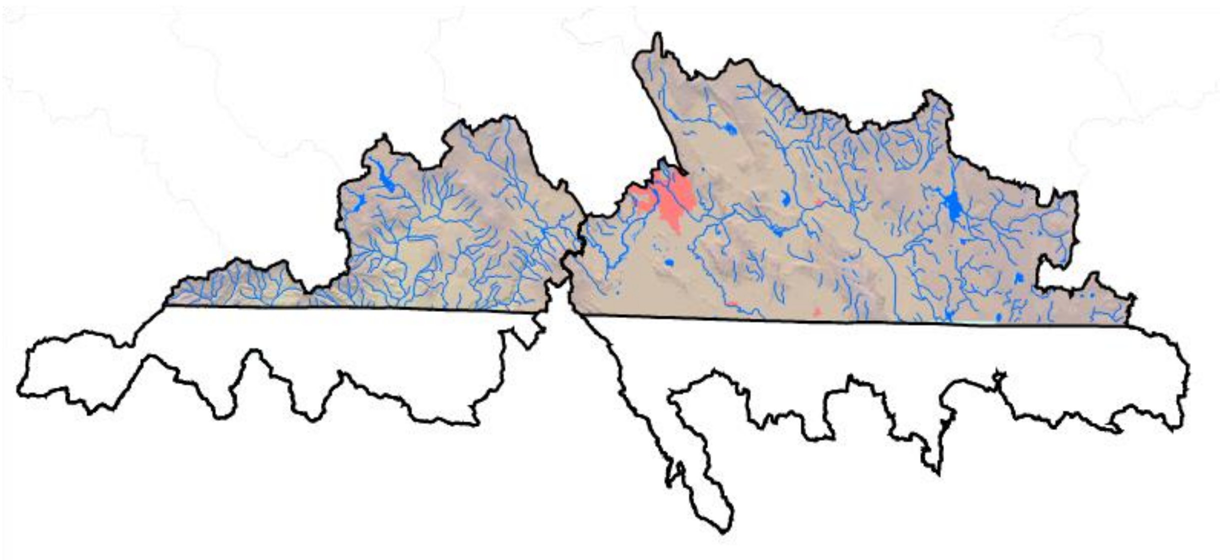
Appendix A:

Upper Klamath and Lost Subbasins Tributary Temperature and Effective Shade Models



This document is supplemental to the Upper Klamath and Lost Subbasins Temperature TMDL

State of Oregon
DEQ Department of Environmental Quality

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Figures

Tables

A.1 Overview

This appendix documents model setup, calibration, and scenario simulations for various streams and rivers modeled with the Heat Source model (Boyd and Kasper 2003). Heat Source was used on ten streams (Figure A-1) in the Upper Klamath and Lost Subbasins to model solar radiation, effective shade, and stream temperatures. For temperature modeling on the Klamath River and Lost River system see Appendices B-C and Appendices F-G respectively.

Temperature, solar radiation, and effective shade were modeled with Heat Source on the following streams:

- Jenny Creek
- Spencer Creek
- Miller Creek (upstream of Pine Creek)

Solar radiation and effective shade were modeled with Heat Source on the following streams:

- Antelope Creek
- Barnes Valley Creek
- Horse Canyon Creek
- Lapham Creek
- Long Branch Creek
- Lost River
- Miller Creek (downstream of Pine Creek)
- North Fork Willow Creek

