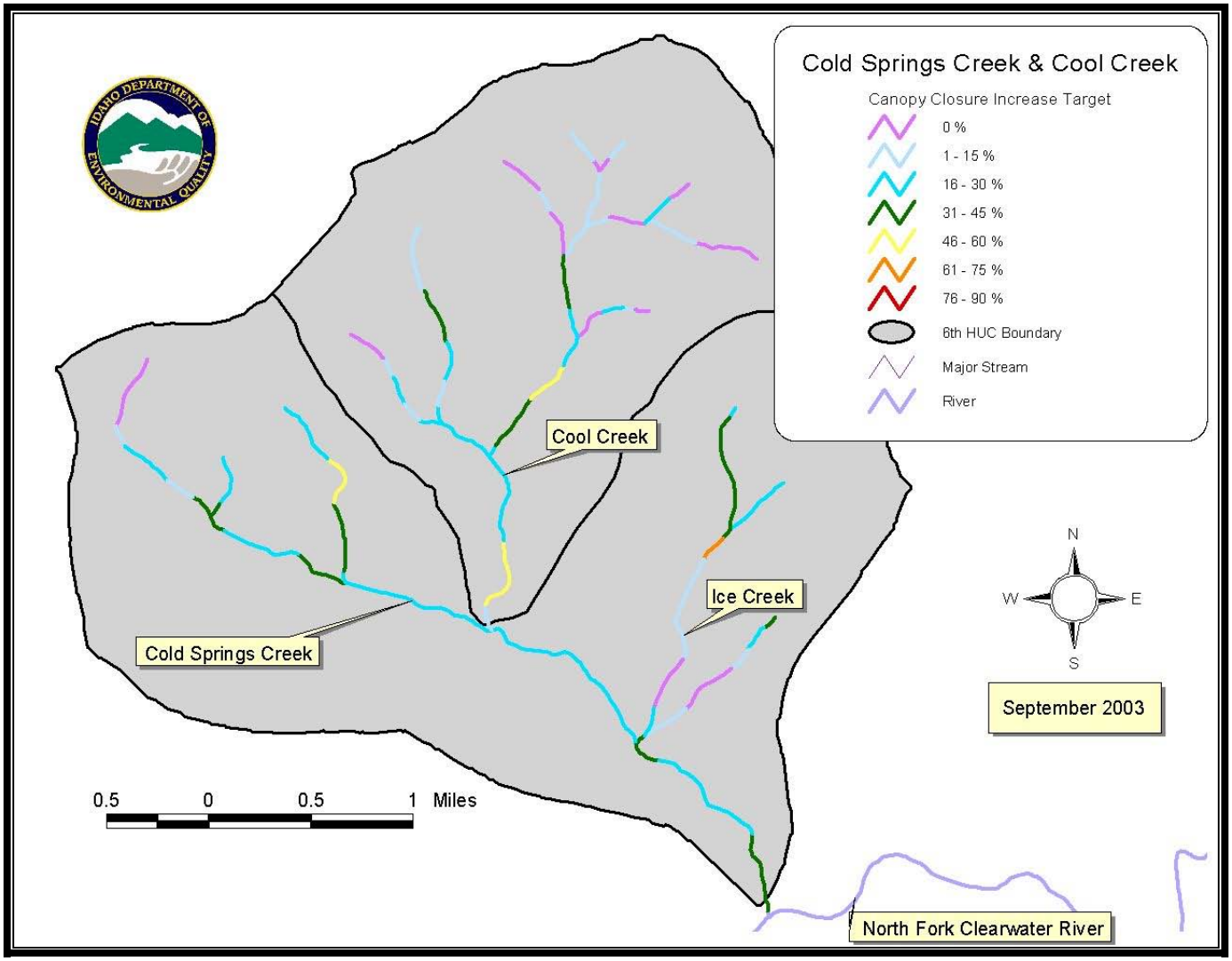

Figure 6-1. Targeted Percent Canopy Closure Increases for Cold Springs Creek and Cool Creek

Table 6-1. Cold Springs Creek temperature TMDL, stream reach by stream reach.

Stream Name	Elevat-ion[1]	Segment Length	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Cold Springs Creek	2,600	2,888	60	145	100	40	111	18	84
Cold Springs Creek	2,800	3,233	75	139	100	25	76	18	76
Cold Springs Creek	3,000	2,655	75	132	100	25	76	18	76
Cold Springs Creek	3,200	3,164	75	126	100	25	76	18	76
Cold Springs Creek	3,400	2,005	75	120	100	25	76	18	76
Cold Springs Creek	3,600	699	60	114	100	40	111	18	84
Cold Springs Creek	3,600	655	45	114	100	55	146	18	88
Cold Springs Creek	3,600	342	75	114	100	25	76	18	76
Cold Springs Creek	3,600	1,451	75	114	100	25	76	18	76
Cold Springs Creek	3,800	894	60	108	100	40	111	18	84
Cold Springs Creek	3,800	815	60	108	100	40	111	18	84
Cold Springs Creek	3,800	595	75	108	100	25	76	18	76
Cold Springs Creek	4,000	1,483	75	101	100	25	76	18	76
Cold Springs Creek	4,000	928	60	101	100	40	111	18	84
Cold Springs Creek	4,200	538	60	95	95	35	111	29	74
Cold Springs Creek	4,200	719	60	95	95	35	111	29	74
Cold Springs Creek	4,200	783	45	95	95	50	146	29	80
Cold Springs Creek	4,200	400	60	95	95	35	111	29	74

Stream Name	Elevat-ion[1]	Segment Length	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Cold Springs Creek	4,400	788	75	89	89	14	76	43	43
Cold Springs Creek	4,400	677	60	89	89	29	111	43	61
Cold Springs Creek	4,600	700	60	83	83	23	111	57	49
Cold Springs Creek	4,600	676	60	83	83	23	111	57	49
Cold Springs Creek	4,600	720	60	83	83	23	111	57	49
Cold Springs Creek	4,800	741	60	77	77	17	111	71	36
Cold Springs Creek	4,800	632	60	77	77	17	111	71	36
Cold Springs Creek	5,000	577	60	71	71	11	111	85	23
Cold Springs Creek	5,000	406	45	71	71	26	146	85	42
Cold Springs Creek	5,200	545	75	64	75	0	76	101	0
Cold Springs Creek	5,400	790	75	58	75	0	76	115	0
Cold Springs Creek	5,600	585	75	52	75	0	76	129	0
Ice Creek	3,000	325	60	132	100	40	101	17	83
Ice Creek	3,000	483	90	132	100	10	38	17	55
Ice Creek	3,000	835	75	132	100	25	70	17	76
Ice Creek	3,200	802	90	126	100	10	38	17	55
Ice Creek	3,200	1,410	100	126	100	0	17	17	0
Ice Creek	3,400	1,370	90	120	100	10	38	17	55
Ice Creek	3,400	784	100	120	100	0	17	17	0

Stream Name	Elevat-ion[1]	Segment Length	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Ice Creek	3,600	767	90	114	100	10	38	17	55
Ice Creek	3,600	825	100	114	100	0	17	17	0
Ice Creek	3,800	719	90	108	100	10	38	17	55
Ice Creek	3,800	689	90	108	100	10	38	17	55
Ice Creek	4,000	738	30	101	100	70	164	17	90
Ice Creek	4,000	685	75	101	100	25	70	17	76
Ice Creek	4,200	326	60	95	95	35	101	28	72
Ice Creek	4,200	507	60	95	95	35	101	28	72
Ice Creek	4,200	425	60	95	95	35	101	28	72
Ice Creek	4,400	755	60	89	89	29	101	40	60
Ice Creek	4,400	1,080	45	89	89	44	133	40	70
Ice Creek	4,600	575	60	83	83	23	101	53	48
Ice Creek	4,600	864	45	83	83	38	133	53	60
Ice Creek	4,800	470	60	77	77	17	101	65	36
Ice Creek	4,800	576	45	77	77	32	133	65	51
Ice Creek	5,000	275	45	71	71	26	133	78	41

[1]More than one segment of a named water body may occur in the same 200-foot elevation zone. Generally this is because unnamed perennial tributaries are included in the analysis, a reach is split because of a radical percent canopy closure change, or a reach is split at the confluence of two tributaries (see map). The only way to know which data apply to which reach on the ground is to use the ArcView data set included with this report.
[2]Current Canopy Closure (%) is estimated from recent 1:15,840 stereo aerial photographs.
[3]CWE Modeled Canopy Closure (%) is the percent canopy closure predicted by the CWE temperature model as needed to protect stream temperatures for salmonid spawning and/or bull trout.

Table 6-2. Cool Creek temperature TMDL, stream reach by stream reach.

Stream Name	Elevat-ion[1]	Segment Length	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Cool Creek	3,400	694	90	120	100	10	38	17	55
Cool Creek	3,400	1,987	45	120	100	55	133	17	87
Cool Creek	3,600	1,575	75	114	100	25	70	17	76
Cool Creek	3,800	812	75	108	100	25	70	17	76
Cool Creek	4,000	1,502	75	101	100	25	70	17	76
Cool Creek	4,000	323	75	101	100	25	70	17	76
Cool Creek	4,000	1,523	60	101	100	40	101	17	83
Cool Creek	4,200	496	75	95	95	20	70	28	60
Cool Creek	4,200	606	75	95	95	20	70	28	60
Cool Creek	4,200	1,240	45	95	95	50	133	28	79
Cool Creek	4,400	364	90	89	90	0	38	40	0
Cool Creek	4,400	795	60	89	89	29	101	40	60
Cool Creek	4,400	666	75	89	89	14	70	40	43
Cool Creek	4,400	583	75	89	89	14	70	40	43
Cool Creek	4,400	820	60	89	89	29	101	40	60
Cool Creek	4,600	1,057	60	83	83	23	101	53	48
Cool Creek	4,600	754	60	83	83	23	101	53	48

Stream Name	Elevat-ion[1]	Segment Length	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Cool Creek	4,600	598	90	83	90	0	38	53	0
Cool Creek	4,600	1,378	45	83	83	38	133	53	60
Cool Creek	4,800	802	75	77	77	2	70	65	7
Cool Creek	4,800	947	75	77	77	2	70	65	7
Cool Creek	4,800	655	75	77	77	2	70	65	7
Cool Creek	4,800	544	75	77	77	2	70	65	7
Cool Creek	4,800	1,478	45	77	77	32	133	65	51
Cool Creek	4,800	1,211	90	77	90	0	38	65	0
Cool Creek	4,800	560	60	77	77	17	101	65	36
Cool Creek	5,000	377	75	71	75	0	70	78	0
Cool Creek	5,000	710	60	71	71	11	101	78	23
Cool Creek	5,000	955	75	71	75	0	70	78	0
Cool Creek	5,000	658	60	71	71	11	101	78	23
Cool Creek	5,000	561	75	71	75	0	70	78	0
Cool Creek	5,000	1,086	60	71	71	11	101	78	23
Cool Creek	5,000	294	60	71	71	11	101	78	23
Cool Creek	5,000	332	75	71	75	0	70	78	0
Cool Creek	5,200	630	60	64	64	4	101	93	8
Cool Creek	5,200	514	75	64	75	0	70	93	0

Stream Name	Elevat-ion[1]	Segment Length	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Cool Creek	5,200	646	60	64	64	4	101	93	8
Cool Creek	5,200	625	75	64	75	0	70	93	0
Cool Creek	5,200	1,446	60	64	64	4	101	93	8
Cool Creek	5,200	936	45	64	64	19	133	93	30
Cool Creek	5,200	905	60	64	64	4	101	93	8
Cool Creek	5,200	382	75	64	75	0	70	93	0
Cool Creek	5,400	471	75	58	75	0	70	105	0
Cool Creek	5,400	396	75	58	75	0	70	105	0
Cool Creek	5,400	556	75	58	75	0	70	105	0
Cool Creek	5,400	586	60	58	60	0	101	105	0
Cool Creek	5,600	777	75	52	75	0	70	118	0

[1]More than one segment of a named water body may occur in the same 200-foot elevation zone. Generally this is because unnamed perennial tributaries are included in the analysis, a reach is split at the confluence of two tributaries (see map), or a reach is split because of a radical percent canopy closure change. The only way to know which data apply to which reach on the ground is to use the ArcView data set included with this report.
[2]Current Canopy Closure (%) is estimated from recent 1:15,840 stereo aerial photographs.
[3]CWE Modeled Canopy Closure (%) is the percent canopy closure predicted by the CWE temperature model as needed to protect stream temperatures for salmonid spawning and/or bull trout.

Appendix 7. Grizzly Creek and Cougar Creek Temperature TMDLs

An ArcView shapefile of
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Appendix 7. Grizzly Creek and Cougar Creek Temperature TMDLs

This appendix, along with ArcView shapefile data included on the enclosed diskette, constitutes the temperature TMDLs for Grizzly Creek and Cougar Creek. Figure 7-1 shows the distribution of stream segements needing increased percent canopy closure to meet the TMDLs targets. Tables 7-1 and 7-2 present the loading calculations data on a stream reach by stream reach basis. The location of each stream reach can be ascertained using the ArcView shapefile. The ArcView shapefile contains all the data used to create the percent canopy closure increase targets in Figure 7-1 and the data presented in Tables 7-1 and 7-2.

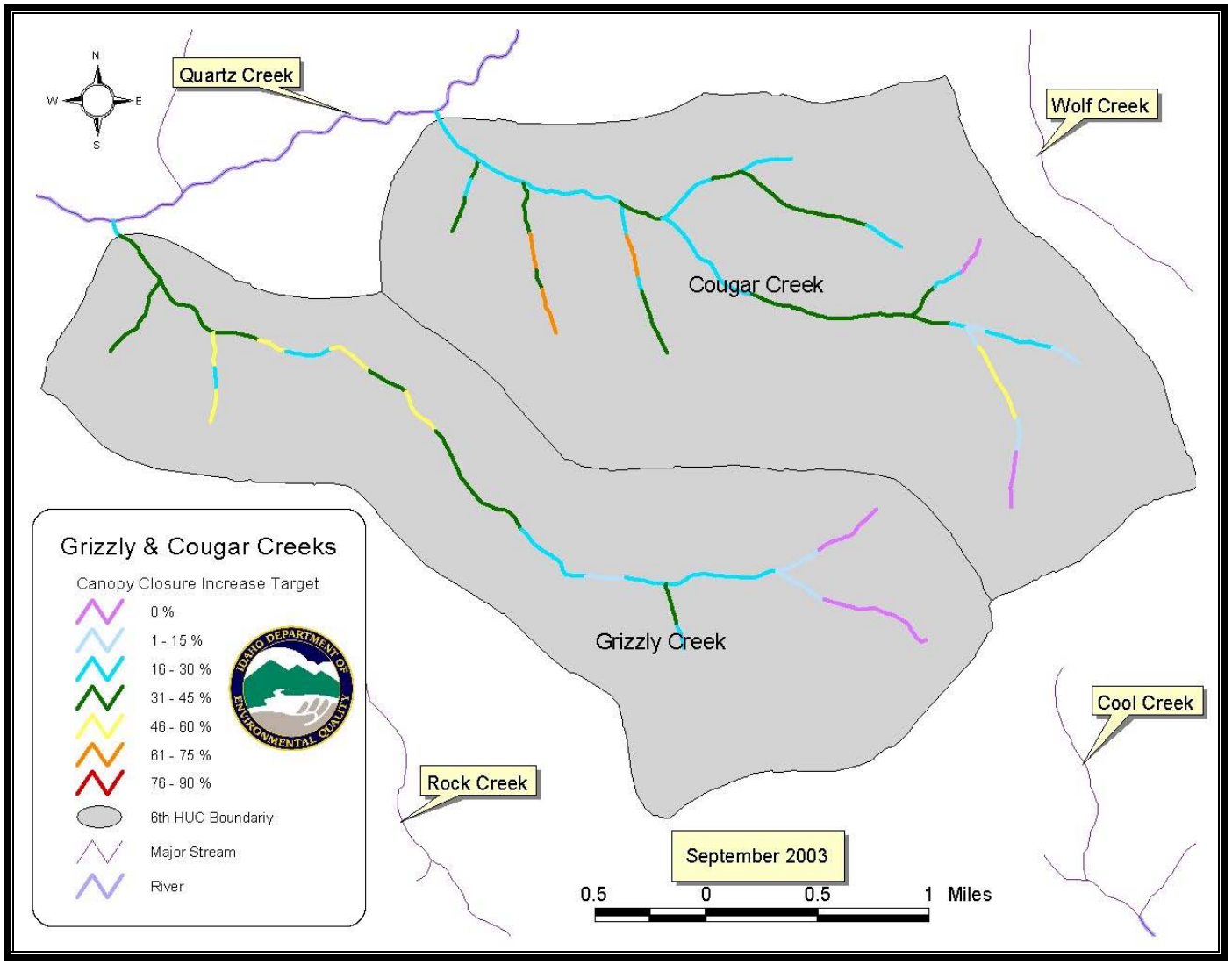

Figure 7-1. Targeted Percent Canopy Closure Increases for Grizzly Creek and Cougar Creek

Table 7-1. Grizzly Creek temperature TMDL, stream reach by stream reach.

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Grizzly Creek	385	2,200	75	157	100	25	76	18	76
Grizzly Creek	1,435	2,200	60	157	100	40	111	18	84
Grizzly Creek	565	2,400	60	151	100	40	111	18	84
Grizzly Creek	1,271	2,400	60	151	100	40	111	18	84
Grizzly Creek	609	2,600	60	145	100	40	111	18	84
Grizzly Creek	441	2,600	60	145	100	40	111	18	84
Grizzly Creek	1,089	2,800	60	139	100	40	111	18	84
Grizzly Creek	239	2,800	45	139	100	55	146	18	88
Grizzly Creek	432	2,800	60	139	100	40	111	18	84
Grizzly Creek	716	3,000	45	132	100	55	146	18	88
Grizzly Creek	253	3,000	45	132	100	55	146	18	88
Grizzly Creek	387	3,000	60	132	100	40	111	18	84
Grizzly Creek	1,104	3,200	75	126	100	25	76	18	76
Grizzly Creek	344	3,200	45	126	100	55	146	18	88
Grizzly Creek	303	3,200	60	126	100	40	111	18	84
Grizzly Creek	1,099	3,400	45	120	100	55	146	18	88
Grizzly Creek	524	3,400	75	120	100	25	76	18	76
Grizzly Creek	1,024	3,600	60	114	100	40	111	18	84
Grizzly Creek	404	3,600	45	114	100	55	146	18	88

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Grizzly Creek	1,179	3,800	45	108	100	55	146	18	88
Grizzly Creek	374	3,800	45	108	100	55	146	18	88
Grizzly Creek	1,535	4,000	60	101	100	40	111	18	84
Grizzly Creek	1,688	4,200	60	95	95	35	111	29	74
Grizzly Creek	2,027	4,400	60	89	89	29	111	43	61
Grizzly Creek	966	4,600	75	83	83	8	76	57	25
Grizzly Creek	974	4,600	60	83	83	23	111	57	49
Grizzly Creek	1,709	4,800	60	77	77	17	111	71	36
Grizzly Creek	1,004	4,800	60	77	77	17	111	71	36
Grizzly Creek	1,024	4,800	45	77	77	32	146	71	51
Grizzly Creek	569	4,800	60	77	77	17	111	71	36
Grizzly Creek	1,141	5,000	60	71	71	11	111	85	23
Grizzly Creek	1,320	5,000	60	71	71	11	111	85	23
Grizzly Creek	1,709	5,200	90	64	90	0	41	101	0
Grizzly Creek	1,646	5,200	90	64	90	0	41	101	0
Grizzly Creek	1,118	5,400	90	58	90	0	41	115	0

[1]More than one segment of a named water body may occur in the same 200-foot elevation zone. Generally this is because unnamed perennial tributaries are included in the analysis, a reach is split at the confluence of two tributaries (see map), or a reach is split because of a radical percent canopy closure change. The only way to know which data apply to which reach on the ground is to use the ArcView data set included with this report.
[2]Current Canopy Closure (%) is estimated from recent 1:15,840 stereo aerial photographs.
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Table 7-2. Cougar Creek temperature TMDL, stream reach by stream reach.

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Cougar Creek	221	2,400	75	151	100	25	82	18	78
Cougar Creek	1,351	2,400	75	151	100	25	82	18	78
Cougar Creek	498	2,600	60	145	100	40	120	18	85
Cougar Creek	1,200	2,600	75	145	100	25	82	18	78
Cougar Creek	1,007	2,600	75	145	100	25	82	18	78
Cougar Creek	458	2,600	60	145	100	40	120	18	85
Cougar Creek	435	2,800	75	139	100	25	82	18	78
Cougar Creek	1,411	2,800	75	139	100	25	82	18	78
Cougar Creek	421	2,800	60	139	100	40	120	18	85
Cougar Creek	496	3,000	60	132	100	40	120	18	85
Cougar Creek	780	3,000	75	132	100	25	82	18	78
Cougar Creek	377	3,000	60	132	100	40	120	18	85
Cougar Creek	1,088	3,000	60	132	100	40	120	18	85
Cougar Creek	546	3,000	75	132	100	25	82	18	78
Cougar Creek	384	3,200	60	126	100	40	120	18	85
Cougar Creek	387	3,200	30	126	100	70	197	18	91
Cougar Creek	470	3,200	30	126	100	70	197	18	91

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Cougar Creek	1,192	3,200	75	126	100	25	82	18	78
Cougar Creek	770	3,200	75	126	100	25	82	18	78
Cougar Creek	478	3,400	30	120	100	70	197	18	91
Cougar Creek	556	3,400	30	120	100	70	197	18	91
Cougar Creek	1,161	3,400	75	120	100	25	82	18	78
Cougar Creek	757	3,400	75	120	100	25	82	18	78
Cougar Creek	465	3,600	60	114	100	40	120	18	85
Cougar Creek	337	3,600	75	114	100	25	82	18	78
Cougar Creek	1,062	3,600	60	114	100	40	120	18	85
Cougar Creek	341	3,600	75	114	100	25	82	18	78
Cougar Creek	706	3,600	60	114	100	40	120	18	85
Cougar Creek	408	3,600	60	114	100	40	120	18	85
Cougar Creek	624	3,800	30	108	100	70	197	18	91
Cougar Creek	922	3,800	60	108	100	40	120	18	85
Cougar Creek	927	3,800	75	108	100	25	82	18	78
Cougar Creek	1,364	3,800	60	108	100	40	120	18	85
Cougar Creek	1,346	3,800	60	108	100	40	120	18	85
Cougar Creek	474	4,000	30	101	100	70	197	18	91

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Cougar Creek	654	4,000	60	101	100	40	120	18	85
Cougar Creek	759	4,000	60	101	100	40	120	18	85
Cougar Creek	1,494	4,000	60	101	100	40	120	18	85
Cougar Creek	890	4,200	60	95	95	35	120	31	74
Cougar Creek	760	4,200	60	95	95	35	120	31	74
Cougar Creek	938	4,200	60	95	95	35	120	31	74
Cougar Creek	980	4,400	60	89	89	29	120	46	62
Cougar Creek	390	4,400	60	89	89	29	120	46	62
Cougar Creek	485	4,400	75	89	89	14	82	46	44
Cougar Creek	522	4,400	75	89	89	14	82	46	44
Cougar Creek	749	4,400	60	89	89	29	120	46	62
Cougar Creek	945	4,600	60	83	83	23	120	62	48
Cougar Creek	957	4,600	30	83	83	53	197	62	69
Cougar Creek	611	4,600	90	83	90	0	44	62	0
Cougar Creek	308	4,600	90	83	90	0	44	62	0
Cougar Creek	986	4,800	30	77	77	47	197	77	61
Cougar Creek	697	4,800	60	77	77	17	120	77	36
Cougar Creek	796	5,000	60	71	71	11	120	92	23

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Cougar Creek	725	5,000	60	71	71	11	120	92	23
Cougar Creek	913	5,200	75	64	75	0	82	110	0
Cougar Creek	413	5,400	75	58	75	0	82	126	0

[1]More than one segment of a named water body may occur in the same 200-foot elevation zone. Generally this is because unnamed perennial tributaries are included in the analysis, a reach is split at the confluence of two tributaries (see map), or a reach is split because of a radical percent canopy closure change. The only way to know which data apply to which reach on the ground is to use the ArcView data set included with this report.