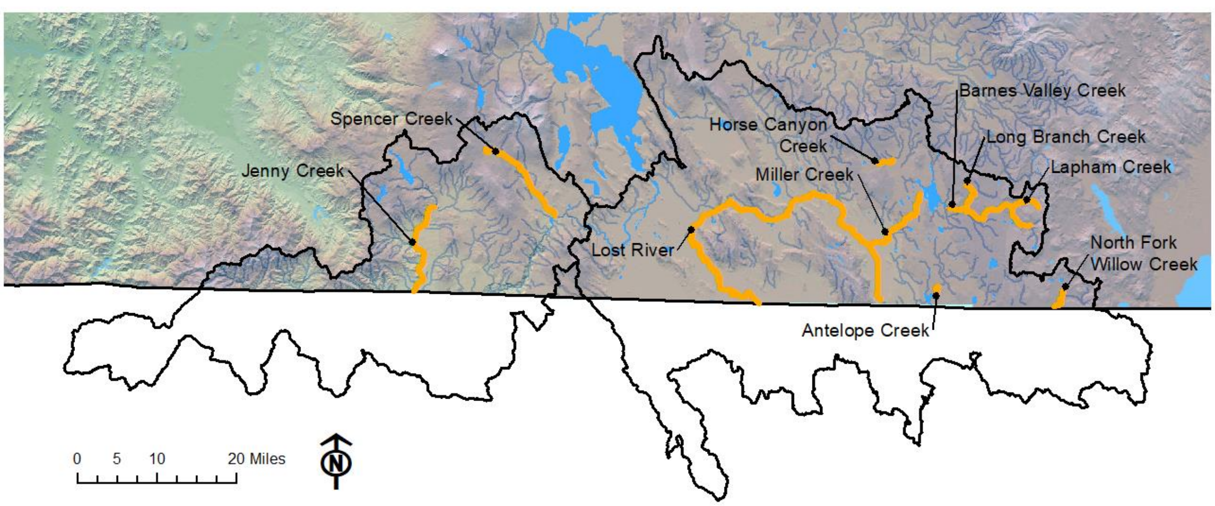


Figure A-1. Streams and rivers modeled with Heat Source.

A.2 Available Data

A.2.1 Ground Level Data

A.2.1.1 Overview

Several ground level data collection efforts have been completed in the Upper Klamath and Lost Subbasins. Specifically, this stream temperature analysis relied on the following data types: continuous temperature data, flow volume (gage data and instream measurements), vegetation surveys, and effective shade measurements.

The following parties are credited for collecting the data used in the Upper Klamath and Lost Tributaries Temperature TMDL:

- Oregon Department of Environmental Quality
- US Bureau of Land Management
- US Bureau of Reclamation
- US Forest Service
- Watershed Sciences, Inc.
- Jackson County
- Oregon Water Resources Department
- US Geological Survey
- National Climatic Data Clearinghouse

A.2.1.2 Continuous Temperature Data

Continuous temperature data measured in 2001 were used in this analysis to:

- Calibrate stream emissivity for thermal infrared radiometry (TIR),
- Calculate temperature statistics and assess the temporal component of stream temperature,
- Calibrate temporal temperature simulations,
- Input for model boundary conditions.

Continuous temperature data was collected at one location for a specified period of time, usually spanning several summertime months. Measurements were collected using thermistors[1] and data from these devices were routinely checked for accuracy. Continuous temperature data were collected throughout the subbasins during several years. Table A- 1 provides a summary of 2001 continuous stream temperature data utilized for heat source modeling as either model boundary conditions or as calibration data. Specific uses for each site are described in the model setup and calibration sections later in this report (Section A.4). Actual stream temperature data is available from DEQ upon request.

[1] Thermistors are small electronic devices that are used to record half-hourly or hourly stream temperature at one location for a specified period of time.

Table A- 1 Continuous temperature data utilized for heat source modeling.

Site ID	Site Name	Latitude	Longitude	Source
BXDW	Keene Creek below Lincoln Creek, at lower BLM line Sec.17 NW1/4	42.0936	-122.3822	BLM
BXON	Jenny Creek below Keene Creek, at Box O Ranch north boundary	42.0816	-122.3490	BLM
BXOS	Jenny Creek below Oregon Gulch, at Box O Ranch south boundary	42.0545	-122.3573	BLM
JNYU	Jenny Creek above Johnson Creek	42.1650	-122.3208	BLM
LWRX	Jenny Creek below Spring Creek, at Road 41-2E-10.1	42.0233	-122.3581	BLM
26574-ORDEQ (SP4920)	Spencer Creek at outlet of Buck Lake	42.2628	-122.1650	USFS
SP4800	Spencer Creek just upstream of lower exclosure fence (Section 17)	42.2571	-122.1472	BLM
27736-ORDEQ (SP4600)	Spencer Creek (Section 21)	42.2472	-122.1260	BLM
27735-ORDEQ (SP4300)	Spencer Creek (Section 28)	42.3128	-122.1844	BLM
27734-ORDEQ (SP3400)	Spencer Creek upstream from Hook-Up Road (Section 34)	42.2279	-122.0991	BLM
SP4000	Spencer Creek at upstream end of meadow (Broken Bridge)	42.2060	-122.0882	BLM
SP3985	Spencer Creek downstream end of meadow	42.1926	-122.0715	BLM
SP3800	Spencer Creek at mouth	42.1560	-122.0271	BLM
NA	Miller Creek downstream of Gerber Reservoir	42.2007	-121.1303	BLM
MR4760	Miller Creek at Round Valley Road bridge	42.1872	-121.1337	BLM
MR4320	Miller Creek in 39S-13E-33	42.1434	-121.1794	BLM

A.2.1.3 Flow Volume – Gage Data and Instream Measurements

Flow volume data and other instream measurements were collected at several sites in the Jenny Creek Watershed (Table A- 2) by the BLM during the critical stream temperature period in 2001. These measurements were used to develop flow mass balances for the Jenny Creek temperature model. Continuous daily outflows from Gerber Reservoir were provided by the Bureau of Reclamation.

Table A- 2 Instantaneous instream flow measurements in the Jenny Creek Watershed.

Site ID	Latitude	Longitude	Date	Flow cfs (cms)	Velocity (ft/s)	Wetted Width (m)	Average Depth (m)
BXOS	42.0545	-122.3573	7/17/2001	7.0 (0.1968)	0.4377	5.8	0.25
BXON	42.0816	-122.3490	7/17/2001	6.6 (0.1878)	0.4971	9.6	0.13
JNYM	42.1283	-122.3525	7/18/2001	1.3 (0.0364)	0.6742	1.5	0.12
JNYU	42.1650	-122.3208	7/17/2001	0.8 (0.0224)	0.2701	2.7	0.10
LWRX	42.0233	-122.3581	7/17/2001	15.3 (0.4323)	0.6469	7.5	0.29
BXDW	42.0936	-122.3822	7/18/2001	2.3 (0.0659)	0.2651	8.3	0.10

A.2.1.4 Vegetation and Habitat Surveys

Vegetation and habitat surveys were conducted by the BLM, USFS, and DEQ to document vegetation conditions and characteristics along many of the model streams. These data were used to assist in model setup. The survey data included vegetation type, height, cover percentage, stream overhang distance, and distance from edge of the channel to vegetation. Survery of stream and substrate conditions were also made. Data are available from DEQ, USFS, or BLM upon request.

A.2.1.5 Effective Shade Measurements

Effective shade data in Table A- 3 were used to calibrate simulation of incoming solar radiation and vegetation conditions. Effective shade measurements were taken by the BLM on Antelope, Barnes Valley, and Long Branch Creeks; and by DEQ on Spencer Creek. All effective shade measurements were collected with a Solar Pathfinder and correspond to solar paths observed during the months of July/August. Multiple measurements were taken at each site with a measurement taken at 50 foot intervals along the stream.

Table A- 3 Effective shade measurements used to calibrate solar radiation simulations.