[2]Current Canopy Closure (%) is estimated from recent 1:15,840 stereo aerial photographs.

[3]CWE Modeled Canopy Closure (%) is the percent canopy closure predicted by the CWE temperature model as needed to protect stream temperatures for salmonid spawning and/or bull trout.

Appendix 8. Gravey Creek and Marten Creek Temperature TMDLs

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these data is on the diskette
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Appendix 8. Gravey Creek and Marten Creek Temperature TMDLs

This appendix, along with ArcView shapefile data included on the enclosed diskette, constitutes the temperature TMDLs for Gravey Creek and Marten Creek. Figure 8-1 shows the distribution of stream segements needing increased percent canopy closure to meet the TMDLs targets. Tables 8-1 and 8-2 present the loading calculations data on a stream reach by stream reach basis. The location of each stream reach can be ascertained using the ArcView shapefile. The ArcView shapefile contains all the data used to create the percent canopy closure increase targets in Figure 8-1 and the data presented in Tables 8-1 and 8-2.

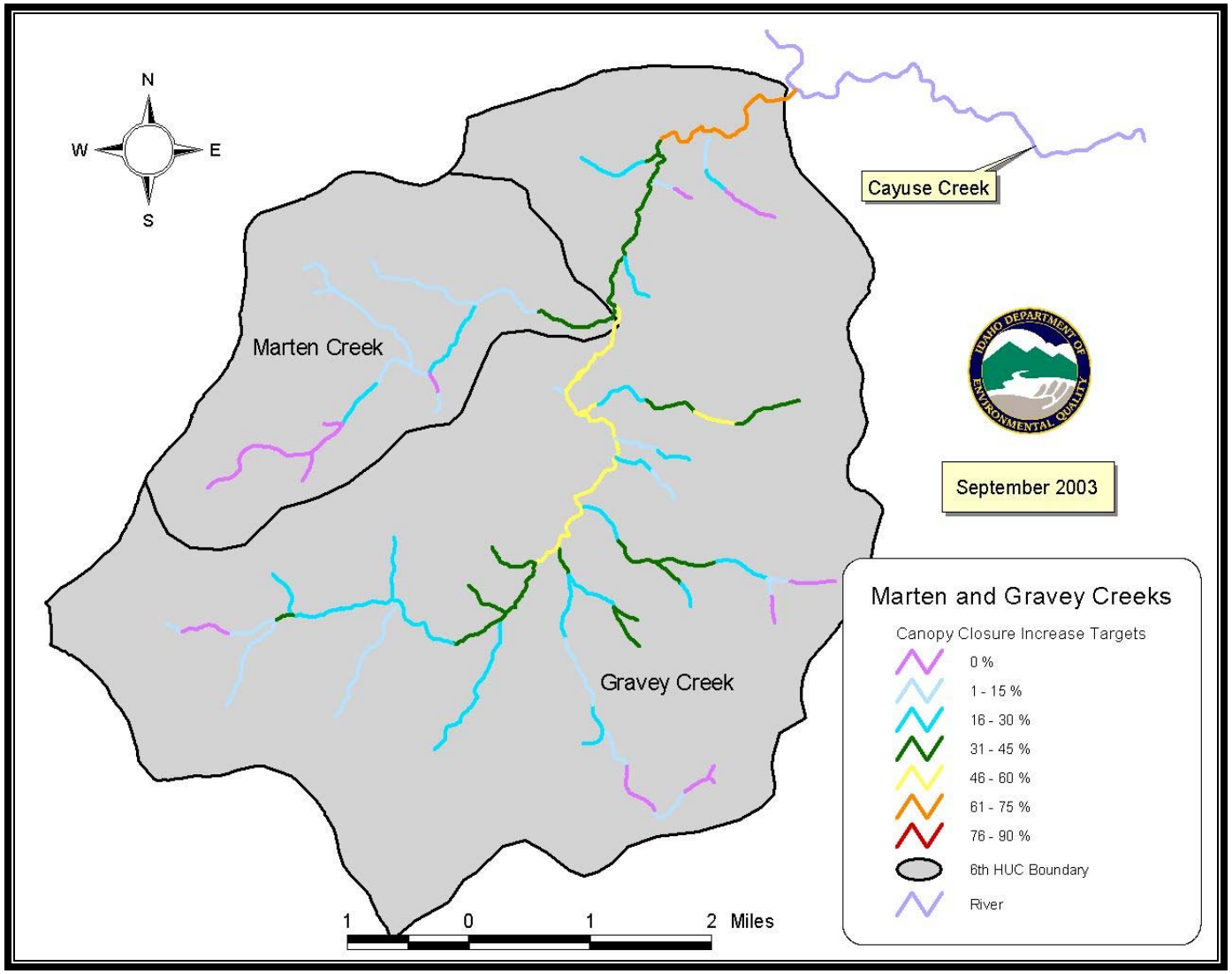

Figure 8-1. Targeted Percent Canopy Closure Increases for Gravey Creek and Marten Creek

Table 8-1. Gravey Creek temperature TMDL, stream reach by stream reach.

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Alder Creek	1,067	4,000	90	101	100	10	41	18	56
Alder Creek	858	4,200	100	95	100	0	18	29	0
Blowup Creek	963	4,200	45	95	95	50	159	31	81
Blowup Creek	2,684	4,400	60	89	89	29	120	46	62
Blowup Creek	2,403	4,600	45	83	83	38	159	62	61
Blowup Creek	1,901	4,800	30	77	77	47	197	77	61
Blowup Creek	1,202	5,000	30	71	71	41	197	92	53
Blowup Creek	1,816	5,200	30	64	64	34	197	110	44
Grass Creek	1,677	4,000	90	101	100	10	41	18	56
Grass Creek	1,211	4,200	75	95	95	20	76	29	62
Grass Creek	1,312	4,400	90	89	90	0	41	43	0
Grass Creek	1,196	4,600	90	83	90	0	41	57	0
Gravey Creek	2,936	4,000	30	101	100	70	181	18	90
Gravey Creek	5,321	4,000	30	101	100	70	181	18	90
Gravey Creek	559	4,000	60	101	100	40	111	18	84
Gravey Creek	1,576	4,000	60	101	100	40	111	18	84
Gravey Creek	3,957	4,000	60	101	100	40	111	18	84

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Gravey Creek	564	4,200	90	95	95	5	41	29	29
Gravey Creek	1,125	4,200	45	95	95	50	146	29	80
Gravey Creek	5,561	4,200	45	95	95	50	146	29	80
Gravey Creek	2,258	4,200	45	95	95	50	146	29	80
Gravey Creek	2,493	4,200	60	95	95	35	111	29	74
Gravey Creek	690	4,200	60	95	95	35	111	29	74
Gravey Creek	2,178	4,200	75	95	95	20	76	29	62
Gravey Creek	2,399	4,400	30	89	89	59	181	43	76
Gravey Creek	2,658	4,400	30	89	89	59	181	43	76
Gravey Creek	1,217	4,400	60	89	89	29	111	43	61
Gravey Creek	854	4,400	30	89	89	59	181	43	76
Gravey Creek	581	4,400	30	89	89	59	181	43	76
Gravey Creek	1,818	4,400	60	89	89	29	111	43	61
Gravey Creek	1,986	4,400	75	89	89	14	76	43	43
Gravey Creek	1,325	4,400	30	89	89	59	181	43	76
Gravey Creek	2,548	4,600	60	83	83	23	111	57	49
Gravey Creek	5,403	4,600	60	83	83	23	111	57	49
Gravey Creek	1,120	4,600	60	83	83	23	111	57	49
Gravey Creek	1,671	4,600	75	83	83	8	76	57	25

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Gravey Creek	1,571	4,600	60	83	83	23	111	57	49
Gravey Creek	3,106	4,600	45	83	83	38	146	57	61
Gravey Creek	2,155	4,600	45	83	83	38	146	57	61
Gravey Creek	2,398	4,600	45	83	83	38	146	57	61
Gravey Creek	1,180	4,800	45	77	77	32	146	71	51
Gravey Creek	2,134	4,800	60	77	77	17	111	71	36
Gravey Creek	2,491	4,800	75	77	77	2	76	71	7
Gravey Creek	1,391	4,800	60	77	77	17	111	71	36
Gravey Creek	2,322	4,800	75	77	77	2	76	71	7
Gravey Creek	832	4,800	60	77	77	17	111	71	36
Gravey Creek	1,419	4,800	45	77	77	32	146	71	51
Gravey Creek	2,039	4,800	45	77	77	32	146	71	51
Gravey Creek	2,764	4,800	60	77	77	17	111	71	36
Gravey Creek	1,233	4,800	60	77	77	17	111	71	36
Gravey Creek	2,224	5,000	60	71	71	11	111	85	23
Gravey Creek	1,084	5,000	45	71	71	26	146	85	42
Gravey Creek	3,460	5,000	60	71	71	11	111	85	23
Gravey Creek	789	5,200	60	64	64	4	111	101	9
Gravey Creek	1,147	5,400	75	58	75	0	76	115	0

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Gravey Creek	389	5,400	75	58	75	0	76	115	0
Horseshoe Creek	2,413	4,400	60	89	89	29	120	46	62
Horseshoe Creek	2,218	4,600	45	83	83	38	159	62	61
Horseshoe Creek	2,602	4,600	45	83	83	38	159	62	61
Horseshoe Creek	2,504	5,000	45	71	71	26	159	92	42
Horseshoe Creek	1,014	5,200	60	64	64	4	120	110	8
Horseshoe Creek	1,972	5,400	75	58	75	0	82	126	0
Mire Creek	3,289	4,600	60	83	83	23	120	62	48
Mire Creek	2,396	4,600	45	83	83	38	159	62	61
Mire Creek	3,734	4,600	60	83	83	23	120	62	48
Mire Creek	2,245	4,800	75	77	77	2	82	77	6
Mire Creek	1,385	4,800	60	77	77	17	120	77	36
Mire Creek	791	4,800	45	77	77	32	159	77	52
Mire Creek	2,205	5,000	75	71	75	0	82	92	0
Mire Creek	769	5,200	60	64	64	4	120	110	8
Serpent Creek	1,356	4,400	45	89	89	44	133	40	70
Serpent Creek	1,098	4,400	60	89	89	29	101	40	60
Serpent Creek	1,793	4,600	60	83	83	23	101	53	48
Serpent Creek	3,256	4,600	75	83	83	8	70	53	24

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Serpent Creek	1,183	4,800	60	77	77	17	101	65	36
Serpent Creek	2,116	4,800	75	77	77	2	70	65	7
Serpent Creek	2,553	5,000	75	71	75	0	70	78	0
Serpent Creek	1,977	5,200	60	64	64	4	101	93	8
Serpent Creek	550	5,400	75	58	75	0	70	105	0
Serpent Creek	1,199	5,400	75	58	75	0	70	105	0

[1]More than one segment of a named water body may occur in the same 200-foot elevation zone. Generally this is because unnamed perennial tributaries are included in the analysis, a reach is split at the confluence of two tributaries (see map), or a reach is split because of a radical percent canopy closure change. The only way to know which data apply to which reach on the ground is to use the ArcView data set included with this report.

[2]Current Canopy Closure (%) is estimated from recent 1:15,840 stereo aerial photographs.

[3]CWE Modeled Canopy Closure (%) is the percent canopy closure predicted by the CWE temperature model as needed to protect stream temperatures for salmonid spawning and/or bull trout.

Table 8-2. Marten Creek temperature TMDL, stream reach by stream reach.

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
False Creek	788	4,400	75	89	89	14	76	43	43
False Creek	2,116	4,600	75	83	83	8	76	57	25
False Creek	2,387	5,000	60	71	71	11	111	85	23
Marten Creek	1,660	4,200	60	95	95	35	111	29	74
Marten Creek	2,457	4,200	60	95	95	35	111	29	74
Marten Creek	3,346	4,400	75	89	89	14	76	43	43
Marten Creek	1,767	4,400	60	89	89	29	111	43	61
Marten Creek	933	4,600	75	83	83	8	76	57	25
Marten Creek	1,946	4,600	60	83	83	23	111	57	49
Marten Creek	1,001	4,600	90	83	90	0	41	57	0
Marten Creek	2,138	4,600	75	83	83	8	76	57	25
Marten Creek	824	4,800	75	77	77	2	76	71	7
Marten Creek	2,272	4,800	60	77	77	17	111	71	36
Marten Creek	1,350	5,000	75	71	75	0	76	85	0
Marten Creek	824	5,000	75	71	75	0	76	85	0
Marten Creek	1,829	5,000	75	71	75	0	76	85	0

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Marten Creek	822	5,000	75	71	75	0	76	85	0
Marten Creek	3,544	5,200	75	64	75	0	76	101	0
Marten Creek	1,263	5,400	60	58	60	0	111	115	0
Shin Tangle Creek	729	4,600	75	83	83	8	76	57	25
Shin Tangle Creek	2,601	4,800	75	77	77	2	76	71	7
Shin Tangle Creek	967	5,000	60	71	71	11	111	85	23
Shin Tangle Creek	1,640	5,000	60	71	71	11	111	85	23
Shin Tangle Creek	2,031	5,000	60	71	71	11	111	85	23

[1]More than one segment of a named water body may occur in the same 200-foot elevation zone. Generally this is because unnamed perennial tributaries are included in the analysis, a reach is split at the confluence of two tributaries (see map), or a reach is split because of a radical percent canopy closure change. The only way to know which data apply to which reach on the ground is to use the ArcView data set included with this report.

[2]Current Canopy Closure (%) is estimated from recent 1:15,840 stereo aerial photographs.

[3]CWE Modeled Canopy Closure (%) is the percent canopy closure predicted by the CWE temperature model as needed to protect stream temperatures for salmonid spawning and/or bull trout.

Appendix 9. Middle Creek Temperature TMDL

An ArcView shapefile of
these data is on the diskette
located in the back of this document

Appendix 9. Middle Creek Temperature TMDL

This appendix, along with ArcView shapefile data included on the enclosed diskette, constitutes the temperature TMDL for Middle Creek. Figure 9-1 shows the distribution of stream segements needing increased percent canopy closure to meet the TMDL targets. Table 9-1 presents the loading calculations data on a stream reach by stream reach basis. The location of each stream reach can be ascertained using the ArcView shapefile. The ArcView shapefile contains all the data used to create the percent canopy closure increase targets in Figure 9-1 and the data presented in Table 9-1.

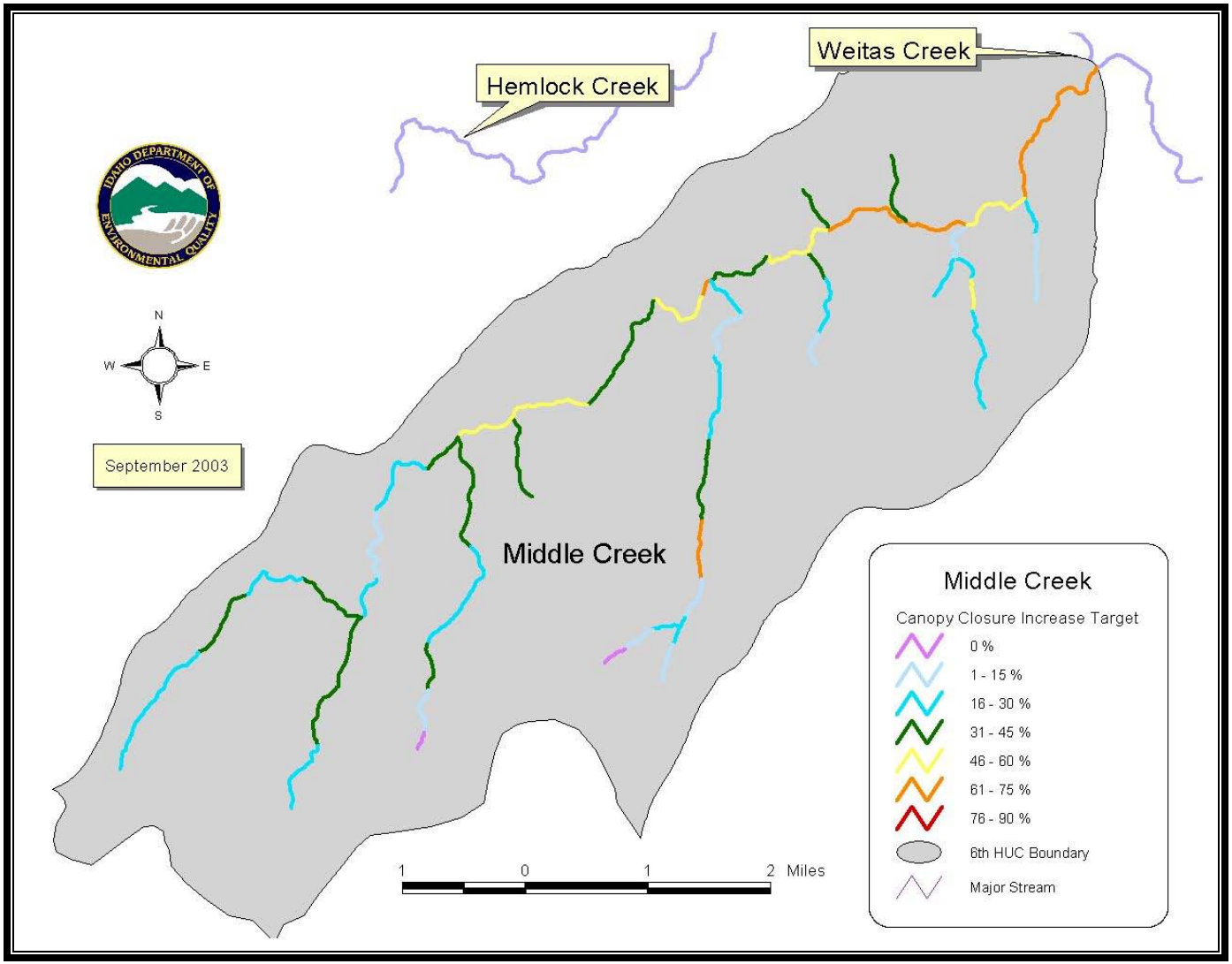

Figure 9-1. Targeted Percent Canopy Closure Increases for Middle Creek

Table 9-1. Middle Creek temperature TMDL, stream reach by stream reach.

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Beaver Dam Creek	6,280	4,600	45	83	83	38	133	53	60
Beaver Dam Creek	3,351	4,800	60	77	77	17	101	65	36
Felix Creek	1,801	4,000	60	101	100	40	101	17	83
Felix Creek	3,420	4,200	60	95	95	35	101	28	72
Felix Creek	2,444	4,400	60	89	89	29	101	40	60
Felix Creek	2,849	4,600	60	83	83	23	101	53	48
Felix Creek	2,100	4,800	45	77	77	32	133	65	51
Felix Creek	2,018	5,000	60	71	71	11	101	78	23
Felix Creek	805	5,200	75	64	75	0	70	93	0
Flame Creek	2,091	3,200	90	126	100	10	38	17	55
Flame Creek	1,282	3,400	75	120	100	25	70	17	76
Flame Creek	1,118	3,400	75	120	100	25	76	18	76
Flame Creek	1,360	3,600	45	114	100	55	133	17	87
Flame Creek	710	3,600	75	114	100	25	76	18	76
Flame Creek	1,235	3,800	75	108	100	25	70	17	76
Flame Creek	1,888	4,000	75	101	100	25	70	17	76
Flame Creek	1,434	4,200	75	95	95	20	70	28	60

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Middle Creek	1,272	2,800	30	139	100	70	181	18	90
Middle Creek	4,856	2,800	30	139	100	70	181	18	90
Middle Creek	793	3,000	75	132	100	25	76	18	76
Middle Creek	1,658	3,000	30	132	100	70	181	18	90
Middle Creek	3,279	3,000	45	132	100	55	146	18	88
Middle Creek	988	3,200	30	126	100	70	181	18	90
Middle Creek	908	3,200	75	126	100	25	76	18	76
Middle Creek	1,969	3,200	30	126	100	70	181	18	90
Middle Creek	3,989	3,200	30	126	100	70	181	18	90
Middle Creek	1,658	3,200	60	126	100	40	111	18	84
Middle Creek	750	3,400	45	120	100	55	146	18	88
Middle Creek	696	3,400	60	120	100	40	111	18	84
Middle Creek	1,150	3,400	90	120	100	10	41	18	56
Middle Creek	715	3,400	60	120	100	40	111	18	84
Middle Creek	823	3,400	60	120	100	40	111	18	84
Middle Creek	877	3,400	45	120	100	55	146	18	88
Middle Creek	2,180	3,400	45	120	100	55	146	18	88
Middle Creek	714	3,600	60	114	100	40	111	18	84
Middle Creek	854	3,600	30	114	100	70	181	18	90

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Middle Creek	1,761	3,600	90	114	100	10	41	18	56
Middle Creek	489	3,600	60	114	100	40	111	18	84
Middle Creek	699	3,600	60	114	100	40	111	18	84
Middle Creek	3,079	3,600	60	114	100	40	111	18	84
Middle Creek	3,055	3,600	45	114	100	55	146	18	88
Middle Creek	1,240	3,600	60	114	100	40	111	18	84
Middle Creek	858	3,800	75	108	100	25	76	18	76
Middle Creek	945	3,800	60	108	100	40	111	18	84
Middle Creek	4,478	3,800	60	108	100	40	111	18	84
Middle Creek	4,436	3,800	45	108	100	55	146	18	88
Middle Creek	1,849	4,000	45	101	100	55	146	18	88
Middle Creek	2,032	4,000	60	101	100	40	111	18	84
Middle Creek	1,786	4,000	75	101	100	25	76	18	76
Middle Creek	2,175	4,000	60	101	100	40	111	18	84
Middle Creek	3,696	4,200	75	95	95	20	76	29	62
Middle Creek	1,535	4,200	90	95	95	5	41	29	29
Middle Creek	1,661	4,200	60	95	95	35	111	29	74
Middle Creek	3,692	4,400	75	89	89	14	76	43	43
Middle Creek	2,039	4,400	60	89	89	29	111	43	61

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Middle Creek	3,264	4,600	45	83	83	38	146	57	61
Middle Creek	3,251	4,800	60	77	77	17	111	71	36
Middle Creek	3,301	5,000	30	71	71	41	181	85	53
Middle Creek	2,159	5,000	45	71	71	26	146	85	42
Middle Creek	4,192	5,200	45	64	64	19	146	101	31
Rocky Ridge Creek	2,085	3,600	75	114	100	25	70	17	76
Rocky Ridge Creek	2,439	3,600	90	114	100	10	38	17	55
Rocky Ridge Creek	3,973	3,800	75	108	100	25	70	17	76
Rocky Ridge Creek	3,570	4,000	60	101	100	40	101	17	83
Rocky Ridge Creek	2,556	4,200	30	95	95	65	164	28	83
Rocky Ridge Creek	1,886	4,400	75	89	89	14	70	40	43
Rocky Ridge Creek	500	4,600	60	83	83	23	101	53	48
Rocky Ridge Creek	766	4,600	60	83	83	23	111	57	49
Rocky Ridge Creek	1,233	4,800	60	77	77	17	111	71	36
Rocky Ridge Creek	1,710	4,800	75	77	77	2	76	71	7
Rocky Ridge Creek	836	5,000	60	71	71	11	111	85	23
Rocky Ridge Creek	632	5,200	60	64	64	4	111	101	9
Rocky Ridge Creek	1,135	5,400	75	58	75	0	76	115	0

[1]More than one segment of a named water body may occur in the same 200-foot elevation zone. Generally this is because unnamed perennial tributaries are included in the analysis, a reach is split at the confluence of two tributaries (see map), or a reach is split because of a radical percent canopy closure change. The only way to know which data apply to which reach on the ground is to use the ArcView data set included with this report.
[2]Current Canopy Closure (%) is estimated from recent 1:15,840 stereo aerial photographs.
[3]CWE Modeled Canopy Closure (%) is the percent canopy closure predicted by the CWE temperature model as needed to protect stream temperatures for salmonid spawning and/or bull trout.

Appendix 10. Sneak Creek Temperature TMDL

An ArcView shapefile of
these data is on the diskette
located in the back of this document

Appendix 10. Sneak Creek Temperature TMDL

This appendix, along with ArcView shapefile data included on the enclosed diskette, constitutes the temperature TMDL for Sneak Creek. Figure 10-1 shows the distribution of stream segements needing increased percent canopy closure to meet the TMDL targets. Table 10-1 presents the loading calculations data on a stream reach by stream reach basis. The location of each stream reach can be ascertained using the ArcView shapefile. The ArcView shapefile contains all the data used to create the percent canopy closure increase targets in Figure 10-1 and the data presented in Table 10-1.

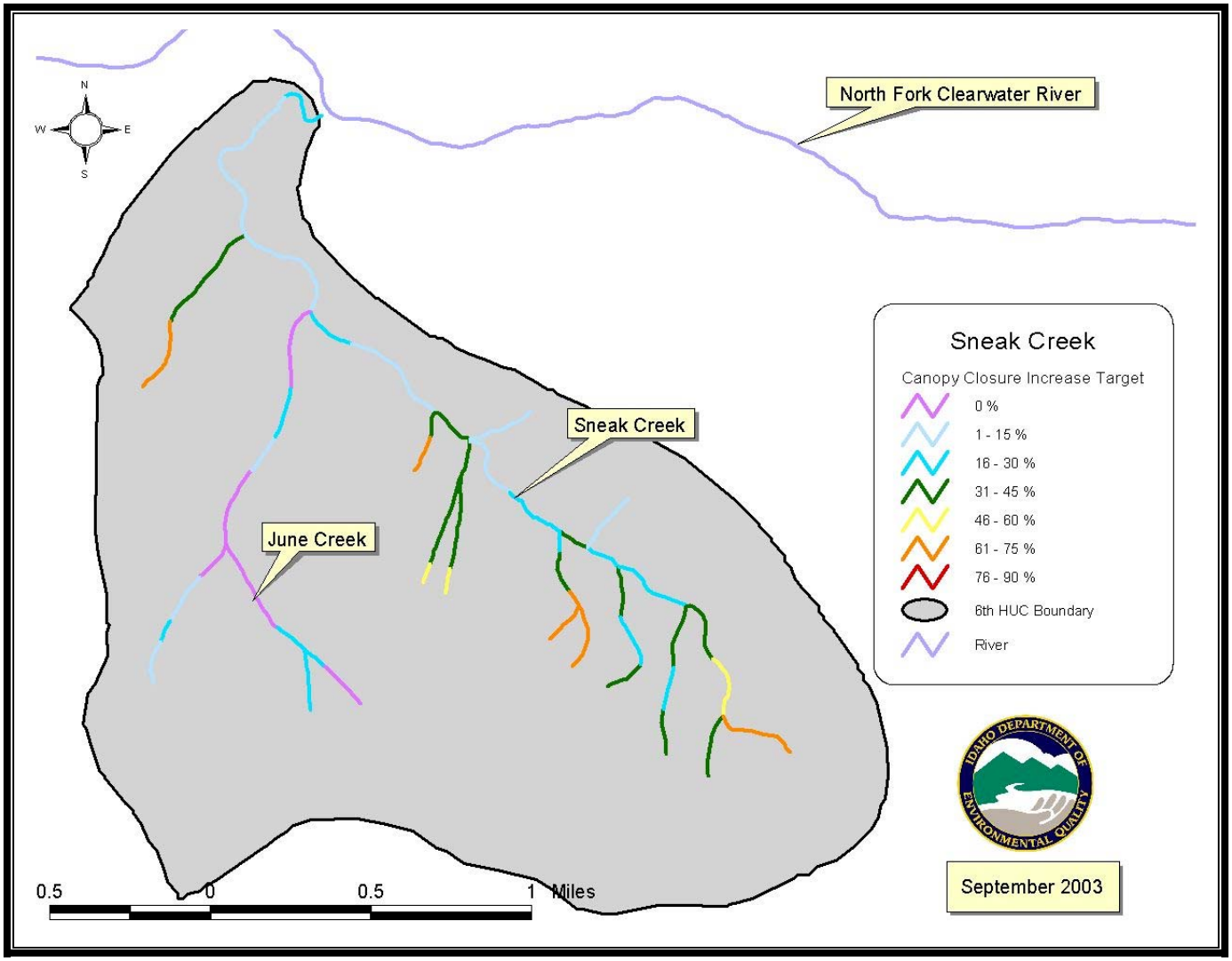

Figure 10-1. Targeted Percent Canopy Closure Increases for Sneak Creek

Table 10-1. Sneak Creek temperature TMDL, stream reach by stream reach.

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
June Creek	793	2,400	100	151	100	0	17	17	0
June Creek	616	2,600	100	145	100	0	17	17	0
June Creek	835	2,800	75	139	100	25	70	17	76
June Creek	681	3,000	90	132	100	10	38	17	55
June Creek	737	3,200	100	126	100	0	17	17	0
June Creek	577	3,400	100	120	100	0	17	17	0
June Creek	720	3,600	100	114	100	0	17	17	0
June Creek	473	3,800	90	108	100	10	38	17	55
June Creek	396	4,000	90	101	100	10	38	17	55
June Creek	380	4,200	75	95	95	20	70	28	60
June Creek	714	4,400	75	89	89	14	70	40	43
Sneak Creek	974	1,800	75	169	100	25	76	18	76
Sneak Creek	1,872	1,800	90	169	100	10	41	18	56
Sneak Creek	1,088	2,000	90	163	100	10	41	18	56
Sneak Creek	447	2,200	60	157	100	40	111	18	84
Sneak Creek	1,978	2,200	90	157	100	10	41	18	56
Sneak Creek	883	2,400	75	151	100	25	76	18	76

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Sneak Creek	598	2,400	60	151	100	40	111	18	84
Sneak Creek	434	2,600	60	145	100	40	111	18	84
Sneak Creek	1,411	2,600	90	145	100	10	41	18	56
Sneak Creek	440	2,800	90	139	100	10	41	18	56
Sneak Creek	742	2,800	60	139	100	40	111	18	84
Sneak Creek	440	2,800	60	139	100	40	111	18	84
Sneak Creek	433	2,800	60	139	100	40	111	18	84
Sneak Creek	320	3,000	30	132	100	70	181	18	90
Sneak Creek	618	3,000	30	132	100	70	181	18	90
Sneak Creek	642	3,000	60	132	100	40	111	18	84
Sneak Creek	382	3,000	90	132	100	10	41	18	56
Sneak Creek	1,214	3,000	90	132	100	10	41	18	56
Sneak Creek	520	3,200	60	126	100	40	111	18	84
Sneak Creek	452	3,200	30	126	100	70	181	18	90
Sneak Creek	708	3,200	60	126	100	40	111	18	84
Sneak Creek	733	3,200	60	126	100	40	111	18	84
Sneak Creek	742	3,200	90	126	100	10	41	18	56
Sneak Creek	1,084	3,200	75	126	100	25	76	18	76
Sneak Creek	356	3,200	75	126	100	25	76	18	76

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Sneak Creek	472	3,400	30	120	100	70	181	18	90
Sneak Creek	374	3,400	60	120	100	40	111	18	84
Sneak Creek	359	3,400	60	120	100	40	111	18	84
Sneak Creek	627	3,400	75	120	100	25	76	18	76
Sneak Creek	679	3,400	60	120	100	40	111	18	84
Sneak Creek	481	3,400	90	120	100	10	41	18	56
Sneak Creek	843	3,400	60	120	100	40	111	18	84
Sneak Creek	1,001	3,400	75	120	100	25	76	18	76
Sneak Creek	719	3,600	100	114	100	0	18	18	0
Sneak Creek	421	3,600	60	114	100	40	111	18	84
Sneak Creek	431	3,600	60	114	100	40	111	18	84
Sneak Creek	281	3,600	30	114	100	70	181	18	90
Sneak Creek	576	3,600	90	114	100	10	41	18	56
Sneak Creek	401	3,600	30	114	100	70	181	18	90
Sneak Creek	613	3,600	30	114	100	70	181	18	90
Sneak Creek	871	3,600	75	114	100	25	76	18	76
Sneak Creek	334	3,600	75	114	100	25	76	18	76
Sneak Creek	1,088	3,600	60	114	100	40	111	18	84
Sneak Creek	345	3,800	100	108	100	0	18	18	0

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Sneak Creek	269	3,800	100	108	100	0	18	18	0
Sneak Creek	332	3,800	45	108	100	55	146	18	88
Sneak Creek	421	3,800	45	108	100	55	146	18	88
Sneak Creek	336	3,800	30	108	100	70	181	18	90
Sneak Creek	492	3,800	30	108	100	70	181	18	90
Sneak Creek	659	3,800	60	108	100	40	111	18	84
Sneak Creek	1,037	3,800	60	108	100	40	111	18	84
Sneak Creek	1,045	3,800	45	108	100	55	146	18	88
Sneak Creek	392	3,800	60	108	100	40	111	18	84
Sneak Creek	603	3,800	30	108	100	70	181	18	90
Sneak Creek	709	3,800	75	108	100	25	76	18	76
Sneak Creek	287	4,000	100	101	100	0	18	18	0
Sneak Creek	415	4,000	75	101	100	25	76	18	76
Sneak Creek	755	4,000	60	101	100	40	111	18	84
Sneak Creek	667	4,000	60	101	100	40	111	18	84
Sneak Creek	760	4,000	30	101	100	70	181	18	90
Sneak Creek	172	4,200	75	95	95	20	76	29	62
Sneak Creek	311	4,200	75	95	95	20	76	29	62
Sneak Creek	421	4,200	75	95	95	20	76	29	62

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Sneak Creek	858	4,400	90	89	90	0	41	43	0
Sneak Creek	689	4,400	60	89	89	29	111	43	61

[1]More than one segment of a named water body may occur in the same 200-foot elevation zone. Generally this is because unnamed perennial tributaries are included in the analysis, a reach is split at the confluence of two tributaries (see map), or a reach is split because of a radical percent canopy closure change. The only way to know which data apply to which reach on the ground is to use the ArcView data set included with this report.

[2]Current Canopy Closure (%) is estimated from recent 1:15,840 stereo aerial photographs.

[3]CWE Modeled Canopy Closure (%) is the percent canopy closure predicted by the CWE temperature model as needed to protect stream temperatures for salmonid spawning and/or bull trout.

Appendix 11. Deception Gulch Temperature TMDL

An ArcView shapefile of
these data is on the diskette
located in the back of this document

Appendix 11. Deception Gulch Temperature TMDL

This appendix, along with ArcView shapefile data included on the enclosed diskette, constitutes the temperature TMDL for Deception Gulch. Figure 11-1 shows the distribution of stream segements needing increased percent canopy closure to meet the TMDL targets. Table 11-1 presents the loading calculations data on a stream reach by stream reach basis. The location of each stream reach can be ascertained using the ArcView shapefile. The ArcView shapefile contains all the data used to create the percent canopy closure increase targets in Figure 11-1 and the data presented in Table 11-1.

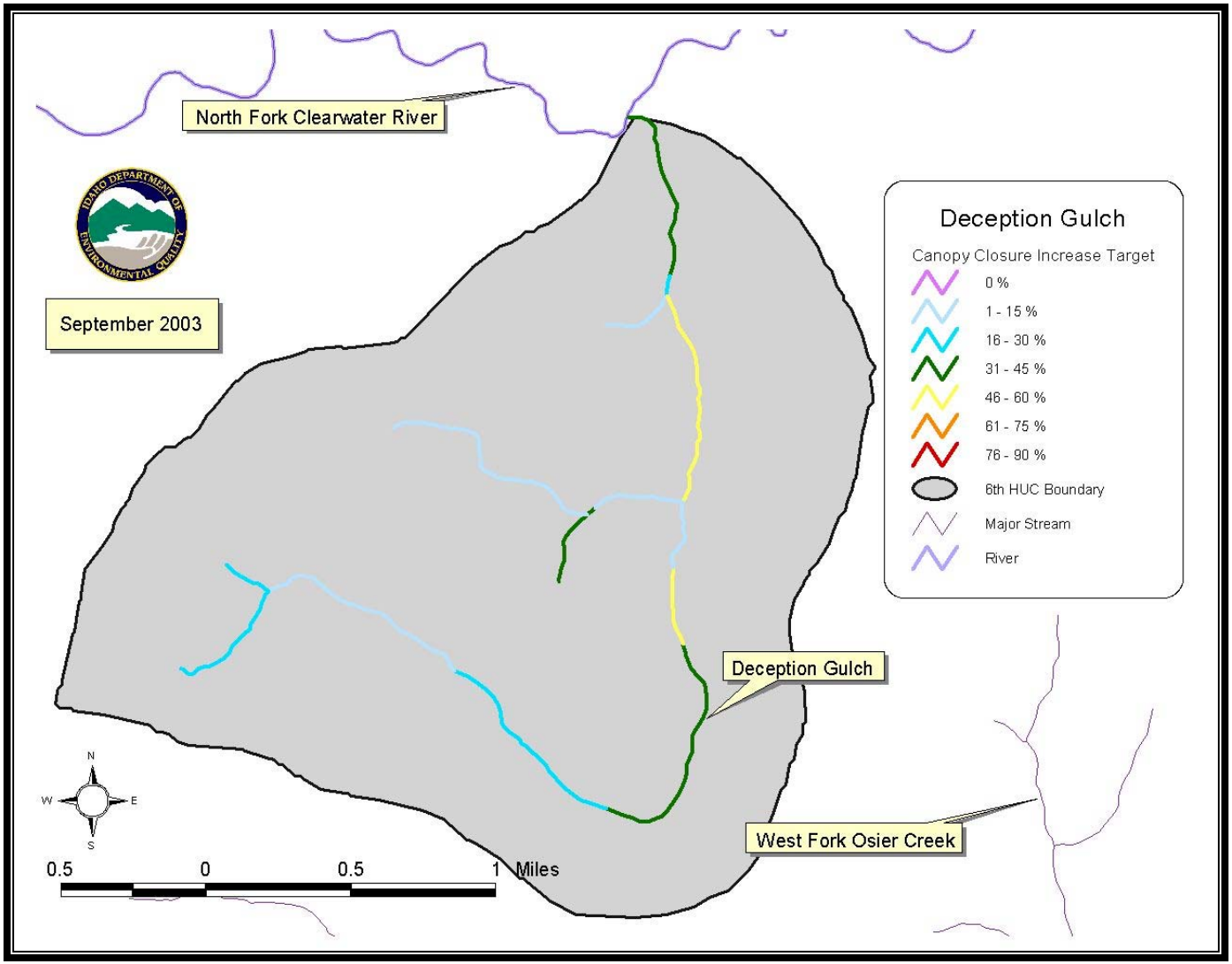

Figure 11-1. Targeted Percent Canopy Closure Increases for Deception Gulch

Table 11-1. Deception Gulch temperature TMDL, stream reach by stream reach.

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Deception Gulch	3,356	3,400	60	120	100	40	101	17	83
Deception Gulch	1,376	3,600	90	114	100	10	38	17	55
Deception Gulch	356	3,600	75	114	100	25	70	17	76
Deception Gulch	3,940	3,600	45	114	100	55	133	17	87
Deception Gulch	184	3,800	60	108	100	40	101	17	83
Deception Gulch	1,670	3,800	90	108	100	10	38	17	55
Deception Gulch	1,397	3,800	60	108	100	40	101	17	83
Deception Gulch	653	3,800	90	108	100	10	38	17	55
Deception Gulch	1,366	3,800	90	108	100	10	38	17	55
Deception Gulch	1,366	3,800	45	108	100	55	133	17	87
Deception Gulch	2,210	4,000	90	101	100	10	38	17	55
Deception Gulch	4,510	4,000	60	101	100	40	101	17	83
Deception Gulch	1,541	4,200	90	95	95	5	38	28	26
Deception Gulch	3,867	4,200	75	95	95	20	70	28	60
Deception Gulch	2,542	4,400	75	89	89	14	70	40	43
Deception Gulch	1,508	4,600	75	83	83	8	70	53	24
Deception Gulch	2,398	4,800	60	77	77	17	101	65	36

Stream Name	Stream Segment Length	Elevat-ion[1]	Current Canopy Closure[2]	CWE Modeled Canopy Closure[3]	Target Canopy Closure	Target Canopy Closure Increase	Current Insolation Heat Load	Target Insolation Heat Load	Target Insolation Heat Load Reduction
	(feet)	(feet)	(%)	(%)	(%)	(%)	(watts/m^2)	(watts/m^2)	(%)
Deception Gulch	915	4,800	60	77	77	17	101	65	36

[1]More than one segment of a named water body may occur in the same 200-foot elevation zone. Generally this is because unnamed perennial tributaries are included in the analysis, a reach is split at the confluence of two tributaries (see map), or a reach is split because of a radical percent canopy closure change. The only way to know which data apply to which reach on the ground is to use the ArcView data set included with this report.

[2]Current Canopy Closure (%) is estimated from recent 1:15,840 stereo aerial photographs.

[3]CWE Modeled Canopy Closure (%) is the percent canopy closure predicted by the CWE temperature model as needed to protect stream temperatures for salmonid spawning and/or bull trout.

Appendix 12. CWE Road Sediment Delivery Assessment Data

The data shown in this appendix are
in an AcrView shapefile
on the diskette
in the back of this document.

Appendix 12. CWE Road Sediment Delivery Assessment Data

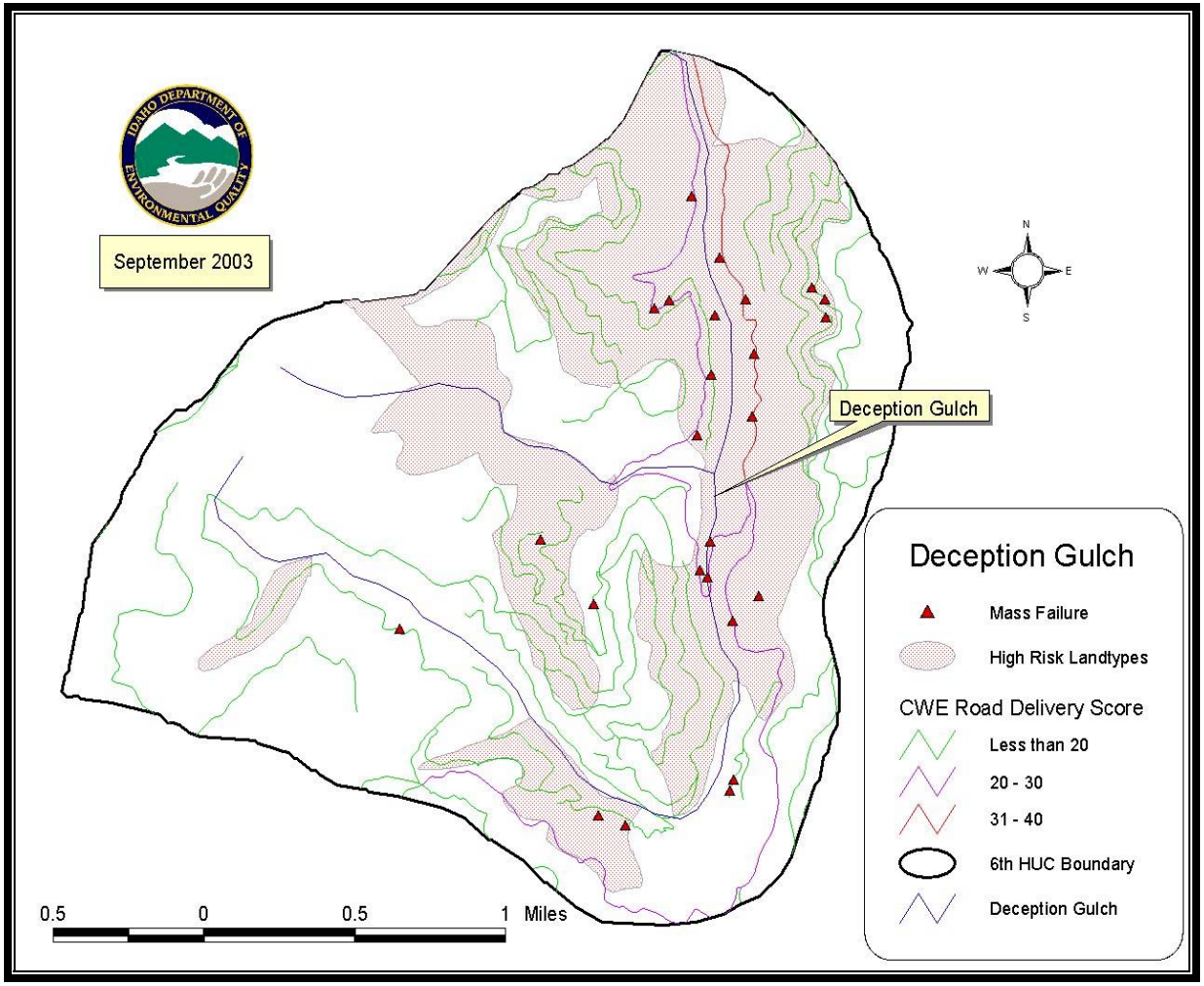

Figure 12-1. Roads Assessed Using the CWE Sediment Delivery Protocol

Table 12-1. CWE road sediment delivery data[1], road segment by road segment.