Stream	Latitude	Longitude	Effective Shade Measurements				
Antelope Creek	42.0273	-121.0895	15%	14%	26%	30%	10%
Barnes Valley Creek	42.1761	-121.0519	8%	2%	18%	14%	28%
Barnes Valley Creek	42.1670	-121.0028	26%	14%	28%	30%	48%
Barnes Valley Creek	42.1576	-120.9966	22%	30%	18%	15%	21%
Barnes Valley Creek	42.1574	-120.9884	10%	5%	31%	15%	23%
Barnes Valley Creek	42.1575	-120.9782	6%	6%	5%	6%	17%
Long Branch Creek	42.1748	-121.0156	8%	10%	34%	38%	44%
Long Branch Creek	42.1797	-121.0151	13%	5%	10%	13%	15%
Long Branch Creek	42.1840	-121.0143	1%	2%	8%	5%	2%
Spencer Creek	42.2628	-122.1570	40%	38%	36%		
Spencer Creek	42.2369	-122.1149	64%	64%	61%		
Spencer Creek	42.2254	-122.0989	67%	74%	50%		
Spencer Creek	42.2237	-122.0986	80%	82%	85%		
Spencer Creek	42.1944	-122.0742	7%	58%	62%		
Spencer Creek	42.1556	-122.0269	15%	37%	90%		

A.2.2 GIS and Remotely Sensed Data

A.2.2.1 Overview

A wealth of spatial data has been developed for the Klamath River Basin. The stream temperature TMDL relies extensively on GIS and remotely sensed data. Water quality issues in the Upper Klamath and Lost Subbasins are interrelated, complex and spread over hundreds of square miles. The TMDL analysis strives to capture these complexities using the highest resolution spatial data available.

A.2.2.2 10-Meter Digital Elevation Model (DEM)

A digital elevation model (DEM) consists of digital information that provides a uniform matrix of terrain elevation values. It provides basic quantitative data for deriving terrain elevation, stream elevation, stream slope, and topographic information. The 10-meter DEM contains a land surface elevation value for each 10-meter square. The US Geological Survey, US Forest Service, and Bureau of Land Management produce these digital cartographic/geographic data files and are distributed through the Oregon Geospatial Data Clearinghouse (OGDC).

A.2.2.3 Light Detection and Ranging (LiDAR)

Light Detection and Ranging (LiDAR) is a remote sensing method that uses pulses of light to calculate the elevation of ground and surface features with a high degree of accuracy and resolution. LiDAR data is used to develop high resolution digital surface models (DSM) and DEMs which can then be used to derive canopy height. The Oregon Department of Geology and Mineral Industries oversees the Oregon LiDAR Consortium (OLC), which develops cooperative agreements for LiDAR collection. LiDAR collected through the OLC is made available for free and can be downloaded at https://www.oregongeology.org/lidar/. LIDAR was used to characterize vegetation height and ground elevations in the Lost River and Miller Creek.

A.2.2.4 Aerial Imagery – Digital Orthophoto Quads

Aerial imagery was used to:

- Map stream features such as stream position, channel edges and wetted channel edges,
- Map near stream vegetation,
- Map instream structures such as dams, weirs, unmapped diversions/withdrawals, etc.

A digital orthophoto quad (DOQ) is a digital image of an aerial photograph in which displacements caused by the camera angle and terrain have been removed. In addition, DOQs are projected in map coordinates combining the image characteristics of a photograph with the geometric qualities of a map. For this analysis, color DOQs were provided by Jackson County (images from 2001 – 2003). The BLM provided false color near infrared photographs for some riparian areas of the Lost River tributaries and for Spencer Creek (images from 2000). Black and white DOQs provided by USGS were used when no other aerial images were available (images from 1994). Color DOQs are now available for the entire state and may be downloaded from http://www.oregonexplorer.info/imagery/.

A.2.2.5 Thermal Infrared Radiometry (TIR) Temperature Data

TIR temperature data were used to:

- Develop continuous spatial temperature data sets,
- Calculate longitudinal heating profiles/gradients,
- Visually observe complex distributions of stream temperatures at a large landscape scale,
- Map/Identify significant thermal features,
- Develop flow mass balances,
- Validate simulated stream temperatures.