Road Segment Length (Feet)	Road Segment Length (Miles)	Cut Slope Erosion Rating	Fill Slope Erosion Rating	Road Surface Erosion Rating	Inside Ditch Erosion Rating	Delivery Multiplier	Total Road Sediment Delivery Score	Assumed Road Sediment Delivery Score
7,719	1.46	2	1	2	2	2	36	0
4,320	0.82	1	1	2	2	2	30	0
1,414	0.27	1	1	2	2	2	30	0
2,341	0.44	1	1	2	2	2	30	0
601	0.11	1	1	1	1	2	20	0
5,480	1.04	1	1	1	1	2	20	0
5,862	1.11	1	1	1	1	2	20	0
4,226	0.80	1	1	1	1	2	20	0
3,877	0.73	1	1	1	1	2	20	0
2,183	0.41	1	1	1	1	2	20	0
615	0.12	1	1	1	1	2	20	0
605	0.12	1	1	1	1	2	20	0
1,371	0.26	1	1	2	2	1	15	0
800	0.15	1	1	2	2	1	15	0
2,397	0.45	1	1	2	2	1	15	0
1,102	0.21	1	1	1	1	1	10	0
1,788	0.34	1	1	1	1	1	10	0
1,731	0.33	0	0	0	0	0	0	15

Road Segment Length (Feet)	Road Segment Length (Miles)	Cut Slope Erosion Rating	Fill Slope Erosion Rating	Road Surface Erosion Rating	Inside Ditch Erosion Rating	Delivery Multiplier	Total Road Sediment Delivery Score	Assumed Road Sediment Delivery Score
502	0.10	0	0	0	0	0	0	15
1,506	0.29	0	0	0	0	0	0	15
535	0.10	0	0	0	0	0	0	15
160	0.03	0	0	0	0	0	0	15
472	0.09	0	0	0	0	0	0	15
248	0.05	0	0	0	0	0	0	15
2,495	0.47	0	0	0	0	0	0	15
715	0.14	0	0	0	0	0	0	15
3,673	0.70	0	0	0	0	0	0	15
2,250	0.43	0	0	0	0	0	0	15
3,331	0.63	0	0	0	0	0	0	15
738	0.14	0	0	0	0	0	0	15
1,363	0.26	0	0	0	0	0	0	15
268	0.05	0	0	0	0	0	0	15
89	0.02	0	0	0	0	0	0	15
4,896	0.93	0	0	0	0	0	0	15
2,169	0.41	0	0	0	0	0	0	15
941	0.18	0	0	0	0	0	0	15
3,633	0.69	0	0	0	0	0	0	15

Road Segment Length (Feet)	Road Segment Length (Miles)	Cut Slope Erosion Rating	Fill Slope Erosion Rating	Road Surface Erosion Rating	Inside Ditch Erosion Rating	Delivery Multiplier	Total Road Sediment Delivery Score	Assumed Road Sediment Delivery Score
4,906	0.93	0	0	0	0	0	0	15
4,899	0.93	0	0	0	0	0	0	15
1,494	0.28	0	0	0	0	0	0	15
1,875	0.36	0	0	0	0	0	0	15
1,734	0.33	0	0	0	0	0	0	15
3,270	0.62	0	0	0	0	0	0	15
449	0.09	0	0	0	0	0	0	15
739	0.14	0	0	0	0	0	0	15
4,144	0.79	0	0	0	0	0	0	15
432	0.08	0	0	0	0	0	0	15
789	0.15	0	0	0	0	0	0	15
1,649	0.31	0	0	0	0	0	0	15
278	0.05	0	0	0	0	0	0	15
219	0.04	0	0	0	0	0	0	15
4,049	0.77	0	0	0	0	0	0	15
68	0.01	0	0	0	0	0	0	15
1,151	0.22	0	0	0	0	0	0	15
96	0.02	0	0	0	0	0	0	15
3,814	0.72	0	0	0	0	0	0	15

Road Segment Length (Feet)	Road Segment Length (Miles)	Cut Slope Erosion Rating	Fill Slope Erosion Rating	Road Surface Erosion Rating	Inside Ditch Erosion Rating	Delivery Multiplier	Total Road Sediment Delivery Score	Assumed Road Sediment Delivery Score
1,276	0.24	0	0	0	0	0	0	15
383	0.07	0	0	0	0	0	0	15
3,948	0.75	0	0	0	0	0	0	15
3,979	0.75	0	0	0	0	0	0	15
70	0.01	0	0	0	0	0	0	15
3,665	0.69	0	0	0	0	0	0	15
3,282	0.62	0	0	0	0	0	0	15
1,086	0.21	0	0	0	0	0	0	15
983	0.19	0	0	0	0	0	0	15
1,105	0.21	0	0	0	0	0	0	15
217	0.04	0	0	0	0	0	0	15
2,653	0.50	0	0	0	0	0	0	15
522	0.10	0	0	0	0	0	0	15
1,416	0.27	0	0	0	0	0	0	15
1,112	0.21	0	0	0	0	0	0	15
2,042	0.39	0	0	0	0	0	0	15
3,467	0.66	0	0	0	0	0	0	15
371	0.07	0	0	0	0	0	0	15
278	0.05	0	0	0	0	0	0	15

Road Segment Length (Feet)	Road Segment Length (Miles)	Cut Slope Erosion Rating	Fill Slope Erosion Rating	Road Surface Erosion Rating	Inside Ditch Erosion Rating	Delivery Multiplier	Total Road Sediment Delivery Score	Assumed Road Sediment Delivery Score
39	0.01	0	0	0	0	0	0	15
643	0.12	0	0	0	0	0	0	15
597	0.11	0	0	0	0	0	0	15
7	0.00	0	0	0	0	0	0	15
991	0.19	0	0	0	0	0	0	15
1,811	0.34	0	0	0	0	0	0	15
1,800	0.34	0	0	0	0	0	0	15
1,048	0.20	0	0	0	0	0	0	15
973	0.18	0	0	0	0	0	0	15
1,024	0.19	0	0	0	0	0	0	15
788	0.15	0	0	0	0	0	0	15
2,702	0.51	0	0	0	0	0	0	15
1,904	0.36	0	0	0	0	0	0	15
217	0.04	0	0	0	0	0	0	15
357	0.07	0	0	0	0	0	0	15
1,847	0.35	0	0	0	0	0	0	15
1,130	0.21	0	0	0	0	0	0	15
180	0.03	0	0	0	0	0	0	15
62	0.01	0	0	0	0	0	0	15

Road Segment Length (Feet)	Road Segment Length (Miles)	Cut Slope Erosion Rating	Fill Slope Erosion Rating	Road Surface Erosion Rating	Inside Ditch Erosion Rating	Delivery Multiplier	Total Road Sediment Delivery Score	Assumed Road Sediment Delivery Score
1,701	0.32	0	0	0	0	0	0	15
770	0.15	0	0	0	0	0	0	15
1,636	0.31	0	0	0	0	0	0	15
63	0.01	0	0	0	0	0	0	15
5,356	1.02	0	0	0	0	0	0	15
1243	0.24	0	0	0	0	0	0	15
6,003	1.14	0	0	0	0	0	0	15
2,049	0.39	0	0	0	0	0	0	15
2,530	0.48	0	0	0	0	0	0	15
61	0.01	0	0	0	0	0	0	15
1,345	0.26	0	0	0	0	0	0	15
152	0.03	0	0	0	0	0	0	15
317	0.06	0	0	0	0	0	0	15
3,675	0.70	0	0	0	0	0	0	15
1,746	0.33	0	0	0	0	0	0	15
1,777	0.34	0	0	0	0	0	0	15
742	0.14	0	0	0	0	0	0	15
151	0.03	0	0	0	0	0	0	15
1,186	0.23	0	0	0	0	0	0	15

Road Segment Length (Feet)	Road Segment Length (Miles)	Cut Slope Erosion Rating	Fill Slope Erosion Rating	Road Surface Erosion Rating	Inside Ditch Erosion Rating	Delivery Multiplier	Total Road Sediment Delivery Score	Assumed Road Sediment Delivery Score
1,179	0.22	0	0	0	0	0	0	15
278	0.05	0	0	0	0	0	0	15
97	0.02	0	0	0	0	0	0	15
512	0.10	0	0	0	0	0	0	15
6,128	1.16	0	0	0	0	0	0	15
1,124	0.21	0	0	0	0	0	0	15
1,506	0.29	0	0	0	0	0	0	15
1,387	0.26	0	0	0	0	0	0	15
864	0.16	0	0	0	0	0	0	15
447	0.09	0	0	0	0	0	0	15
4,420	0.84	0	0	0	0	0	0	15
5,912	1.12	0	0	0	0	0	0	15
53	0.01	0	0	0	0	0	0	15
2,257	0.43	0	0	0	0	0	0	15

[1] The data in this table were generated following the CWE road protocol (IDL 2000).

Appendix 13. Comparison Between Stream Temperature Prediction Models: SSTemp, *Heat Source*, and Idaho Cumulative Watershed Effects

Comparison Between Stream Temperature Prediction Models: SSTemp, *Heat Source*, and Idaho Cumulative Watershed Effects

by

Western Watershed Analysts
Lewiston, Idaho

for

Idaho Department of Environmental Quality
January, 2001

Introduction

Idaho Department of Environmental Quality (IDEQ) contracted Western Watershed Analysts (WWA) to conduct a comparison between three stream temperature prediction models: SSTemp (developed by U.S. Fish and Wildlife Service), *Heat Source* (developed by Oregon Department of Environmental Quality), and the Idaho Cumulative Watershed Effects (CWE) procedure. The first two models are process-based, and require numerous stream morphology and meteorologic input parameters. The Idaho CWE temperature prediction relationships are empirically-based on extensive water temperature measurements made throughout northern Idaho, and require only two inputs - vegetative shade level and elevation.

The Cold Springs/Cool Creek drainage in the Upper North Fork Clearwater basin was used to make comparisons between the three models. Predicted daily maximum and daily average water temperatures from each of the three models were compared to water temperatures measured in the Cold Springs/Cool Creek drainage during 1998, 1999, and 2000. The purpose of the comparison was to ascertain whether the Idaho CWE temperature relationships predicted actual temperatures as accurately as the other two process-based models. If so, the CWE relationships could be used within the context of a Total Maximum Daily Load (TMDL) allocation to determine shade levels required to maintain water quality temperature standards.

Background

The federal Clean Water Act (CWA) requires states to protect the quality of their rivers, streams, and lakes. The IDEQ has the responsibility for developing standards that protect

beneficial uses of Idaho's water resources. Section 303(d) of the Clean Water Act requires the state to develop a list of waterbodies that do not meet standards. Listed streams are water quality limited for physical and biological factors, such as temperature, pH, bacteria, and dissolved oxygen. The IDEQ has proposed a TMDL program to address water quality problems, including temperature. A temperature TMDL addresses stream heating problems by linking them to watershed characteristics and management practices, establishing objectives for water quality improvement, and identifying and implementing new or altered management measures designed to achieve those objectives.

In developing a temperature TMDL, regulators must be able to identify locations within the listed waterbody where temperatures exceed water quality standards, and determine the factors (both natural and anthropogenic) that contribute to high water temperatures at those locations. Only then can the agency determine the management actions necessary to maintain the water temperature standards. To identify these factors, typically a combination of temperature monitoring at selected locations along with stream temperature modeling is utilized.

Two general types of stream temperature prediction models are available. Reach-based models predict water temperatures on a site by site basis and generally require extensive inputs to calculate the various heat fluxes associated with stream heating and cooling. Basin models are capable of predicting water temperatures over a wider area and typically require fewer input parameters, which makes them generally easier and less expensive to use in applications to entire watersheds.

Temperature Model Descriptions

Heat Source

The *Heat Source* model was developed at Oregon State University as a tool for analyzing stream temperature data (Boyd 1996). The model is used to predict effects on stream temperatures resulting from changes in various stream parameters, and allows evaluation of variations due to different management scenarios. The *Heat Source* model has been described in detail by ODEQ (1999). The code is written in Visual Basic, with an Excel spreadsheet input/output interface. *Heat Source* uses the same fundamental physical and thermodynamic concepts as many other process-based models. The fundamental premise of the model is that the water temperature at any given time and location in the stream is the result of the physical heat transfer processes between the stream and its surrounding environment. As a reach-based model, *Heat Source* predicts water temperatures at a downstream location based on some known water temperatures at an upstream location; it cannot predict stream temperatures at a given location in the stream system unless it is given water temperature inputs from an upstream location.

The model itself requires four basic types of input:

1. stream characteristics - location, aspect, wetted width, flow, etc.
2. riparian characteristics - buffer height, width, overhang, etc.

3. atmospheric conditions - air temperature, humidity, wind speed
4. hourly water temperatures at the upstream end of the reach through the course of a day

Based on these inputs, the model predicts the hourly water temperatures at the downstream end of the reach, and displays the results in tabular and graphic formats.

SSTemp

The SSTemp model was developed by the U.S. Fish and Wildlife Service Technical Services Branch (Theurer et al 1984; Bartholow 1989). SSTemp runs in a fashion similar to *Heat Source*, and many of the inputs required for SSTemp are the same or similar to those for *Heat Source*. However, SSTemp is oriented toward average daily conditions. For example, rather than inputting minimum and maximum daily air temperatures and humidities, as in *Heat Source*, SSTemp uses only daily average values of air temperature and humidity. As a result, SSTemp is designed to predict only the daily average water temperature for the reach. The SSTemp model results do report an estimated maximum daily temperature, but it is only an estimate based on empirical relations, not on heat transfer process calculations. In addition, SSTemp is implemented as an executable application, and therefore the code is not visible to, nor changeable by, the user.

Idaho Cumulative Watershed Effects (CWE)

The Idaho CWE temperature model is an empirical model based on extensive water temperature monitoring conducted throughout northern Idaho by Plum Creek Timber Company (PCTC), Potlatch Corporation, and Idaho Department of Lands (IDL). The data collection and analysis methods are described in detail in Sugden et al (1998). The results of the analysis indicated that maximum weekly maximum water temperature (MWMT), which is the average of the daily maximum water temperatures for the warmest seven-day period in the summer, can be predicted with only two parameters - elevation and canopy cover - with a correlation coefficient of $r^2 = 0.49$ (MWMT was used because most temperature standards for fish species are written in terms of the MWMT). Slightly better predictions ($r^2 = 0.58$) could be obtained by adding a third parameter - the average July-August drought index.

The Idaho CWE process (IDL 2000) uses the MWMT relationships developed in the PCTC analysis, solving the equation for canopy cover in order to predict the shade level required to maintain the various temperature standards, depending on fish species. The result is a table that estimates required canopy cover, given elevation and the appropriate temperature standard.

For our analysis, we used canopy cover and elevation as inputs to the CWE relationships to predict the MWMT for the stream reach. Additional relationships developed by Sugden et al (1998) were then used to predict instantaneous maximum and daily average water temperatures in order to make comparisons to the results of the other two process-based models.

Study Area

The Cold Springs/Cool Creek drainage was chosen for temperature modeling comparisons because of the relative abundance of available data. Stream morphology characteristics were available from stream surveys done by Clearwater BioStudies (1996), streamflow records were available for water years 1983-92, and water temperature data had been recorded in 1998, 1999, and 2000. The drainage is located in the Upper North Fork Clearwater basin, and flows into the North Fork Clearwater just downstream of Kelly Forks. The drainage ranges in elevation from 2,700 feet to over 5,800 feet, and encompasses approximately 11 square miles. The stream system was divided into 43 reaches (see Figure 1), with reach breaks taken at major tributary junctions or significant changes in stream characteristics, such as aspect, gradient, or riparian shade. A total of approximately 16 miles of stream was modeled.

Model Inputs

Heat Source

The complete set of input parameters used for the *Heat Source* model are shown in Tables 1 and 2. Table 1 shows the input values used to calibrate the model from data derived for July 27, 1998, which was the date that the warmest water temperatures were recorded in the study drainage in 1998. Table 2 shows the input values used to predict water temperatures on August 6, 1999, which was the date of warmest water temperatures recorded in that year. Stream gauge data was recorded in Cold Springs Creek near the downstream end of Reach # 41. Unfortunately, water temperature data and stream flow data were not available for any overlapping time period. Therefore, discharge of the North Fork Clearwater at the Canyon Ranger Station was correlated to discharge in Cold Springs Creek for the months of July and August from 1985 to 1992 (Figure 2). This correlation was then used to predict the flow at Reach #41 for July 27, 1998, and August 6, 1999, from flows recorded for the North Fork Clearwater. Flows for all other reach locations on those two dates were then estimated by multiplying the flow at Reach # 41 by the ratio of the drainage areas, as measured from GIS. Reach lengths were also obtained from GIS.

Latitude, longitude, stream aspect, stream elevations, and topographic shade angles were estimated for each reach from topographic maps. Average wetted width of each reach was estimated from stream survey data obtained by Clearwater BioStudies (1997). Rosgen stream types recorded by Clearwater BioStudies (1997) were used to estimate bankfull values of Manning's n, as suggested by Rosgen (1996), with adjustments made to account for low flow conditions based on recommendations by Jarrett (1984). Average stream depth and velocity for each reach were then estimated using Manning relationships.

Height and density of riparian vegetation along each reach was estimated from recent stereo aerial photography. The width of the riparian buffer was taken as one-half the height, in order to enable compatibility between input parameters between *Heat Source* and SSTemp (i.e., *Heat Source* requires buffer width as an input, whereas SSTemp requires tree crown diameter as the equivalent input).

Minimum and maximum air temperatures for each day were obtained from weather station data at Pierce, Idaho (3,150 feet elevation), and adjusted for variations in elevation using a typical lapse rate of 1.8ºC per 1,000 feet. Values of humidity and average wind speed used in the modeling were those reported for Missoula, Montana, because that was the nearest weather station location for which humidity and wind speed data could be obtained. Groundwater temperature was assumed to be equal to the average annual air temperature as reported for Pierce, Idaho, and again adjusted for elevation.

Initial runs of the model resulted in predicted water temperatures well below those actually measured on July 27, 1998. Several input parameters were therefore adjusted to calibrate the model (see Table 1). Since the air column immediately above the stream may be moister than that recorded in the open (i.e., at a weather station), average humidity was raised from 55% to 65%. Similarly, because the air temperature immediately above the water surface may be partially regulated due to its proximity to the water, the daily variation in air temperature was reduced to one-sixth of the actual measured variation, keeping the daily average air temperature the same (i.e., measured minimum and maximum temperatures on July 27, 1998, of 11ºC and 36ºC, respectively, at Pierce were adjusted to 22ºC and 26ºC, respectively, in the modeling). Because groundwater temperature is in fact not a well known quantity, the value for groundwater temperature was also raised by 8ºC, yielding the following relationship:

$$T_{gw} = 14 + 0.0018\,(3{,}150 - E)$$

where T_{gw} = groundwater temperature (ºC)
E = average stream reach elevation (feet)

To predict temperatures on August 6, 1999, the only input parameters that needed to be changed were stream flow and air temperature. Flow on that day was slightly higher than for July 27, 1998 (see Table 2). Measured air temperatures at Pierce for that date were 12ºC minimum and 32ºC maximum. Therefore, consistent with the adjustments made for the calibration on July 27, 1998, air temperatures input to the model for August 6, 1999 were 20.5ºC minimum and 23.5ºC maximum (at 3,150 feet elevation).

SSTemp

The complete set of input parameters used for the SSTemp model are shown in Tables 3 and 4. Table 3 shows the input values used to calibrate the model from data derived for July 27, 1998, and Table 4 shows the input values used to predict water temperatures on August 6, 1999.

All of the input parameters for the SSTemp model could be taken directly from or were easily derived from the inputs used for the *Heat Source* model. Initial runs of SSTemp also indicated that predicted average water temperatures were below those actually measured on July 27, 1998, although the difference was less than that encountered in the initial runs of *Heat Source*. Therefore, calibration of the SSTemp model consisted of increasing the

average humidity to 65% (the same as for *Heat Source*) and raising groundwater temperature by only 2ºC (i.e., 6ºC cooler than that used for the calibration of *Heat Source*). As was true for the *Heat Source* calibration, the average daily air temperature was left unchanged (see Table 3). To predict temperatures on August 6, 1999, the stream flow and average air temperature were changed to the same values as those used in the *Heat Source* model for that date (see Table 4).

Idaho CWE

The Idaho CWE temperature model uses only two input parameters - canopy cover and elevation. These parameters are shown in Table 5, and are the same values as those used for *Heat Source* and SSTemp. The CWE prediction equation for northern Idaho is:

$$MWMT = 29.1 - 0.00262\ E - 0.0849\ C$$

where MWMT = maximum weekly maximum temperature (ºC)
E = stream reach elevation (feet)
C = riparian canopy cover (%)

In addition, the daily average temperature is predicted by:

$$T_{ave} = 0.95 + 0.83\ MWMT$$

and the daily maximum temperature is predicted by:

$$T_{max} = 0.15 + 1.04\ MWMT$$

Results

The predicted average and maximum water temperatures for each model/date combination are shown in Tables 1-5 (last two rows of each table); these values are also plotted in Figures 3-7, along with the actual measured temperatures for comparison.

Calibration of *Heat Source* for the best achievable agreement at Reach # 27 on July 27, 1998, resulted in under-prediction of temperatures at Reach #41 for that date (see Figure 3). However, *Heat Source* temperature predictions for August 6, 1999, were very close to measured values at reach #41, and somewhat high for Reach # 27 (Figure 4). Calibration of SSTemp for the best possible agreement with the average measured temperature at Reach # 27 on July 27, 1998, also resulted in under-prediction of the average temperature at Reach #41 for that date (Figure 5), but SSTemp over-predicted maximum temperatures at both locations. SSTemp predictions of average temperatures for August 6, 1999, were fairly close to the measured values, but SSTemp again over-predicted maximum temperatures (Figure 6).

In order to provide an estimate of the "goodness of fit" of the model calibrations, the root-mean-square (RMS) of the deviations between simulated and measured temperatures for July 27, 1998, were calculated for each model (see Table 6). The RMS values were calculated for

all measurements, and also for maximum temperatures only, because maximum temperatures are the primary quantity of interest in a water quality context. Table 6 indicates that with our model calibration, the average error in temperature predictions that might be expected from *Heat Source* would be a little more than 1ºC, and the average error in maximum predicted temperatures might be about 1.5ºC. Similarly, given our model calibration, the average error in temperature predictions that might be expected with SSTemp would be around 1ºC, or possibly a little less for average water temperatures.

RMS errors for *Heat Source* temperature predictions on August 6, 1999, are approximately 1.3ºC to 1.6ºC (Table 7), which are consistent with the calibration RMS deviations for the *Heat Source* model. RMS errors for SSTemp temperature predictions on August 6, 1999, are approximately 1.3ºC to 1.7ºC (Table 7), which are considerably higher than the calibration RMS deviations for SSTemp.

The results of the CWE prediction equations are shown in Figure 7. Because its inputs are not dependent upon the specific date, the CWE model predicts water temperatures that would be found during the warmest period of a typical summer in northern Idaho. Therefore, for comparison purposes, Figure 7 shows measured temperatures for the warmest days in 1998, 1999, and 2000; the averages of these measurements are shown in Table 7. Comparing the CWE predictions to these average measured values shows RMS errors of 1.0ºC to 1.2ºC for the CWE model (Table 7).

Discussion

The best calibrations of the *Heat Source* and SSTemp models that we were able to achieve through adjustment of humidity, air temperature, and groundwater temperature inputs were on the order of 1ºC to 1.5ºC (Table 6). RMS errors for *Heat Source* temperature predictions of 1.3ºC to 1.6ºC (Table 7) were entirely consistent with the calibration RMS deviations for the *Heat Source* model. In other words, given our ability to calibrate the *Heat Source* model for this drainage, we would not expect to be able to predict temperatures much better than this on average.

RMS errors for SSTemp temperature predictions of 1.3ºC to 1.7ºC (Table 7) were considerably higher than the calibration RMS deviations for SSTemp. Possible explanations for this poorer prediction performance are either we adjusted the wrong input parameters to calibrate the model, or the SSTemp model does not perform well under varying atmospheric and stream flow conditions. The fact that we were able to obtain consistent results with a similar calibration of the *Heat Source* model suggests that the former is unlikely. Furthermore, even when calibrated to predict average temperatures with reasonable accuracy, SSTemp consistently over-predicted maximum temperatures in all conditions tested for this drainage, indicating a systematic bias in the model's prediction of maximum temperatures.

RMS errors for the CWE temperature predictions of 1.0ºC to 1.2ºC (Table 7) were slightly better than those for either of the other two models, suggesting that the CWE model performs at least as well as the other models in a drainage such as Cold Springs Creek. In addition, the

CWE model requires no calibration, and also involves substantially less time and effort in obtaining the necessary model inputs and executing the model calculations.

Conclusions

Water temperatures were modeled during summer low flow conditions in approximately 16 miles of stream in Cold Springs Creek, a small (11 sq. mi.) headwater drainage in the Upper North Fork Clearwater basin, using three different temperature models, and compared to temperatures measured in 1998, 1999, and 2000. The *Heat Source* and SSTemp models require extensive inputs regarding stream and riparian characteristics and atmospheric conditions. The CWE model requires only elevation and canopy cover as model inputs.

After calibration, *Heat Source* predicted average and maximum water temperatures to within about 1.5ºC or less. Accuracy of predictions from the SSTemp model was similar to that for *Heat Source*. However, SSTemp appears to consistently over-predict maximum temperatures. CWE predictions of average and maximum water temperatures were as good as or slightly better than predictions from the other two models. CWE exhibits additional advantages in its simplicity of inputs and rapid execution.

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Figure 1. Stream Reaches Defined for Cold Springs/Cool Creek Drainage