TIR imagery measures the temperature of the outermost portions of the bodies/objects in the image (i.e., ground, vegetation, and stream). The bodies of interest are opaque to longer wavelengths and there is little, if any, penetration of the bodies.

TIR data was gathered through a sensor mounted on a helicopter that collected digital data directly to an on-board computer at a rate that insured the imagery maintained a continuous image overlap of at least 40%. The TIR detected emitted radiation at wavelengths from 8-12 microns (long-wave) and recorded the level of emitted radiation as a digital image across the full 12-bit dynamic range of the sensor. Each image pixel contained a measured value that was directly converted to a temperature. Each thermal image has a spatial resolution of less than one-half meter/pixel. Visible video sensor captured the same field-of-view as the TIR sensor. GPS time was encoded on the imagery.

Data collection was timed to capture maximum daily stream temperatures, which typically occur between 14:00 and 18:00 hours. The helicopter was flown longitudinally over the center of the stream channel with the sensors in a vertical (or near vertical) position. In general, the flight altitude was selected so that the stream channel occupied approximately 20-40% of the image frame. A minimum altitude of approximately 300 meters was used both for maneuverability and for safety reasons. If the stream split into two channels that could not be covered in the sensor's field of view, the survey was conducted over the larger of the two channels.

In-stream temperature data loggers were distributed in each subbasin prior to the survey to ground truth the radiant temperatures measured by the TIR. TIR data can be viewed as GIS point coverages or TIR imagery.

Direct observation of spatial temperature patterns and thermal gradients is a powerful application of TIR derived stream temperature data. Thermally significant areas can be identified in a longitudinal stream temperature profile and related directly to specific sources (i.e., water withdrawal, tributary confluence, vegetation patterns, etc.). Areas with stream water mixing with subsurface flows (i.e., hyporheic and inflows) are apparent and often dramatic in TIR data. Thermal changes captured with TIR data can be quantified as a specific change in stream temperature or a stream temperature gradient that results in a temperature change over a specified distance.

DEQ contracted with Watershed Sciences, Inc. to collect TIR data in the Upper Klamath and Lost Subbasins during 2001 (**Figure A-** 2). Longitudinal river temperatures were sampled using thermal infrared radiometry (TIR) in separate flights for each stream. Temperature data sampled from the TIR imagery revealed spatial patterns that are variable due to localized stream heating, tributary mixing, and groundwater influences.

Thermal stratification was identified in TIR imagery and by comparison with the instream temperatures loggers. For example, the imagery may reveal a sudden cooling at a riffle or downstream of an instream structure, where water was rather stagnant or deep just upstream.

TIR-derived longitudinal stream temperature profiles are presented in **Section 4**. The Klamath Basin TIR survey report is available for download at the Oregon DEQ website (Watershed Sciences, Inc. 2002). The TIR survey reports contain detailed flight information, results discussions, sample imagery, and longitudinal temperature profiles. (Actual TIR data is available upon request from DEQ. Viewing the TIR data requires ArcView with Spatial Analyst.)

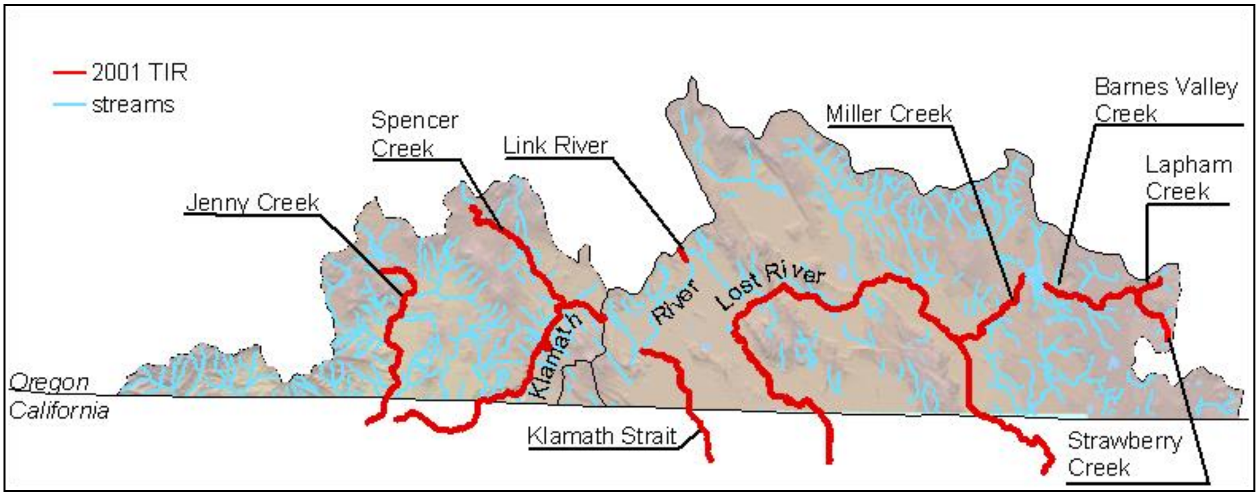


Figure A- 2. TIR flight paths in the Upper Klamath and Lost Subbasins.

A.3 Derived Data and Sampled Parameters

Several landscape scale GIS data sets were sampled to derive spatial stream data. Sampling density was user-defined and generally matched any GIS data resolution and accuracy. The sampled parameters used in the stream temperature analysis were:

- Stream Position and Aspect
- Stream Elevation and Gradient
- Maximum Topographic Shade Angles (East, South, West)
- Channel Width
- Mass balance TIR Temperature Data Associations
- Vegetation

The following sub-sections detail the methodologies used for each derived data type. The results, resolution and accuracy for each derived data type are discussed in **Sections 4.1-4.10**.

A.3.1 Channel Morphology

A.3.1.1 Overview

Channel morphology is largely a function of high flow volume magnitude and frequency, stream gradient, sediment supply and transportation, stream bed and bank materials and stream bank stability (Rosgen 1996 and Leopold et al. 1964).

The predominant thermodynamic influence of channel morphology is quite simple. Wider channels result in the combined effect of increased solar radiation loading via decreased stream surface shade and increased stream surface area exposed to solar radiation loading. A wider stream has a larger surface exposed to surface thermal processes. Other thermal effects that relate to channel morphology include altered stream hydraulics caused by increased wetted perimeter and decreased stream depth. Disturbance of surface water and groundwater interactions may also result from channel morphology modifications and have the combined effects of lowering near stream groundwater tables, reducing the groundwater inflow, removing cool sources of groundwater that serve to reduce instream temperatures and modifying hyporheic flows. Substrate changes may decrease or impair hyporheic flows (i.e., flows that occur in the interstitial spaces in the bed substrate) that help buffer stream temperature change.

In places where channel morphology is anthropogenically disturbed, resulting in decreased effective shade levels, passive restoration could be a primary focus of temperature related restoration efforts. Passive restoration efforts could include removing sources of channel disturbance that are known to degrade and slow or prevent restoration. Vegetation is a primary component in shaping channel form and function and should be a significant emphasis in all restoration planning and activities. Active restoration could be considered where severe channel disturbances cannot be remedied via passive restoration techniques. Examples of areas where active restoration could be considered include severe vertical down cutting, diked channels and removal of instream structures that prevent progress towards the desired stream channel condition. Other instream structures can serve as beneficial components in channel restoration such as rock barbs, sediment catchments, etc.

A.3.1.2 Channel Width Assessment

Channel width is an important component in stream heat transfer and mass transfer processes. Effective shade, stream surface area, wetted perimeter, stream depth and stream hydraulics are all highly sensitive to channel width. Accurate measurement of channel width across the stream network, coupled with other derived data, allows a comprehensive analytical methodology for assessing channel morphology. The steps for conducting channel width assessment are listed below (Figure A-2).