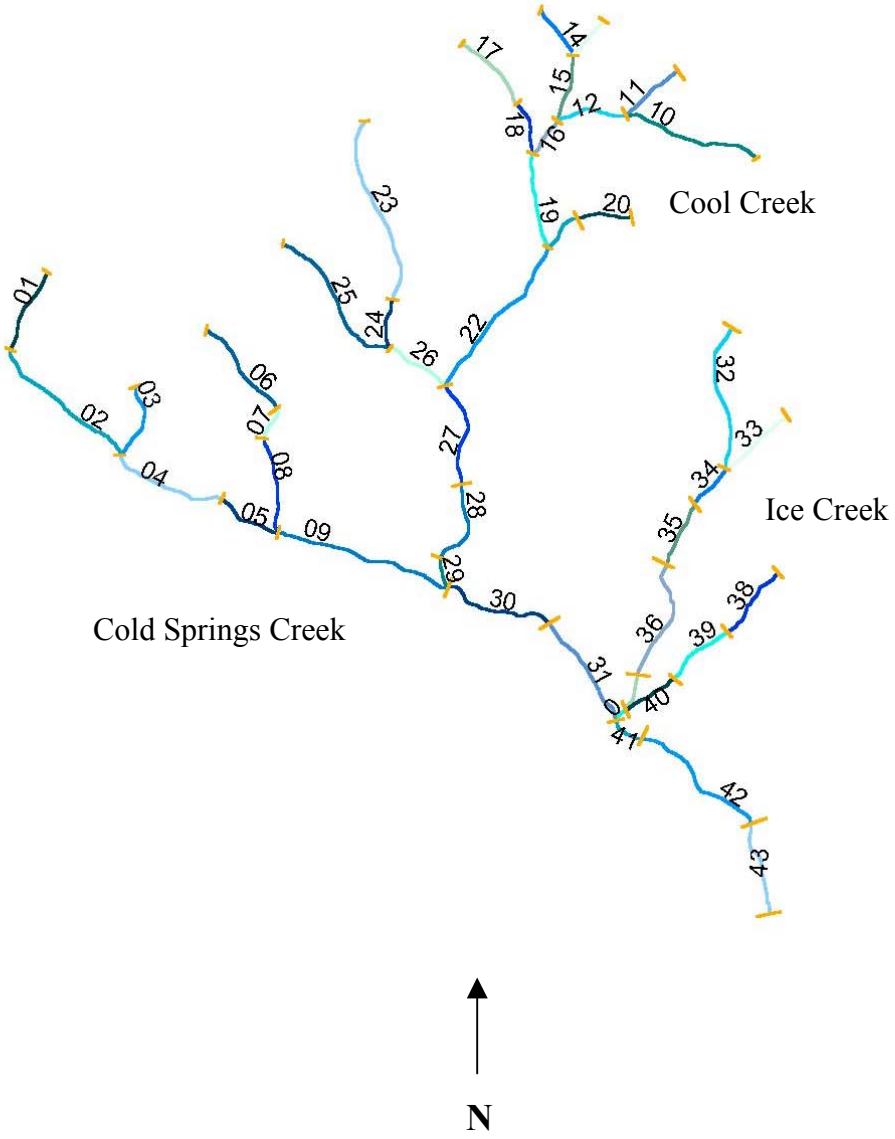

Figure 2. Stream Gauge Correlation

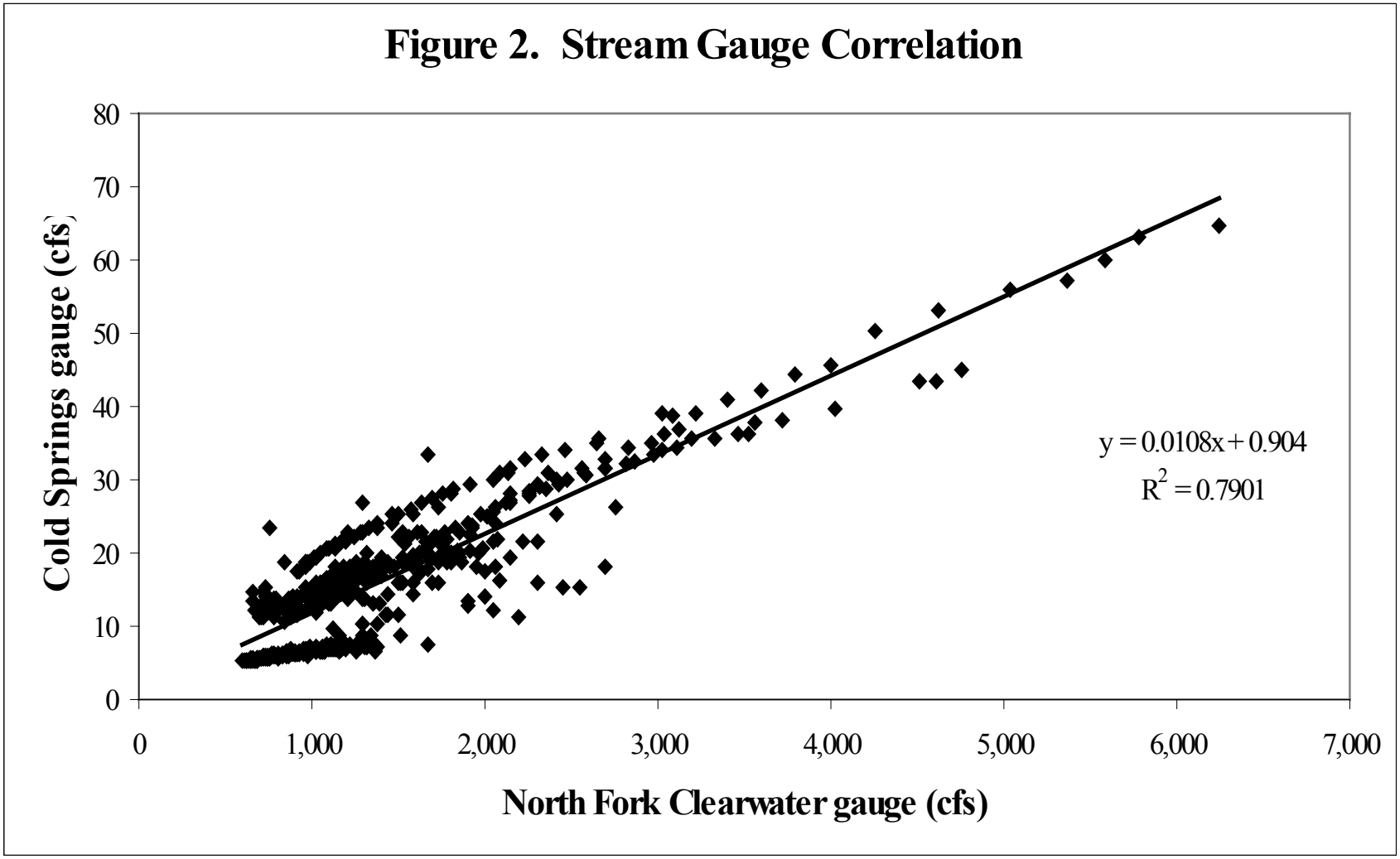

Figure 3. He*at Source* Calibration – 7/27/98

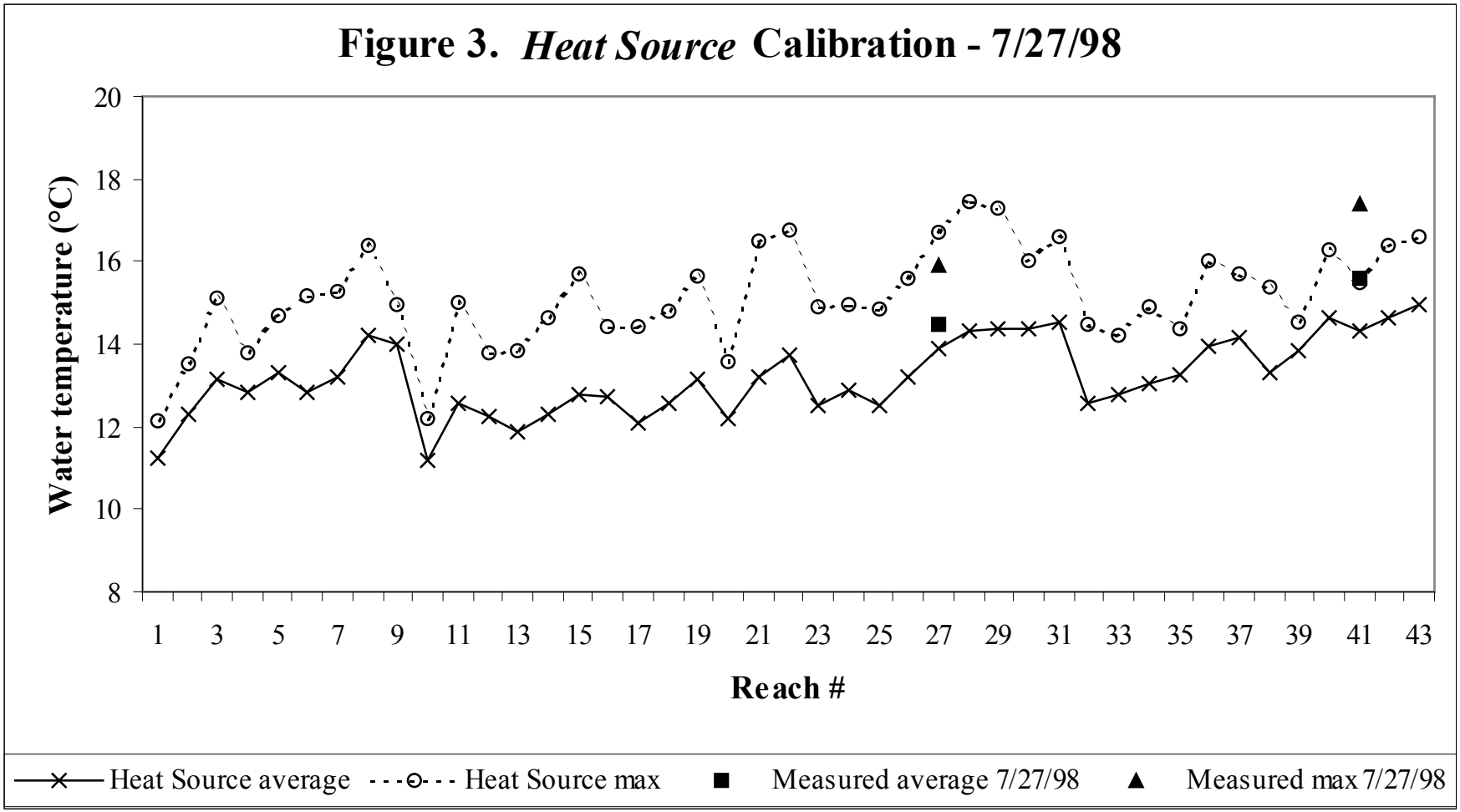

Figure 4. *Heat Source* Prediction – 8/6/99

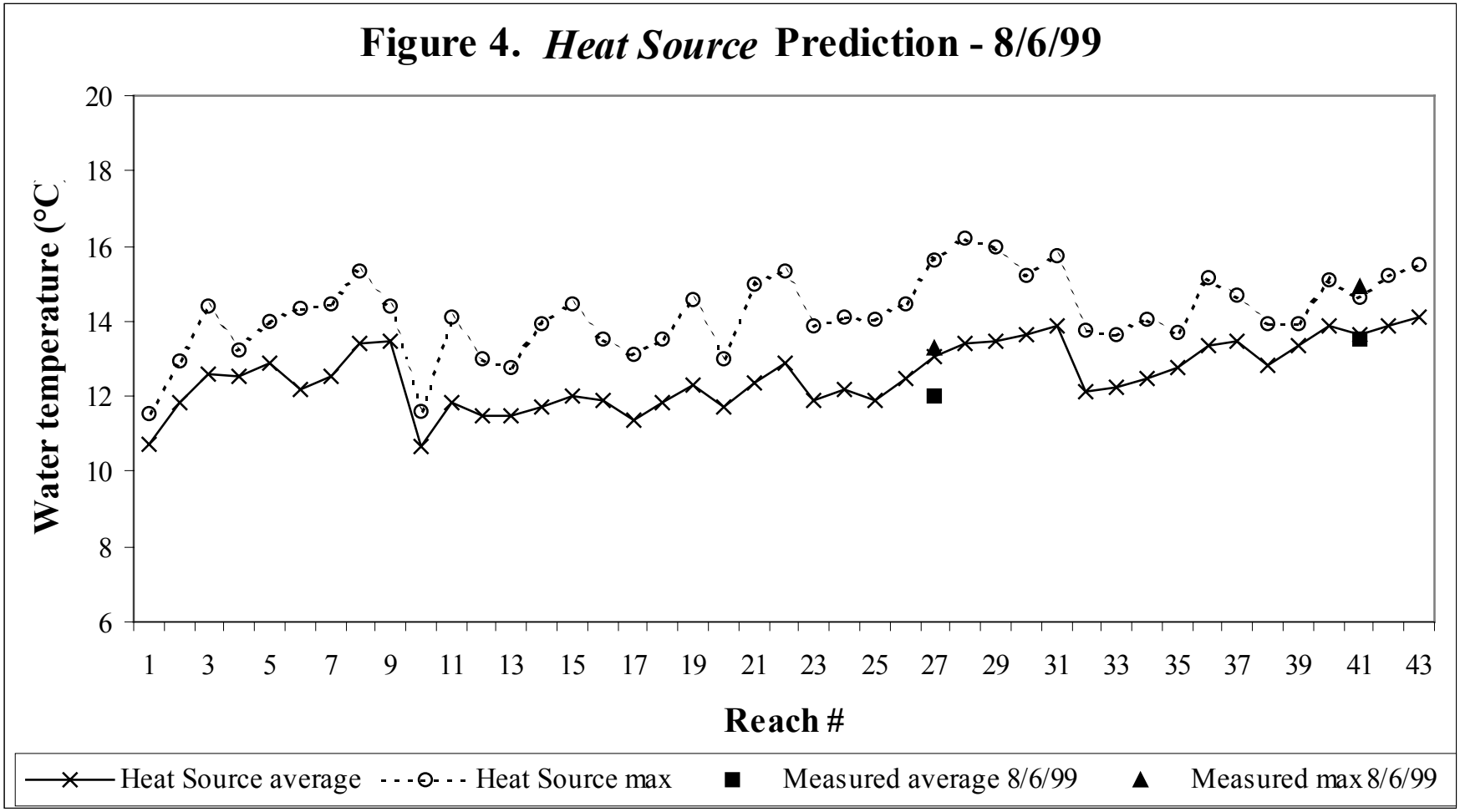

Figure 5. SSTEMP Calibration – 7/27/98

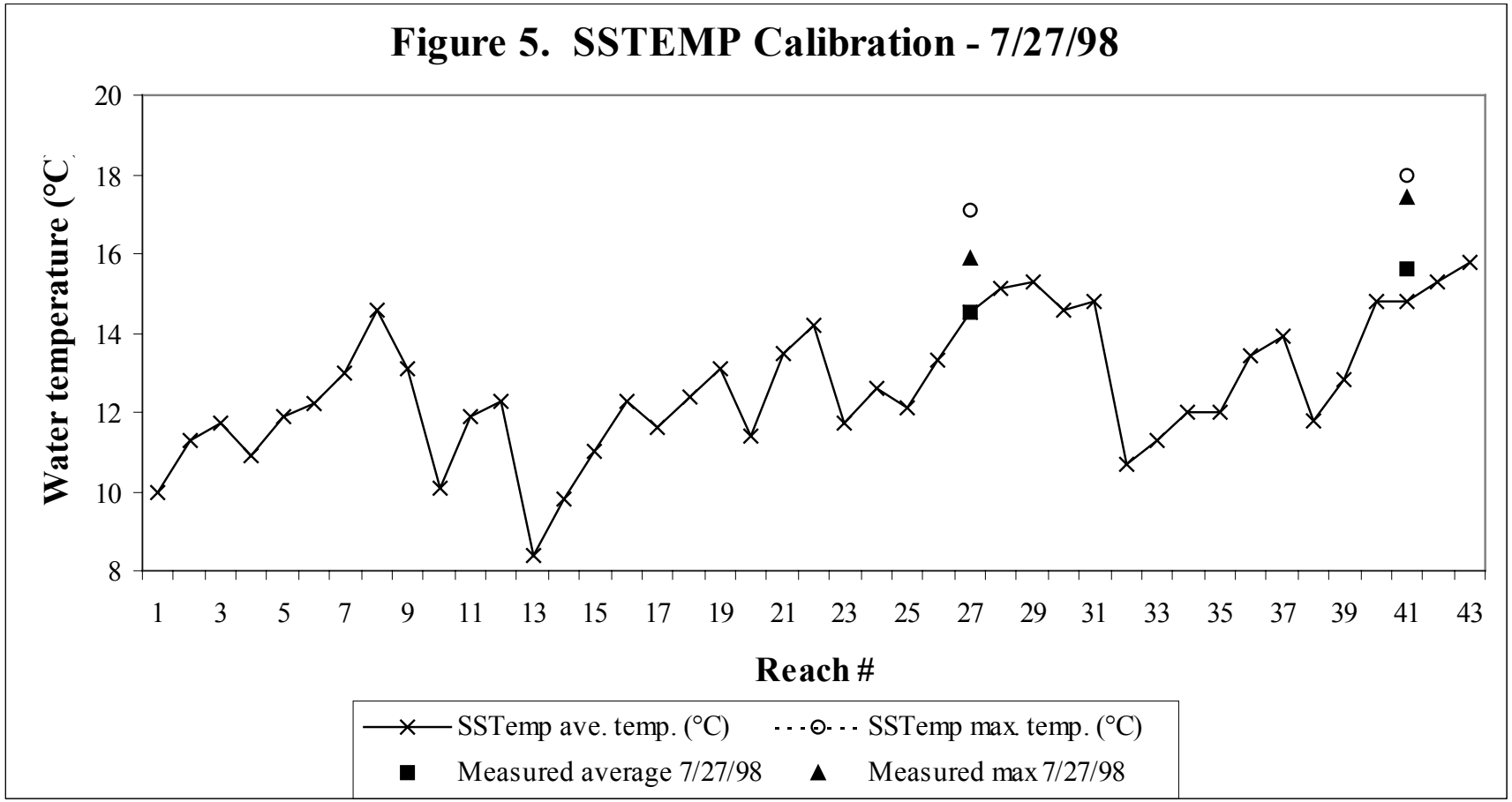

Figure 6. SSTEMP Prediction – 8/6/99

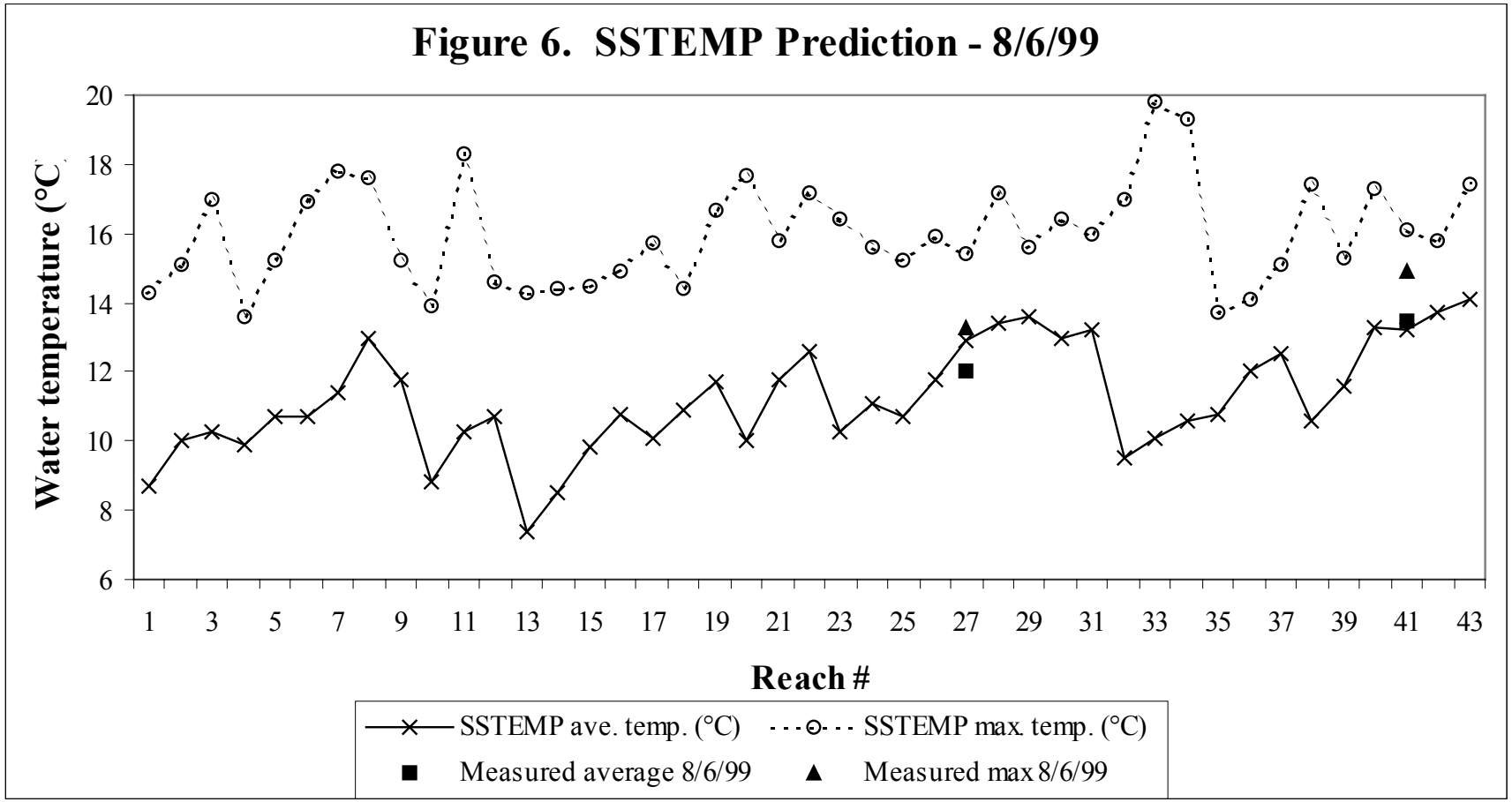

Figure 7. CWE Prediction

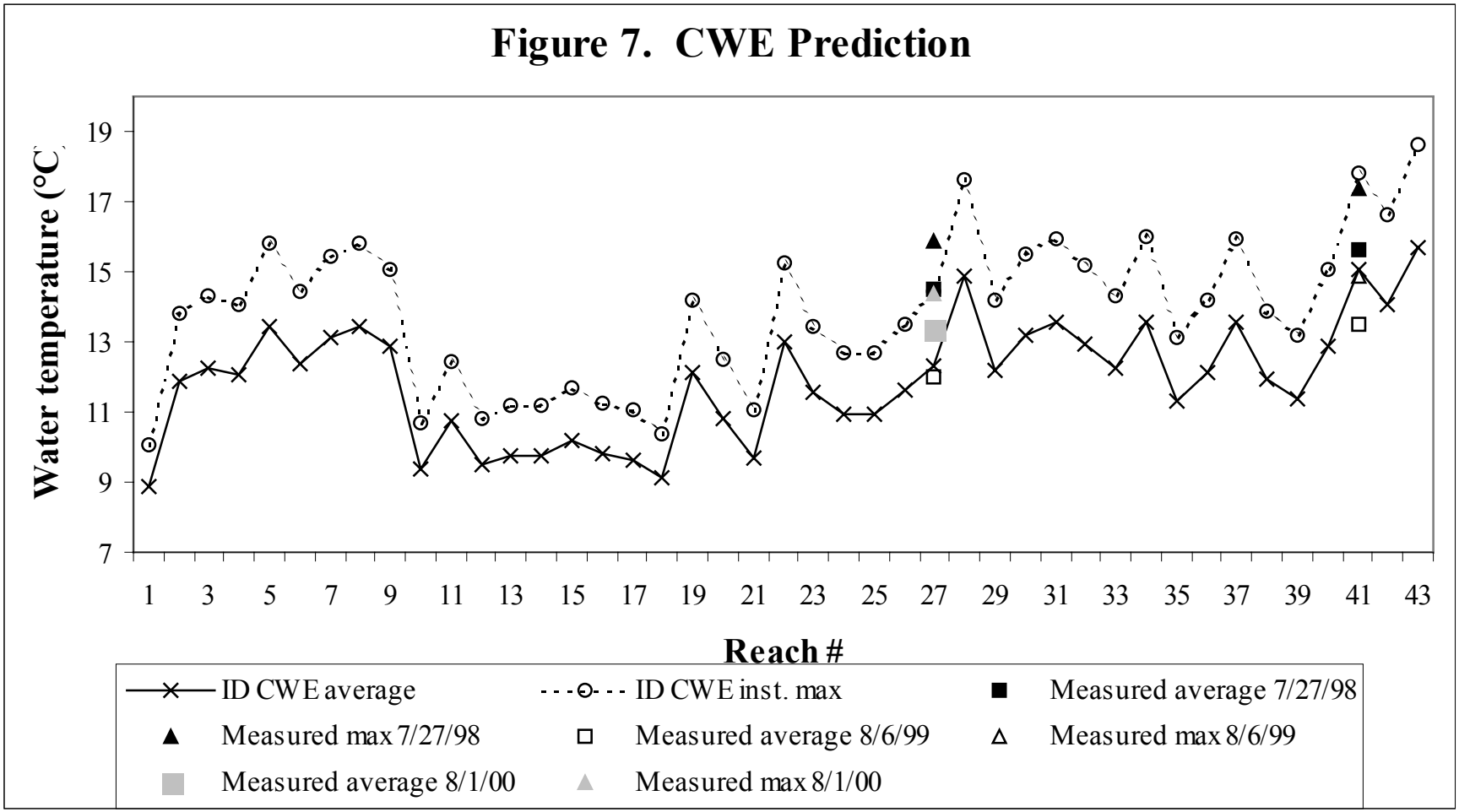

Table 1. *Heat Source* Calibration for 7/27/98 (page 1 of 5)

Cold Springs Creek -

Heat Source Inputs for 7/27/98 Calibration

Input parameters

Reach #	1	2	3	4	5	6	7	8	9
Stream	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Latitude (°)	47	47	47	47	47	47	47	47	47
Longitude (°)	115	115	115	115	115	115	115	115	115
Stream aspect (°)	210	130	215	115	120	135	215	170	105
% bedrock	25%	25%	25%	25%	25%	25%	25%	25%	25%
Reach length (m)	586	1,074	534	798	462	736	238	660	1,231
Stream width (m)	1.5	2.0	1.5	2.3	2.7	2.0	2.0	2.0	3.5
Flow volume (cms)	0.0020	0.0085	0.0060	0.0387	0.0728	0.0062	0.0138	0.0165	0.1011
Velocity (m/s)	0.18	0.24	0.18	0.28	0.26	0.19	0.19	0.20	0.38
G/W inflow (cms)	0.0065	0.0202	0.0040	0.0341	0.0069	0.0076	0.0027	0.0049	0.0394
G/W temperature (°C)	9.8	11.1	11.5	12.3	12.8	11.0	11.9	12.5	13.3
Stream depth (m)	0.032	0.060	0.036	0.112	0.115	0.035	0.043	0.053	0.106
Buffer height (m)	18	18	18	18	18	18	18	18	18
Buffer width (m)	10	10	10	10	10	10	10	10	10
Canopy density	70%	55%	50%	65%	50%	45%	40%	50%	70%
Distance to stream (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Incision (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tree overhang (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Topographic west (°)	17	39	35	35	39	45	40	39	35
Topographic east (°)	17	39	35	35	39	45	40	39	35
Min. air temp. (°C)	17.8	19.1	19.5	20.3	20.8	19.0	19.9	20.5	21.3
Max. air temp. (°C)	21.8	23.1	23.5	24.3	24.8	23.0	23.9	24.5	25.3

Cold Springs Creek - *Heat Source* Inputs for 7/27/98 Calibration									
Input parameters									
Reach #	1	2	3	4	5	6	7	8	9
Stream	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr
Min. humidity	45%	45%	45%	45%	45%	45%	45%	45%	45%
Max. humidity	85%	85%	85%	85%	85%	85%	85%	85%	85%
Elevation (m)	1,676	1,448	1,387	1,250	1,167	1,463	1,311	1,210	1,082
Wind speed (m/s)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Ave. outflow temp (°C)	11.2	12.3	13.2	12.8	13.3	12.8	13.2	14.2	14.0
Max. outflow temp (°C)	12.2	13.5	15.1	13.8	14.7	15.2	15.3	16.4	15.0

Table 1. *Heat Source* Calibration for 7/27/98 (page 2 of 5)

Cold Springs Creek -									
Input parameters									
Reach #	10	11	12	13	14	15	16	17	18
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Latitude (°)	47	47	47	47	47	47	47	47	47
Longitude (°)	115	115	115	115	115	115	115	115	115
Stream aspect (°)	290	230	265	225	140	195	215	135	155
% bedrock	25%	25%	25%	25%	25%	25%	25%	25%	25%
Reach length (m)	955	464	491	307	377	460	288	560	369
Stream width (m)	2.0	2.0	3.0	2.0	2.0	2.7	3.2	2.0	2.2

Cold Springs Creek - Input parameters									
Reach #	10	11	12	13	14	15	16	17	18
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool
Flow volume (cms)	0.0022	0.0049	0.0263	0.0080	0.0067	0.0214	0.0554	0.0031	0.0085
Velocity (m/s)	0.17	0.14	0.15	0.16	0.13	0.15	0.33	0.14	0.13
G/W inflow (cms)	0.0156	0.0036	0.0038	0.0040	0.0027	0.0038	0.0016	0.0054	0.0033
G/W temperature (°C)	9.8	10.0	10.6	10.2	10.2	10.6	11.0	10.1	10.9
Stream depth (m)	0.053	0.031	0.065	0.039	0.036	0.063	0.055	0.030	0.040
Buffer height (m)	18	18	18	18	18	18	18	18	18
Buffer width (m)	10	10	10	10	10	10	10	10	10
Canopy density	65%	45%	70%	60%	60%	60%	70%	65%	80%
Distance to stream (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Incision (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tree overhang (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Topographic west (°)	29	27	39	29	39	29	35	31	29
Topographic east (°)	29	27	39	29	39	29	35	31	29
Min. air temp. (°C)	17.8	18.0	18.6	18.2	18.2	18.6	19.0	18.1	18.9
Max. air temp. (°C)	21.8	22.0	22.6	22.2	22.2	22.6	23.0	22.1	22.9
Min. humidity	45%	45%	45%	45%	45%	45%	45%	45%	45%
Max. humidity	85%	85%	85%	85%	85%	85%	85%	85%	85%
Elevation (m)	1,670	1,637	1,533	1,603	1,603	1,530	1,475	1,615	1,487
Wind speed (m/s)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Ave. outflow temp (°C)	11.2	12.6	12.2	11.9	12.3	12.8	12.7	12.1	12.6
Max. outflow temp (°C)	12.2	15.0	13.8	13.8	14.6	15.7	14.4	14.4	14.8

Table 1. *Heat Source* Calibration for 7/27/98 (page 3 of 5)

Cold Springs Creek - Input parameters									
Reach #	19	20	21	22	23	24	25	26	27
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	W. Cool	W. Cool	W. Cool	W. Cool	Lower Cool
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Latitude (°)	47	47	47	47	47	47	47	47	47
Longitude (°)	115	115	115	115	115	115	115	115	115
Stream aspect (°)	170	265	220	220	160	190	140	120	170
% bedrock	25%	25%	25%	25%	25%	25%	25%	25%	25%
Reach length (m)	663	377	293	1,191	1,309	346	1,087	459	728
Stream width (m)	3.6	2.0	2.2	4.0	2.5	2.7	2.0	3.1	5.2
Flow volume (cms)	0.0688	0.0031	0.0080	0.0886	0.0098	0.0314	0.0040	0.0507	0.1672
Velocity (m/s)	0.32	0.15	0.14	0.37	0.29	0.35	0.28	0.34	0.29
G/W inflow (cms)	0.0107	0.0049	0.0011	0.0231	0.0216	0.0036	0.0116	0.0049	0.0136
G/W temperature (°C)	11.3	10.6	11.3	12.1	10.7	11.7	11.0	12.3	12.9
Stream depth (m)	0.069	0.027	0.030	0.075	0.043	0.038	0.027	0.052	0.121
Buffer height (m)	18	18	18	18	18	18	18	18	18
Buffer width (m)	10	10	10	10	10	10	10	10	10
Canopy density	45%	55%	80%	50%	50%	70%	70%	70%	70%
Distance to stream (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Incision (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tree overhang (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Topographic west (°)	35	17	22	39	31	39	45	45	45
Topographic east (°)	35	17	22	39	31	39	45	45	45
Min. air temp. (°C)	19.3	18.6	19.3	20.1	18.7	19.7	19.0	20.3	20.9
Max. air temp. (°C)	23.3	22.6	23.3	24.1	22.7	23.7	23.0	24.3	24.9
Min. humidity	45%	45%	45%	45%	45%	45%	45%	45%	45%

Cold Springs Creek - Input parameters									
Reach #	19	20	21	22	23	24	25	26	27
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	W. Cool	W. Cool	W. Cool	W. Cool	Lower Cool
Max. humidity	85%	85%	85%	85%	85%	85%	85%	85%	85%
Elevation (m)	1,411	1,536	1,417	1,286	1,524	1,347	1,469	1,247	1,149
Wind speed (m/s)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Ave. outflow temp (°C)	13.1	12.2	13.2	13.7	12.5	12.9	12.5	13.2	13.9
Max. outflow temp (°C)	15.7	13.6	16.5	16.7	14.9	15.0	14.8	15.6	16.7

Table 1. *Heat Source* Calibration for 7/27/98 (page 4 of 5)

Cold Springs Creek - Input parameters									
Reach #	28	29	30	31	32	33	34	35	36
Stream	Lower Cool	Lower Cool	Lo Cld Spr	Lo Cld Spr	N. Ice	N. Ice	N. Ice	N. Ice	N. Ice
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Latitude (°)	47	47	47	47	47	47	47	47	47
Longitude (°)	115	115	115	115	115	115	115	115	115
Stream aspect (°)	170	165	105	145	185	230	230	210	210
% bedrock	25%	25%	25%	25%	25%	25%	25%	25%	25%
Reach length (m)	605	212	787	810	1,006	549	325	452	847
Stream width (m)	4.5	4.5	4.5	4.5	2.0	2.0	2.5	2.5	2.9
Flow volume (cms)	0.1809	0.1883	0.3298	0.3566	0.0116	0.0084	0.0450	0.0505	0.0643
Velocity (m/s)	0.39	0.33	0.77	0.78	0.44	0.39	0.40	0.43	0.25
G/W inflow (cms)	0.0074	0.0009	0.0269	0.0229	0.0182	0.0069	0.0054	0.0138	0.0091

Cold Springs Creek - Input parameters									
Reach #	28	29	30	31	32	33	34	35	36
Stream	Lower Cool	Lower Cool	Lo Cld Spr	Lo Cld Spr	N. Ice	N. Ice	N. Ice	N. Ice	N. Ice
G/W temperature (°C)	13.4	13.6	13.8	14.1	11.2	11.3	12.2	12.8	13.6
Stream depth (m)	0.107	0.127	0.103	0.108	0.034	0.019	0.051	0.059	0.099
Buffer height (m)	18	18	18	18	12	12	3	18	18
Buffer width (m)	10	10	10	10	7	7	3	10	10
Canopy density	40%	80%	70%	70%	40%	50%	40%	85%	85%
Distance to stream (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Incision (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tree overhang (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Topographic west (°)	45	45	45	45	39	29	39	46	46
Topographic east (°)	45	45	45	45	39	29	39	46	46
Min. air temp. (°C)	21.4	21.6	21.8	22.1	19.2	19.3	20.2	20.8	21.6
Max. air temp. (°C)	25.4	25.6	25.8	26.1	23.2	23.3	24.2	24.8	25.6
Min. humidity	45%	45%	45%	45%	45%	45%	45%	45%	45%
Max. humidity	85%	85%	85%	85%	85%	85%	85%	85%	85%
Elevation (m)	1,067	1,030	1,000	951	1,426	1,417	1,265	1,158	1,036
Wind speed (m/s)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Ave. outflow temp (°C)	14.3	14.4	14.3	14.5	12.6	12.8	13.0	13.2	13.9
Max. outflow temp (°C)	17.5	17.3	16.0	16.6	14.5	14.2	14.9	14.4	16.0

Table 1. *Heat Source* Calibration for 7/27/98 (page 5 of 5)

Cold Springs Creek - Input parameters							
Reach #	37	38	39	40	41	42	43
Stream	N. Ice	S. Ice	S. Ice	S. Ice	Lo Cld Spr	Lo Cld Spr	Lo Cld Spr
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Latitude (°)	47	47	47	47	47	47	47
Longitude (°)	115	115	115	115	115	115	115
Stream aspect (°)	210	225	230	240	120	130	170
% bedrock	25%	25%	25%	25%	25%	25%	25%
Reach length (m)	254	549	491	391	229	995	646
Stream width (m)	2.9	2.0	2.0	2.5	5.5	5.5	5.5
Flow volume (cms)	0.0734	0.0076	0.0147	0.0214	0.4761	0.4814	0.4959
Velocity (m/s)	0.28	0.37	0.39	0.29	0.43	0.46	0.43
G/W inflow (cms)	0.0007	0.0071	0.0067	0.0011	0.0053	0.0145	0.0056
G/W temperature (°C)	14.1	12.3	13.2	13.9	14.2	14.5	14.7
Stream depth (m)	0.092	0.020	0.027	0.031	0.201	0.197	0.214
Buffer height (m)	18	18	18	18	18	18	12
Buffer width (m)	10	10	10	10	10	10	7
Canopy density	70%	70%	90%	80%	50%	70%	50%
Distance to stream (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Incision (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tree overhang (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Topographic west (°)	54	29	17	42	45	45	11
Topographic east (°)	54	29	17	42	45	45	11
Min. air temp. (°C)	22.1	20.3	21.2	21.9	22.2	22.5	22.7
Max. air temp. (°C)	26.1	24.3	25.2	25.9	26.2	26.5	26.7
Min. humidity	45%	45%	45%	45%	45%	45%	45%
Max. humidity	85%	85%	85%	85%	85%	85%	85%

Cold Springs Creek - Input parameters							
Reach #	37	38	39	40	41	42	43
Stream	N. Ice	S. Ice	S. Ice	S. Ice	Lo Cld Spr	Lo Cld Spr	Lo Cld Spr
Elevation (m)	951	1,250	1,097	981	920	884	838
Wind speed (m/s)	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Ave. outflow temp (°C)	14.2	13.3	13.9	14.6	14.3	14.6	14.9
Max. outflow temp (°C)	15.7	15.4	14.5	16.3	15.5	16.4	16.6

Table 2. *Heat Source* Calibration for 8/6/99 (page 1 of 5)

Cold Springs Creek - ***Heat Source* Inputs for 8/6/99 Prediction** Input parameters									
Reach #	1	2	3	4	5	6	7	8	9
Stream	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Latitude (°)	47	47	47	47	47	47	47	47	47
Longitude (°)	115	115	115	115	115	115	115	115	115
Stream aspect (°)	210	130	215	115	120	135	215	170	105
% bedrock	25%	25%	25%	25%	25%	25%	25%	25%	25%
Reach length (m)	586	1,074	534	798	462	736	238	660	1,231
Stream width (m)	1.5	2.0	1.5	2.3	2.7	2.0	2.0	2.0	3.5
Flow volume (cms)	0.0020	0.0085	0.0060	0.0387	0.0728	0.0062	0.0138	0.0165	0.1011
Velocity (m/s)	0.18	0.24	0.18	0.28	0.26	0.19	0.19	0.20	0.38
G/W inflow (cms)	0.0065	0.0202	0.0040	0.0341	0.0069	0.0076	0.0027	0.0049	0.0394
G/W temperature (°C)	9.8	11.1	11.5	12.3	12.8	11.0	11.9	12.5	13.3
Stream depth (m)	0.032	0.060	0.036	0.112	0.115	0.035	0.043	0.053	0.106

Cold Springs Creek - ***Heat Source*** **Inputs for 8/6/99 Prediction**

Input parameters

Reach #	1	2	3	4	5	6	7	8	9
Stream	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr
Buffer height (m)	18	18	18	18	18	18	18	18	18
Buffer width (m)	10	10	10	10	10	10	10	10	10
Canopy density	70%	55%	50%	65%	50%	45%	40%	50%	70%
Distance to stream (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Incision (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tree overhang (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Topographic west (°)	17	39	35	35	39	45	40	39	35
Topographic east (°)	17	39	35	35	39	45	40	39	35
Min. air temp. (°C)	17.8	19.1	19.5	20.3	20.8	19.0	19.9	20.5	21.3
Max. air temp. (°C)	21.8	23.1	23.5	24.3	24.8	23.0	23.9	24.5	25.3
Min. humidity	45%	45%	45%	45%	45%	45%	45%	45%	45%
Max. humidity	85%	85%	85%	85%	85%	85%	85%	85%	85%
Elevation (m)	1,676	1,448	1,387	1,250	1,167	1,463	1,311	1,210	1,082
Wind speed (m/s)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Ave. outflow temp (°C)	11.2	12.3	13.2	12.8	13.3	12.8	13.2	14.2	14.0
Max. outflow temp (°C)	12.2	13.5	15.1	13.8	14.7	15.2	15.3	16.4	15.0