Step 1. Stream channel edges were digitized from DOQs at a 1:5,000 or less map scale. These channel boundaries establish the active channel width (e.g. Figure A- 3), which is defined for purposes of the TMDL, as the width between shade-producing near-stream vegetation. Where near-stream vegetation is absent, the near-stream boundary is used, defined as downcut stream banks or areas where the near-stream zone is unsuitable for vegetation growth due to external factors (i.e., roads, railways, buildings, etc.).

Step 2. Channel widths were sampled at every 50 meters using TTools[2]. The sampling algorithm measured the channel width in the transverse direction relative to the stream aspect.

Step 3. Compared sampled channel width and ground level measurements. TTools sampled channel widths were then compared to ground level measurements for verification purposes.

Step 4. The **bottom width** was derived by assuming a trapezoidal channel and parameterized side slopes and width-to-depth ratios.

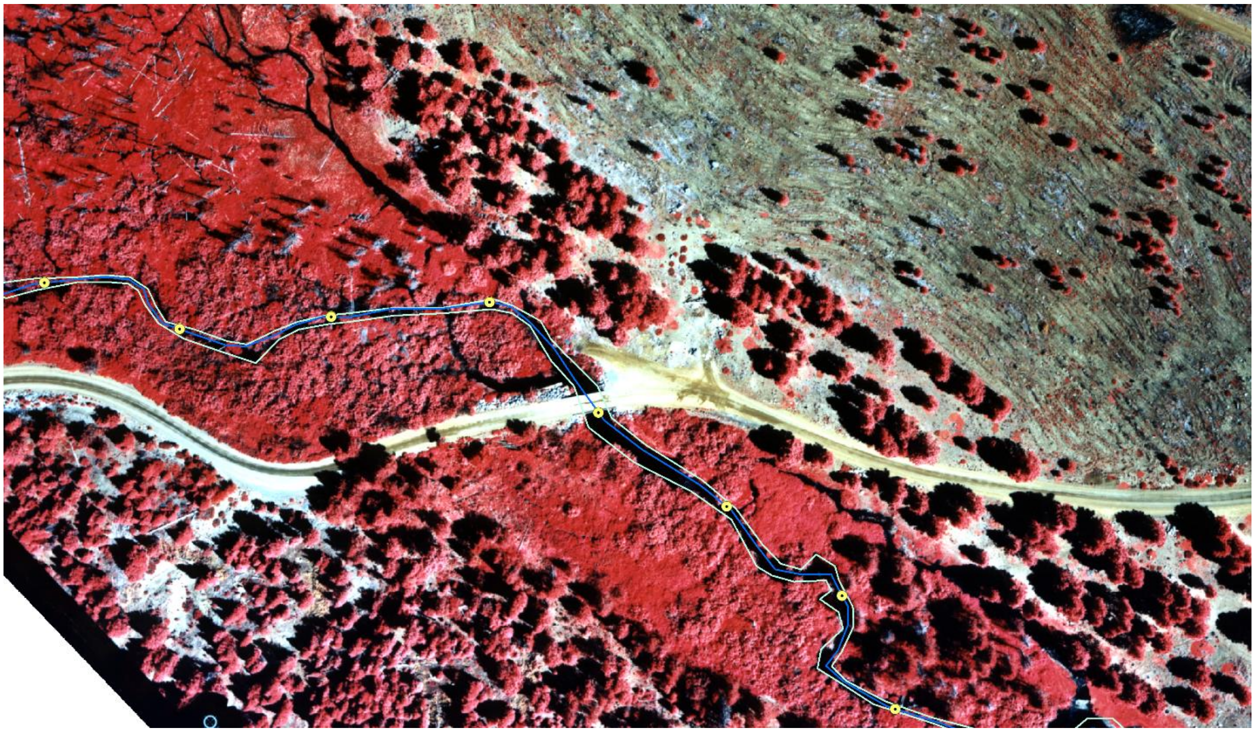


Figure A- 3. Digitized active channel with centerline, model nodes (points), right bank, and left bank features.