Table 2. *Heat Source* Calibration for 8/6/99 (page 2 of 5)

Cold Springs Creek - Input parameters									
Reach #	10	11	12	13	14	15	16	17	18
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Latitude (°)	47	47	47	47	47	47	47	47	47
Longitude (°)	115	115	115	115	115	115	115	115	115
Stream aspect (°)	290	230	265	225	140	195	215	135	155
% bedrock	25%	25%	25%	25%	25%	25%	25%	25%	25%
Reach length (m)	955	464	491	307	377	460	288	560	369
Stream width (m)	2.0	2.0	3.0	2.0	2.0	2.7	3.2	2.0	2.2
Flow volume (cms)	0.0022	0.0049	0.0263	0.0080	0.0067	0.0214	0.0554	0.0031	0.0085
Velocity (m/s)	0.17	0.14	0.15	0.16	0.13	0.15	0.33	0.14	0.13
G/W inflow (cms)	0.0156	0.0036	0.0038	0.0040	0.0027	0.0038	0.0016	0.0054	0.0033
G/W temperature (°C)	9.8	10.0	10.6	10.2	10.2	10.6	11.0	10.1	10.9
Stream depth (m)	0.053	0.031	0.065	0.039	0.036	0.063	0.055	0.030	0.040
Buffer height (m)	18	18	18	18	18	18	18	18	18
Buffer width (m)	10	10	10	10	10	10	10	10	10
Canopy density	65%	45%	70%	60%	60%	60%	70%	65%	80%
Distance to stream (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Incision (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tree overhang (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Topographic west (°)	29	27	39	29	39	29	35	31	29
Topographic east (°)	29	27	39	29	39	29	35	31	29
Min. air temp. (°C)	17.8	18.0	18.6	18.2	18.2	18.6	19.0	18.1	18.9
Max. air temp. (°C)	21.8	22.0	22.6	22.2	22.2	22.6	23.0	22.1	22.9
Min. humidity	45%	45%	45%	45%	45%	45%	45%	45%	45%

Cold Springs Creek - Input parameters									
Reach #	10	11	12	13	14	15	16	17	18
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool
Max. humidity	85%	85%	85%	85%	85%	85%	85%	85%	85%
Elevation (m)	1,670	1,637	1,533	1,603	1,603	1,530	1,475	1,615	1,487
Wind speed (m/s)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Ave. outflow temp (°C)	11.2	12.6	12.2	11.9	12.3	12.8	12.7	12.1	12.6
Max. outflow temp (°C)	12.2	15.0	13.8	13.8	14.6	15.7	14.4	14.4	14.8

Table 2. *Heat Source* Calibration for 8/6/99 (page 3 of 5)

Cold Springs Creek - Input parameters									
Reach #	19	20	21	22	23	24	25	26	27
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	W. Cool	W. Cool	W. Cool	W. Cool	Lower Cool
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Latitude (°)	47	47	47	47	47	47	47	47	47
Longitude (°)	115	115	115	115	115	115	115	115	115
Stream aspect (°)	170	265	220	220	160	190	140	120	170
% bedrock	25%	25%	25%	25%	25%	25%	25%	25%	25%
Reach length (m)	663	377	293	1,191	1,309	346	1,087	459	728
Stream width (m)	3.6	2.0	2.2	4.0	2.5	2.7	2.0	3.1	5.2
Flow volume (cms)	0.0688	0.0031	0.0080	0.0886	0.0098	0.0314	0.0040	0.0507	0.1672
Velocity (m/s)	0.32	0.15	0.14	0.37	0.29	0.35	0.28	0.34	0.29
G/W inflow (cms)	0.0107	0.0049	0.0011	0.0231	0.0216	0.0036	0.0116	0.0049	0.0136

Cold Springs Creek - Input parameters									
Reach #	19	20	21	22	23	24	25	26	27
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	W. Cool	W. Cool	W. Cool	W. Cool	Lower Cool
G/W temperature (°C)	11.3	10.6	11.3	12.1	10.7	11.7	11.0	12.3	12.9
Stream depth (m)	0.069	0.027	0.030	0.075	0.043	0.038	0.027	0.052	0.121
Buffer height (m)	18	18	18	18	18	18	18	18	18
Buffer width (m)	10	10	10	10	10	10	10	10	10
Canopy density	45%	55%	80%	50%	50%	70%	70%	70%	70%
Distance to stream (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Incision (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tree overhang (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Topographic west (°)	35	17	22	39	31	39	45	45	45
Topographic east (°)	35	17	22	39	31	39	45	45	45
Min. air temp. (°C)	19.3	18.6	19.3	20.1	18.7	19.7	19.0	20.3	20.9
Max. air temp. (°C)	23.3	22.6	23.3	24.1	22.7	23.7	23.0	24.3	24.9
Min. humidity	45%	45%	45%	45%	45%	45%	45%	45%	45%
Max. humidity	85%	85%	85%	85%	85%	85%	85%	85%	85%
Elevation (m)	1,411	1,536	1,417	1,286	1,524	1,347	1,469	1,247	1,149
Wind speed (m/s)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Ave. outflow temp (°C)	13.1	12.2	13.2	13.7	12.5	12.9	12.5	13.2	13.9
Max. outflow temp (°C)	15.7	13.6	16.5	16.7	14.9	15.0	14.8	15.6	16.7

Table 2. *Heat Source* Calibration for 8/6/99 (page 4 of 5)

Cold Springs Creek - Input parameters									
Reach #	28	29	30	31	32	33	34	35	36
Stream	Lower Cool	Lower Cool	Lo Cld Spr	Lo Cld Spr	N. Ice	N. Ice	N. Ice	N. Ice	N. Ice
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Latitude (°)	47	47	47	47	47	47	47	47	47
Longitude (°)	115	115	115	115	115	115	115	115	115
Stream aspect (°)	170	165	105	145	185	230	230	210	210
% bedrock	25%	25%	25%	25%	25%	25%	25%	25%	25%
Reach length (m)	605	212	787	810	1,006	549	325	452	847
Stream width (m)	4.5	4.5	4.5	4.5	2.0	2.0	2.5	2.5	2.9
Flow volume (cms)	0.1809	0.1883	0.3298	0.3566	0.0116	0.0084	0.0450	0.0505	0.0643
Velocity (m/s)	0.39	0.33	0.77	0.78	0.44	0.39	0.40	0.43	0.25
G/W inflow (cms)	0.0074	0.0009	0.0269	0.0229	0.0182	0.0069	0.0054	0.0138	0.0091
G/W temperature (°C)	13.4	13.6	13.8	14.1	11.2	11.3	12.2	12.8	13.6
Stream depth (m)	0.107	0.127	0.103	0.108	0.034	0.019	0.051	0.059	0.099
Buffer height (m)	18	18	18	18	12	12	3	18	18
Buffer width (m)	10	10	10	10	7	7	3	10	10
Canopy density	40%	80%	70%	70%	40%	50%	40%	85%	85%
Distance to stream (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Incision (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tree overhang (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Topographic west (°)	45	45	45	45	39	29	39	46	46
Topographic east (°)	45	45	45	45	39	29	39	46	46
Min. air temp. (°C)	21.4	21.6	21.8	22.1	19.2	19.3	20.2	20.8	21.6
Max. air temp. (°C)	25.4	25.6	25.8	26.1	23.2	23.3	24.2	24.8	25.6
Min. humidity	45%	45%	45%	45%	45%	45%	45%	45%	45%

Cold Springs Creek - Input parameters									
Reach #	28	29	30	31	32	33	34	35	36
Stream	Lower Cool	Lower Cool	Lo Cld Spr	Lo Cld Spr	N. Ice	N. Ice	N. Ice	N. Ice	N. Ice
Max. humidity	85%	85%	85%	85%	85%	85%	85%	85%	85%
Elevation (m)	1,067	1,030	1,000	951	1,426	1,417	1,265	1,158	1,036
Wind speed (m/s)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Ave. outflow temp (°C)	14.3	14.4	14.3	14.5	12.6	12.8	13.0	13.2	13.9
Max. outflow temp (°C)	17.5	17.3	16.0	16.6	14.5	14.2	14.9	14.4	16.0

Table 2. *Heat Source* Calibration for 8/6/99 (page 5 of 5)

Cold Springs Creek - Input parameters							
Reach #	37	38	39	40	41	42	43
Stream	N. Ice	S. Ice	S. Ice	S. Ice	Lo Cld Spr	Lo Cld Spr	Lo Cld Spr
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Latitude (°)	47	47	47	47	47	47	47
Longitude (°)	115	115	115	115	115	115	115
Stream aspect (°)	210	225	230	240	120	130	170
% bedrock	25%	25%	25%	25%	25%	25%	25%
Reach length (m)	254	549	491	391	229	995	646
Stream width (m)	2.9	2.0	2.0	2.5	5.5	5.5	5.5
Flow volume (cms)	0.0734	0.0076	0.0147	0.0214	0.4761	0.4814	0.4959
Velocity (m/s)	0.28	0.37	0.39	0.29	0.43	0.46	0.43
G/W inflow (cms)	0.0007	0.0071	0.0067	0.0011	0.0053	0.0145	0.0056
G/W temperature (°C)	14.1	12.3	13.2	13.9	14.2	14.5	14.7

Cold Springs Creek - Input parameters							
Reach #	37	38	39	40	41	42	43
Stream	N. Ice	S. Ice	S. Ice	S. Ice	Lo Cld Spr	Lo Cld Spr	Lo Cld Spr
Stream depth (m)	0.092	0.020	0.027	0.031	0.201	0.197	0.214
Buffer height (m)	18	18	18	18	18	18	12
Buffer width (m)	10	10	10	10	10	10	7
Canopy density	70%	70%	90%	80%	50%	70%	50%
Distance to stream (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Incision (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tree overhang (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Topographic west (°)	54	29	17	42	45	45	11
Topographic east (°)	54	29	17	42	45	45	11
Min. air temp. (°C)	22.1	20.3	21.2	21.9	22.2	22.5	22.7
Max. air temp. (°C)	26.1	24.3	25.2	25.9	26.2	26.5	26.7
Min. humidity	45%	45%	45%	45%	45%	45%	45%
Max. humidity	85%	85%	85%	85%	85%	85%	85%
Elevation (m)	951	1,250	1,097	981	920	884	838
Wind speed (m/s)	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Ave. outflow temp (°C)	14.2	13.3	13.9	14.6	14.3	14.6	14.9
Max. outflow temp (°C)	15.7	15.4	14.5	16.3	15.5	16.4	16.6

Table 3. SSTemp Calibration for 7/27/98 (page 1 of 5)

Cold Springs Creek -	SSTemp Inputs for 7/27/98								
Reach #	1	2	3	4	5	6	7	8	9
Stream	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Inflow volume (cfs)	0.07	0.30	0.21	1.37	2.57	0.22	0.49	0.58	3.57
Inflow temp. (°C)	3.8	10.0	5.5	11.4	10.9	5.0	12.2	13.0	12.5
Outflow volume (cfs)	0.30	1.01	0.35	2.57	2.82	0.49	0.58	0.76	4.96
G/W temperature (°C)	3.8	5.1	5.5	6.3	6.8	5.0	5.9	6.5	7.3
Latitude (°)	47	47	47	47	47	47	47	47	47
Reach length (mi)	0.364	0.667	0.332	0.496	0.287	0.457	0.148	0.410	0.765
Upstream elev. (ft)	5,800	5,200	4,800	4,300	3,920	5,200	4,400	4,200	3,740
Downstream elev. (ft)	5,200	4,300	4,300	3,900	3,740	4,400	4,200	3,740	3,360
Width A term (s/ft^2)	6.89	7.13	6.34	6.59	7.26	8.08	7.43	7.11	8.59
B term (W = A Q^B)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Manning's n (wetted)	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.183
Azimuth (° from south)	30	-50	35	-65	-60	-45	35	-10	-75
Topographic west (°)	17	39	35	35	39	45	40	39	35
Topographic east (°)	17	39	35	35	39	45	40	39	35
Buffer height west (ft)	60	60	60	60	60	60	60	60	60
Buffer height east (ft)	60	60	60	60	60	60	60	60	60
Buffer crown west (ft)	30	30	30	30	30	30	30	30	30
Buffer crown east (ft)	30	30	30	30	30	30	30	30	30
Buffer offset west (ft)	15	15	15	15	15	15	15	15	15
Buffer offset east (ft)	15	15	15	15	15	15	15	15	15
Canopy density west	70%	55%	50%	65%	50%	45%	40%	50%	70%

Cold Springs Creek -	SSTemp Inputs for 7/27/98								
Reach #	1	2	3	4	5	6	7	8	9
Stream	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr
Canopy density east	70%	55%	50%	65%	50%	45%	40%	50%	70%
Average air temp. (°C)	19.3	20.6	21.0	21.8	22.3	20.5	21.4	22.0	22.8
Average humidity	65%	65%	65%	65%	65%	65%	65%	65%	65%
Wind speed (mph)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Ground temp. (°C)	3.8	5.1	5.5	6.3	6.8	5.0	5.9	6.5	7.3
Ave. wetted width (ft)	4.9	6.6	4.9	7.5	8.9	6.6	6.6	6.6	11.5
Calculated depth (ft)	0.11	0.20	0.12	0.37	0.38	0.12	0.14	0.17	0.35
SSTemp ave. temp. (°C)	10.0	11.3	11.7	10.9	11.9	12.2	13.0	14.6	13.1
SSTemp max. temp. (°C)									

Table 3. SSTemp Calibration for 7/27/98 (page 2 of 5)

Cold Springs Creek -									
Reach #	10	11	12	13	14	15	16	17	18
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Inflow volume (cfs)	0.08	0.17	0.93	0.28	0.24	0.76	1.96	0.11	0.30
Inflow temp. (°C)	3.8	4.0	10.7	4.2	4.2	9.0	11.7	4.1	11.6
Outflow volume (cfs)	0.63	0.30	1.06	0.42	0.33	0.89	2.01	0.30	0.42
G/W temperature (°C)	3.8	4.0	4.6	4.2	4.2	4.6	5.0	4.1	4.9
Latitude (°)	47	47	47	47	47	47	47	47	47
Reach length (mi)	0.593	0.288	0.305	0.191	0.234	0.286	0.179	0.348	0.229

Cold Springs Creek -									
Reach #	10	11	12	13	14	15	16	17	18
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool
Upstream elev. (ft)	5,800	5,600	5,140	5,400	5,400	5,120	4,920	5,600	5,000
Downstream elev. (ft)	5,140	5,140	4,920	5,120	5,120	4,920	4,760	5,000	4,760
Width A term (s/ft^2)	8.08	8.75	9.85	8.08	8.43	9.21	9.15	9.00	8.86
B term (W = A Q^B)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Manning's n (wetted)	0.389	0.389	0.389	0.389	0.389	0.389	0.183	0.389	0.389
Azimuth (° from south)	-70	50	85	45	-40	15	35	-45	-25
Topographic west (°)	29	27	39	29	39	29	35	31	29
Topographic east (°)	29	27	39	29	39	29	35	31	29
Buffer height west (ft)	60	60	60	60	60	60	60	60	60
Buffer height east (ft)	60	60	60	60	60	60	60	60	60
Buffer crown west (ft)	30	30	30	30	30	30	30	30	30
Buffer crown east (ft)	30	30	30	30	30	30	30	30	30
Buffer offset west (ft)	15	15	15	15	15	15	15	15	15
Buffer offset east (ft)	15	15	15	15	15	15	15	15	15
Canopy density west	65%	45%	70%	60%	60%	60%	70%	65%	80%
Canopy density east	65%	45%	70%	60%	60%	60%	70%	65%	80%
Average air temp. (°C)	19.3	19.5	20.1	19.7	19.7	20.1	20.5	19.6	20.4
Average humidity	65%	65%	65%	65%	65%	65%	65%	65%	65%
Wind speed (mph)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Ground temp. (°C)	3.8	4.0	4.6	4.2	4.2	4.6	5.0	4.1	4.9
Ave. wetted width (ft)	6.6	6.6	9.8	6.6	6.6	8.9	10.5	6.6	7.2
Calculated depth (ft)	0.17	0.10	0.21	0.13	0.12	0.21	0.18	0.10	0.13
SSTemp ave. temp. (°C)	10.1	11.9	12.3	8.4	9.8	11.0	12.3	11.6	12.4
SSTemp max. temp. (°C)									

Table 3. SSTemp Calibration for 7/27/98 (page 3 of 5)

Cold Springs Creek -									
Reach #	19	20	21	22	23	24	25	26	27
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	W. Cool	W. Cool	W. Cool	W. Cool	Lower Cool
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Inflow volume (cfs)	2.43	0.11	0.28	3.13	0.35	1.11	0.14	1.79	5.91
Inflow temp. (°C)	12.3	4.6	11.4	13.1	4.7	11.7	5.0	12.4	13.9
Outflow volume (cfs)	2.81	0.28	0.32	3.94	1.11	1.24	0.55	1.96	6.39
G/W temperature (°C)	5.3	4.6	5.3	6.1	4.7	5.7	5.0	6.3	6.9
Latitude (°)	47	47	47	47	47	47	47	47	47
Reach length (mi)	0.412	0.234	0.182	0.740	0.813	0.215	0.675	0.285	0.452
Upstream elev. (ft)	4,760	5,280	4,800	4,500	5,400	4,600	5,400	4,240	3,940
Downstream elev. (ft)	4,500	4,800	4,500	3,940	4,600	4,240	4,240	3,940	3,600
Width A term (s/ft^2)	9.74	9.09	9.17	10.19	8.74	8.58	8.11	8.97	11.86
B term (W = A Q^B)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Manning's n (wetted)	0.183	0.389	0.389	0.183	0.183	0.183	0.183	0.183	0.320
Azimuth (° from south)	-10	85	40	40	-20	10	-40	-60	-10
Topographic west (°)	35	17	22	39	31	39	45	45	45
Topographic east (°)	35	17	22	39	31	39	45	45	45
Buffer height west (ft)	60	60	60	60	60	60	60	60	60
Buffer height east (ft)	60	60	60	60	60	60	60	60	60
Buffer crown west (ft)	30	30	30	30	30	30	30	30	30
Buffer crown east (ft)	30	30	30	30	30	30	30	30	30
Buffer offset west (ft)	15	15	15	15	15	15	15	15	15
Buffer offset east (ft)	15	15	15	15	15	15	15	15	15
Canopy density west	45%	55%	80%	50%	50%	70%	70%	70%	70%
Canopy density east	45%	55%	80%	50%	50%	70%	70%	70%	70%
Average air temp. (°C)	20.8	20.1	20.8	21.6	20.2	21.2	20.5	21.8	22.4

Cold Springs Creek -									
Reach #	19	20	21	22	23	24	25	26	27
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	W. Cool	W. Cool	W. Cool	W. Cool	Lower Cool
Average humidity	65%	65%	65%	65%	65%	65%	65%	65%	65%
Wind speed (mph)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Ground temp. (°C)	5.3	4.6	5.3	6.1	4.7	5.7	5.0	6.3	6.9
Ave. wetted width (ft)	11.8	6.6	7.2	13.1	8.2	8.9	6.6	10.2	17.1
Calculated depth (ft)	0.23	0.09	0.10	0.25	0.14	0.12	0.09	0.17	0.40
SSTemp ave. temp. (°C)	13.1	11.4	13.5	14.2	11.7	12.6	12.1	13.3	14.5
SSTemp max. temp. (°C)									17.1

Table 3. SSTemp Calibration for 7/27/98 (page 4 of 5)

Cold Springs Creek -									
Reach #	28	29	30	31	32	33	34	35	36
Stream	Lower Cool	Lower Cool	Lo Cld Spr	Lo Cld Spr	N. Ice	N. Ice	N. Ice	N. Ice	N. Ice
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Inflow volume (cfs)	6.39	6.65	11.65	12.59	0.41	0.29	1.59	1.78	2.27
Inflow temp. (°C)	14.5	15.1	14.4	14.6	5.2	5.3	10.9	12.0	12.0
Outflow volume (cfs)	6.65	6.68	12.59	13.40	1.05	0.54	1.78	2.27	2.59
G/W temperature (°C)	7.4	7.6	7.8	8.1	5.2	5.3	6.2	6.8	7.6
Latitude (°)	47	47	47	47	47	47	47	47	47
Reach length (mi)	0.376	0.132	0.489	0.503	0.625	0.341	0.202	0.281	0.526
Upstream elev. (ft)	3,600	3,400	3,360	3,200	5,060	5,000	4,300	4,000	3,600
Downstream elev. (ft)	3,400	3,360	3,200	3,040	4,300	4,300	4,000	3,600	3,200
Width A term (s/ft^2)	10.15	10.10	8.96	8.84	6.98	7.81	7.39	7.12	7.96
B term (W = A Q^B)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Manning's n (wetted)	0.183	0.183	0.071	0.071	0.114	0.114	0.183	0.183	0.320

Cold Springs Creek -									
Reach #	28	29	30	31	32	33	34	35	36
Stream	Lower Cool	Lower Cool	Lo Cld Spr	Lo Cld Spr	N. Ice	N. Ice	N. Ice	N. Ice	N. Ice
Azimuth (° from south)	-10	-15	-75	-35	5	50	50	30	30
Topographic west (°)	45	45	45	45	39	29	39	46	46
Topographic east (°)	45	45	45	45	39	29	39	46	46
Buffer height west (ft)	60	60	60	60	40	40	10	60	60
Buffer height east (ft)	60	60	60	60	40	40	10	60	60
Buffer crown west (ft)	30	30	30	30	20	20	5	30	30
Buffer crown east (ft)	30	30	30	30	20	20	5	30	30
Buffer offset west (ft)	15	15	15	15	10	10	3	15	15
Buffer offset east (ft)	15	15	15	15	10	10	3	15	15
Canopy density west	40%	80%	70%	70%	40%	50%	40%	85%	85%
Canopy density east	40%	80%	70%	70%	40%	50%	40%	85%	85%
Average air temp. (°C)	22.9	23.1	23.3	23.6	20.7	20.8	21.7	22.3	23.1
Average humidity	65%	65%	65%	65%	65%	65%	65%	65%	65%
Wind speed (mph)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Ground temp. (°C)	7.4	7.6	7.8	8.1	5.2	5.3	6.2	6.8	7.6
Ave. wetted width (ft)	14.8	14.8	14.8	14.8	6.6	6.6	8.2	8.2	9.5
Calculated depth (ft)	0.35	0.42	0.34	0.35	0.11	0.06	0.17	0.19	0.33
SSTemp ave. temp. (°C)	15.1	15.3	14.6	14.8	10.7	11.3	12.0	12.0	13.4
SSTemp max. temp. (°C)									

Table 3. SSTemp Calibration for 7/27/98 (page 5 of 5)

Cold Springs Creek -							
Reach #	37	38	39	40	41	42	43
Stream	N. Ice	S. Ice	S. Ice	S. Ice	Lo Cld Spr	Lo Cld Spr	Lo Cld Spr
Date	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98	7/27/98
Inflow volume (cfs)	2.59	0.27	0.52	0.76	16.81	17.00	17.51
Inflow temp. (°C)	13.4	6.3	11.8	12.8	14.7	14.8	15.3
Outflow volume (cfs)	2.62	0.52	0.76	0.80	17.00	17.51	17.71
G/W temperature (°C)	8.1	6.3	7.2	7.9	8.2	8.5	8.7
Latitude (°)	47	47	47	47	47	47	47
Reach length (mi)	0.158	0.341	0.305	0.243	0.142	0.618	0.401
Upstream elev. (ft)	3,200	4,400	3,800	3,400	3,040	3,000	2,800
Downstream elev. (ft)	3,040	3,800	3,400	3,040	3,000	2,800	2,700
Width A term (s/ft^2)	7.86	7.90	7.18	8.63	10.25	10.21	10.16
B term (W = A Q^B)	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Manning's n (wetted)	0.320	0.114	0.114	0.183	0.183	0.183	0.183
Azimuth (° from south)	30	45	50	60	-60	-50	-10
Topographic west (°)	54	29	17	42	45	45	11
Topographic east (°)	54	29	17	42	45	45	11
Buffer height west (ft)	60	60	60	60	60	60	40
Buffer height east (ft)	60	60	60	60	60	60	40
Buffer crown west (ft)	30	30	30	30	30	30	20
Buffer crown east (ft)	30	30	30	30	30	30	20
Buffer offset west (ft)	15	15	15	15	15	15	10
Buffer offset east (ft)	15	15	15	15	15	15	10
Canopy density west	70%	70%	90%	80%	50%	70%	50%
Canopy density east	70%	70%	90%	80%	50%	70%	50%
Average air temp. (°C)	23.6	21.8	22.7	23.4	23.7	24.0	24.2
Average humidity	65%	65%	65%	65%	65%	65%	65%

Cold Springs Creek -							
Reach #	37	38	39	40	41	42	43
Stream	N. Ice	S. Ice	S. Ice	S. Ice	Lo Cld Spr	Lo Cld Spr	Lo Cld Spr
Wind speed (mph)	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Ground temp. (°C)	8.1	6.3	7.2	7.9	8.2	8.5	8.7
Ave. wetted width (ft)	9.5	6.6	6.6	8.2	18.0	18.0	18.0
Calculated depth (ft)	0.30	0.07	0.09	0.10	0.66	0.65	0.70
SSTemp ave. temp. (°C)	13.9	11.8	12.8	14.8	14.8	15.3	15.8
SSTemp max. temp. (°C)					18.0		

Table 4. SSTemp Calibration for 8/6/99 (page 1 of 5)

Cold Springs Creek -	SSTemp Inputs for 8/6/99 Prediction								
Reach #	1	2	3	4	5	6	7	8	9
Stream	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr
Date	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99
Inflow volume (cfs)	0.08	0.35	0.25	1.61	3.03	0.26	0.57	0.69	4.20
Inflow temp. (°C)	3.8	8.7	5.5	10.1	9.9	5.0	10.7	11.4	11.2
Outflow volume (cfs)	0.35	1.19	0.41	3.03	3.31	0.57	0.69	0.89	5.84
G/W temperature (°C)	3.8	5.1	5.5	6.3	6.8	5.0	5.9	6.5	7.3
Latitude (°)	47	47	47	47	47	47	47	47	47
Reach length (mi)	0.364	0.667	0.332	0.496	0.287	0.457	0.148	0.410	0.765
Upstream elev. (ft)	5,800	5,200	4,800	4,300	3,920	5,200	4,400	4,200	3,740
Downstream elev. (ft)	5,200	4,300	4,300	3,900	3,740	4,400	4,200	3,740	3,360
Width A term (s/ft^2)	6.67	6.91	6.13	6.38	7.03	7.82	7.20	6.88	8.31
B term (W = A Q^B)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Manning's n (wetted)	0.317	0.317	0.317	0.317	0.317	0.317	0.317	0.317	0.181
Azimuth (° from south)	30	-50	35	-65	-60	-45	35	-10	-75

Cold Springs Creek -	SSTemp Inputs for 8/6/99 Prediction								
Reach #	1	2	3	4	5	6	7	8	9
Stream	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr
Topographic west (°)	17	39	35	35	39	45	40	39	35
Topographic east (°)	17	39	35	35	39	45	40	39	35
Buffer height west (ft)	60	60	60	60	60	60	60	60	60
Buffer height east (ft)	60	60	60	60	60	60	60	60	60
Buffer crown west (ft)	30	30	30	30	30	30	30	30	30
Buffer crown east (ft)	30	30	30	30	30	30	30	30	30
Buffer offset west (ft)	15	15	15	15	15	15	15	15	15
Buffer offset east (ft)	15	15	15	15	15	15	15	15	15
Canopy density west	70%	55%	50%	65%	50%	45%	40%	50%	70%
Canopy density east	70%	55%	50%	65%	50%	45%	40%	50%	70%
Average air temp. (°C)	17.8	19.1	19.5	20.3	20.8	19.0	19.9	20.5	21.3
Average humidity	65%	65%	65%	65%	65%	65%	65%	65%	65%
Wind speed (mph)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Ground temp. (°C)	3.8	5.1	5.5	6.3	6.8	5.0	5.9	6.5	7.3
Ave. wetted width (ft)	4.9	6.6	4.9	7.5	8.9	6.6	6.6	6.6	11.5
Calculated depth (ft)	0.12	0.21	0.13	0.40	0.42	0.13	0.15	0.19	0.38
SSTEMP ave. temp. (°C)	8.7	10.0	10.3	9.9	10.7	10.7	11.4	13.0	11.8
SSTEMP max. temp. (°C)	14.3	15.1	17.0	13.6	15.2	16.9	17.8	17.6	15.2

Table 4. SSTemp Calibration for 8/6/99 (page 2 of 5)

Cold Springs Creek -									
Reach #	10	11	12	13	14	15	16	17	18
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool
Date	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99
Inflow volume (cfs)	0.09	0.20	1.09	0.33	0.28	0.89	2.30	0.13	0.35
Inflow temp. (°C)	3.8	4.0	9.3	4.2	4.2	7.9	10.3	4.1	10.1
Outflow volume (cfs)	0.74	0.35	1.25	0.50	0.39	1.05	2.37	0.35	0.49
G/W temperature (°C)	3.8	4.0	4.6	4.2	4.2	4.6	5.0	4.1	4.9
Latitude (°)	47	47	47	47	47	47	47	47	47
Reach length (mi)	0.593	0.288	0.305	0.191	0.234	0.286	0.179	0.348	0.229
Upstream elev. (ft)	5,800	5,600	5,140	5,400	5,400	5,120	4,920	5,600	5,000
Downstream elev. (ft)	5,140	5,140	4,920	5,120	5,120	4,920	4,760	5,000	4,760
Width A term (s/ft^2)	7.82	8.47	9.53	7.82	8.16	8.91	8.86	8.72	8.57
B term (W = A Q^B)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Manning's n (wetted)	0.385	0.385	0.385	0.385	0.385	0.385	0.181	0.385	0.385
Azimuth (° from south)	-70	50	85	45	-40	15	35	-45	-25
Topographic west (°)	29	27	39	29	39	29	35	31	29
Topographic east (°)	29	27	39	29	39	29	35	31	29
Buffer height west (ft)	60	60	60	60	60	60	60	60	60
Buffer height east (ft)	60	60	60	60	60	60	60	60	60
Buffer crown west (ft)	30	30	30	30	30	30	30	30	30
Buffer crown east (ft)	30	30	30	30	30	30	30	30	30
Buffer offset west (ft)	15	15	15	15	15	15	15	15	15
Buffer offset east (ft)	15	15	15	15	15	15	15	15	15
Canopy density west	65%	45%	70%	60%	60%	60%	70%	65%	80%
Canopy density east	65%	45%	70%	60%	60%	60%	70%	65%	80%
Average air temp. (°C)	17.8	18.0	18.6	18.2	18.2	18.6	19.0	18.1	18.9

Cold Springs Creek -									
Reach #	10	11	12	13	14	15	16	17	18
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool
Average humidity	65%	65%	65%	65%	65%	65%	65%	65%	65%
Wind speed (mph)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Ground temp. (°C)	3.8	4.0	4.6	4.2	4.2	4.6	5.0	4.1	4.9
Ave. wetted width (ft)	6.6	6.6	9.8	6.6	6.6	8.9	10.5	6.6	7.2
Calculated depth (ft)	0.19	0.11	0.23	0.14	0.13	0.23	0.20	0.11	0.14
SSTEMP ave. temp. (°C)	8.8	10.3	10.7	7.4	8.5	9.8	10.8	10.1	10.9
SSTEMP max. temp. (°C)	13.9	18.3	14.6	14.3	14.4	14.5	14.9	15.7	14.4

Table 4. SSTemp Calibration for 8/6/99 (page 3 of 5)

Cold Springs Creek -									
Reach #	19	20	21	22	23	24	25	26	27
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	W. Cool	W. Cool	W. Cool	W. Cool	Lower Cool
Date	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99
Inflow volume (cfs)	2.86	0.13	0.33	3.68	0.41	1.31	0.17	2.10	6.95
Inflow temp. (°C)	10.8	4.6	10.0	11.7	4.7	10.3	5.0	11.0	12.3
Outflow volume (cfs)	3.30	0.33	0.38	4.64	1.31	1.46	0.65	2.31	7.51
G/W temperature (°C)	5.3	4.6	5.3	6.1	4.7	5.7	5.0	6.3	6.9
Latitude (°)	47	47	47	47	47	47	47	47	47
Reach length (mi)	0.412	0.234	0.182	0.740	0.813	0.215	0.675	0.285	0.452
Upstream elev. (ft)	4,760	5,280	4,800	4,500	5,400	4,600	5,400	4,240	3,940
Downstream elev. (ft)	4,500	4,800	4,500	3,940	4,600	4,240	4,240	3,940	3,600
Width A term (s/ft^2)	9.43	8.80	8.88	9.87	8.46	8.30	7.85	8.68	11.48
B term (W = A Q^B)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Manning's n (wetted)	0.181	0.385	0.385	0.181	0.181	0.181	0.181	0.181	0.317

Cold Springs Creek -									
Reach #	19	20	21	22	23	24	25	26	27
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	W. Cool	W. Cool	W. Cool	W. Cool	Lower Cool
Azimuth (° from south)	-10	85	40	40	-20	10	-40	-60	-10
Topographic west (°)	35	17	22	39	31	39	45	45	45
Topographic east (°)	35	17	22	39	31	39	45	45	45
Buffer height west (ft)	60	60	60	60	60	60	60	60	60
Buffer height east (ft)	60	60	60	60	60	60	60	60	60
Buffer crown west (ft)	30	30	30	30	30	30	30	30	30
Buffer crown east (ft)	30	30	30	30	30	30	30	30	30
Buffer offset west (ft)	15	15	15	15	15	15	15	15	15
Buffer offset east (ft)	15	15	15	15	15	15	15	15	15
Canopy density west	45%	55%	80%	50%	50%	70%	70%	70%	70%
Canopy density east	45%	55%	80%	50%	50%	70%	70%	70%	70%
Average air temp. (°C)	19.3	18.6	19.3	20.1	18.7	19.7	19.0	20.3	20.9
Average humidity	65%	65%	65%	65%	65%	65%	65%	65%	65%
Wind speed (mph)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Ground temp. (°C)	5.3	4.6	5.3	6.1	4.7	5.7	5.0	6.3	6.9
Ave. wetted width (ft)	11.8	6.6	7.2	13.1	8.2	8.9	6.6	10.2	17.1
Calculated depth (ft)	0.25	0.10	0.11	0.27	0.16	0.13	0.10	0.19	0.43
SSTEMP ave. temp. (°C)	11.7	10.0	11.8	12.6	10.3	11.1	10.7	11.8	12.9
SSTEMP max. temp. (°C)	16.7	17.7	15.8	17.2	16.4	15.6	15.2	15.9	15.4

Table 4. SSTemp Calibration for 8/6/99 (page 4 of 5)

Cold Springs Creek -									
Reach #	28	29	30	31	32	33	34	35	36
Stream	Lower Cool	Lower Cool	Lo Cld Spr	Lo Cld Spr	N. Ice	N. Ice	N. Ice	N. Ice	N. Ice
Date	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99
Inflow volume (cfs)	7.51	7.82	13.70	14.82	0.48	0.35	1.87	2.10	2.67
Inflow temp. (°C)	12.9	13.4	12.8	13.0	5.2	5.3	9.7	10.6	10.8
Outflow volume (cfs)	7.82	7.86	14.82	15.77	1.24	0.63	2.10	2.67	3.05
G/W temperature (°C)	7.4	7.6	7.8	8.1	5.2	5.3	6.2	6.8	7.6
Latitude (°)	47	47	47	47	47	47	47	47	47
Reach length (mi)	0.376	0.132	0.489	0.503	0.625	0.341	0.202	0.281	0.526
Upstream elev. (ft)	3,600	3,400	3,360	3,200	5,060	5,000	4,300	4,000	3,600
Downstream elev. (ft)	3,400	3,360	3,200	3,040	4,300	4,300	4,000	3,600	3,200
Width A term (s/ft^2)	9.82	9.78	8.68	8.55	6.76	7.56	7.15	6.89	7.71
B term (W = A Q^B)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Manning's n (wetted)	0.181	0.181	0.070	0.070	0.113	0.113	0.181	0.181	0.317
Azimuth (° from south)	-10	-15	-75	-35	5	50	50	30	30
Topographic west (°)	45	45	45	45	39	29	39	46	46
Topographic east (°)	45	45	45	45	39	29	39	46	46
Buffer height west (ft)	60	60	60	60	40	40	10	60	60
Buffer height east (ft)	60	60	60	60	40	40	10	60	60
Buffer crown west (ft)	30	30	30	30	20	20	5	30	30
Buffer crown east (ft)	30	30	30	30	20	20	5	30	30
Buffer offset west (ft)	15	15	15	15	10	10	3	15	15
Buffer offset east (ft)	15	15	15	15	10	10	3	15	15
Canopy density west	40%	80%	70%	70%	40%	50%	40%	85%	85%
Canopy density east	40%	80%	70%	70%	40%	50%	40%	85%	85%
Average air temp. (°C)	21.4	21.6	21.8	22.1	19.2	19.3	20.2	20.8	21.6

Cold Springs Creek -									
Reach #	28	29	30	31	32	33	34	35	36
Stream	Lower Cool	Lower Cool	Lo Cld Spr	Lo Cld Spr	N. Ice	N. Ice	N. Ice	N. Ice	N. Ice
Average humidity	65%	65%	65%	65%	65%	65%	65%	65%	65%
Wind speed (mph)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Ground temp. (°C)	7.4	7.6	7.8	8.1	5.2	5.3	6.2	6.8	7.6
Ave. wetted width (ft)	14.8	14.8	14.8	14.8	6.6	6.6	8.2	8.2	9.5
Calculated depth (ft)	0.38	0.46	0.37	0.39	0.12	0.07	0.18	0.21	0.36
SSTEMP ave. temp. (°C)	13.4	13.6	13.0	13.2	9.5	10.1	10.6	10.8	12.0
SSTEMP max. temp. (°C)	17.2	15.6	16.4	16.0	17.0	19.8	19.3	13.7	14.1

Table 4. SSTemp Calibration for 8/6/99 (page 5 of 5)

Cold Springs Creek -							
Reach #	37	38	39	40	41	42	43
Stream	N. Ice	S. Ice	S. Ice	S. Ice	Lo Cld Spr	Lo Cld Spr	Lo Cld Spr
Date	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99	8/6/99
Inflow volume (cfs)	3.05	0.32	0.61	0.89	19.78	20.00	20.60
Inflow temp. (°C)	12.0	6.3	10.6	11.6	13.1	13.2	13.7
Outflow volume (cfs)	3.08	0.61	0.89	0.94	20.00	20.60	20.84
G/W temperature (°C)	8.1	6.3	7.2	7.9	8.2	8.5	8.7
Latitude (°)	47	47	47	47	47	47	47
Reach length (mi)	0.158	0.341	0.305	0.243	0.142	0.618	0.401
Upstream elev. (ft)	3,200	4,400	3,800	3,400	3,040	3,000	2,800
Downstream elev. (ft)	3,040	3,800	3,400	3,040	3,000	2,800	2,700
Width A term (s/ft^2)	7.60	7.65	6.95	8.35	9.92	9.88	9.84
B term (W = A Q^B)	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Manning's n (wetted)	0.317	0.113	0.113	0.181	0.181	0.181	0.181
Azimuth (° from south)	30	45	50	60	-60	-50	-10

Cold Springs Creek -							
Reach #	37	38	39	40	41	42	43
Stream	N. Ice	S. Ice	S. Ice	S. Ice	Lo Cld Spr	Lo Cld Spr	Lo Cld Spr
Topographic west (°)	54	29	17	42	45	45	11
Topographic east (°)	54	29	17	42	45	45	11
Buffer height west (ft)	60	60	60	60	60	60	40
Buffer height east (ft)	60	60	60	60	60	60	40
Buffer crown west (ft)	30	30	30	30	30	30	20
Buffer crown east (ft)	30	30	30	30	30	30	20
Buffer offset west (ft)	15	15	15	15	15	15	10
Buffer offset east (ft)	15	15	15	15	15	15	10
Canopy density west	70%	70%	90%	80%	50%	70%	50%
Canopy density east	70%	70%	90%	80%	50%	70%	50%
Average air temp. (°C)	22.1	20.3	21.2	21.9	22.2	22.5	22.7
Average humidity	65%	65%	65%	65%	65%	65%	65%
Wind speed (mph)	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Ground temp. (°C)	8.1	6.3	7.2	7.9	8.2	8.5	8.7
Ave. wetted width (ft)	9.5	6.6	6.6	8.2	18.0	18.0	18.0
Calculated depth (ft)	0.33	0.07	0.10	0.11	0.72	0.71	0.77
SSTEMP ave. temp. (°C)	12.5	10.6	11.6	13.3	13.2	13.7	14.1
SSTEMP max. temp. (°C)	15.1	17.4	15.3	17.3	16.1	15.8	17.4

Table 5. CWE Prediction

Cold Springs Creek - CWE Prediction

Reach #	1	2	3	4	5	6	7	8	9
Stream	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr
Downstream elev. (ft)	5,200	4,300	4,300	3,900	3,740	4,400	4,200	3,740	3,360
Canopy density	70%	55%	50%	65%	50%	45%	40%	50%	70%
Ave. outflow temp. (°C)	8.9	11.9	12.2	12.0	13.4	12.4	13.2	13.4	12.9
Max. outflow temp. (°C)	10.1	13.8	14.3	14.0	15.8	14.5	15.4	15.8	15.1

Reach #	10	11	12	13	14	15	16	17	18
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool	Upper Cool
Downstream elev. (ft)	5,140	5,140	4,920	5,120	5,120	4,920	4,760	5,000	4,760
Canopy density	65%	45%	70%	60%	60%	60%	70%	65%	80%
Ave. outflow temp. (°C)	9.3	10.8	9.5	9.7	9.7	10.2	9.8	9.6	9.1
Max. outflow temp. (°C)	10.7	12.4	10.8	11.2	11.2	11.7	11.3	11.1	10.4

Reach #	19	20	21	22	23	24	25	26	27
Stream	Upper Cool	Upper Cool	Upper Cool	Upper Cool	W. Cool	W. Cool	W. Cool	W. Cool	Lower Cool
Downstream elev. (ft)	4,500	4,800	4,500	3,940	4,600	4,240	4,240	3,940	3,600
Canopy density	45%	55%	80%	50%	50%	70%	70%	70%	70%
Ave. outflow temp. (°C)	12.1	10.8	9.7	13.0	11.6	11.0	11.0	11.6	12.3
Max. outflow temp. (°C)	14.2	12.5	11.1	15.3	13.5	12.7	12.7	13.5	14.4

Reach #	28	29	30	31	32	33	34	35	36
Stream	Lower Cool	Lower Cool	Lo Cld Spr	Lo Cld Spr	N. Ice	N. Ice	N. Ice	N. Ice	N. Ice

Cold Springs Creek - CWE Prediction

Reach #	1	2	3	4	5	6	7	8	9
Stream	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr	Up Cld Spr
Downstream elev. (ft)	3,400	3,360	3,200	3,040	4,300	4,300	4,000	3,600	3,200
Canopy density	40%	80%	70%	70%	40%	50%	40%	85%	85%
Ave. outflow temp. (°C)	14.9	12.2	13.2	13.6	12.9	12.2	13.6	11.3	12.2
Max. outflow temp. (°C)	17.6	14.2	15.5	15.9	15.2	14.3	16.0	13.1	14.2

Reach #	37	38	39	40	41	42	43
Stream	N. Ice	S. Ice	S. Ice	S. Ice	Lo Cld Spr	Lo Cld Spr	Lo Cld Spr
Downstream elev. (ft)	3,040	3,800	3,400	3,040	3,000	2,800	2,700
Canopy density	70%	70%	90%	80%	50%	70%	50%
Ave. outflow temp. (°C)	13.6	11.9	11.4	12.9	15.1	14.1	15.7
Max. outflow temp. (°C)	15.9	13.9	13.2	15.1	17.8	16.6	18.6

Table 6. Temperature Modeling Comparisons for 7/27/98 Calibration

Parameter/location	Measured (°C)	Heat Source (°C)		SSTEMP (°C)	
		simulated	deviation	simulated	deviation
Reach 27 average temperature	14.5	13.9	-0.6	14.5	0.0
Reach 27 maximum temperature	15.9	16.7	0.8	17.1	1.2
Reach 41 average temperature	15.6	14.3	-1.3	14.8	-0.8
Reach 41 maximum temperature	17.4	15.5	-1.9	18.0	0.6
RMS deviation (all)			**1.25**		**0.78**
RMS deviation in maximums			**1.46**		**0.95**

Table 7. Temperature Modeling Comparisons for 8/6/99 Prediction

Parameter/location	Measured (°C)	Heat Source (°C)		SSTEMP (°C)		Measured - ave. '98-'00 (°C)	CWE (°C)	
		predicted	error	predicted	error		predicted	error
Reach 27 average temperature	12.0	13.1	1.1	12.9	0.9	13.3	12.3	-1.0
Reach 27 maximum temperature	13.3	15.6	2.3	15.4	2.1	14.5	14.4	-0.1
Reach 41 average temperature	13.5	13.6	0.1	13.2	-0.3	14.6	15.1	0.5
Reach 41 maximum temperature	14.9	14.6	-0.3	16.1	1.2	16.2	17.8	1.7
RMS error (all)			**1.28**		**1.30**			**1.01**
RMS error in maximums			**1.64**		**1.71**			**1.17**