[2] A GIS tool developed by Oregon DEQ for automatically sampling spatial data sets and creating a Heat Source input database (Boyd and Kasper 2003).

A.3.2 Vegetation

A.3.2.1 Overview

The role of vegetation in maintaining a healthy stream condition and water quality is well documented and accepted in scientific literature (Beschta et al. 1987). Vegetation impacts the stream and the surrounding environment in the following ways:

- Vegetation plays an important role in regulating radiant heat in stream thermodynamic regimes.
- Channel morphology is often highly influenced by vegetation type and condition by affecting flood plain and instream roughness, contributing coarse woody debris, and influencing sedimentation, stream substrate compositions and stream bank stability.
- Vegetation creates a thermal microclimate that generally maintains cooler air temperatures, higher relative humidity and lower wind speeds along stream corridors.
- Riparian and instream nutrient cycles are affected by vegetation.

A.3.2.2 Vegetation – Mapping, Classification and Sampling

With the recognition that vegetation is an important parameter in influencing water quality, DEQ made the development of vegetation data sets in the Upper Klamath and Lost Subbbasins a high priority. Variable vegetation conditions in the Klamath River Basin require a higher resolution than currently available GIS data sources. To meet this need, DEQ has mapped vegetation for most streams using Digital Orthophoto Quads (DOQs) at a 1:5,000 map scale. On the Lost River, LiDAR data was used to characterize vegetation.

For vegetation mapped using DOQ, existing vegetation was digitized and sampled for the streams with TIR Data (Figure A- 4) following the steps listed below. Vegetation features were mapped out to a maximum of 300 feet in the transverse direction from channel edge. Vegetation data was developed by DEQ in successive steps.

Step 1. Vegetation polygons and stream polylines were digitized from DOQs. All digitized polygons were drawn to capture visually like vegetation features. All digitized line work was completed at a 1:5,000 map scale or less.

Step 2. Basic vegetation types were categorized and assigned to individual polygons. The vegetation categories used in this effort were aggregate vegetation groups, such as: conifers, hardwoods, shrubs, etc. Existing heights and densities were assigned according to aerial photograph analysis and ground level data collection.

Step 3. Automated sampling was conducted on classified vegetation spatial data sets using TTools. At regular interval along the stream is a stream node (e.g. every 50 meters). At each node the vegetation was sampled radially starting at the channel center, out to a specified distance (transverse sample distance). The transverse sample distance for each modeled stream is unique to each stream and was determined based on stream specific factors including the width of the stream and the type and spatial extent of shade producing vegetation.

Step 4. Ground level vegetation data was statistically summarized and sorted by vegetation type. Median values for vegetation height and density were then used to describe DEQ vegetation classifications.

Figure A- 4 summarizes the steps followed for vegetation classification. More detailed information can be found in *Analytical Methods for Dynamic Open Channel Heat and Mass Transfer: Methodology for Heat Source Model Version 7.0* (Boyd and Kasper 2003), which can be downloaded from the DEQ website. (https://www.oregon.gov/deq/wq/tmdls/Pages/TMDLs-Tools.aspx)

Vegetation on the Lost River was characterized from existing LiDAR data collected by Watershed Sciences for the Bureau of Reclamation (WS, 2011). A one meter resolution land cover height raster was derived by subtracting the LiDAR bare earth elevation raster from the LiDAR highest hit elevation raster. This raster was used to statistically summarize the vegetation and other land cover heights along the stream. Automated sampling was conducted on height rasters using a python script called TTools. Every 50 meters along the stream (i.e., in the longitudinal direction), the vegetation height was sampled radially every 8 meters; starting at the channel center, out to 40 meters. This sampling rate resulted in 36 samples per node.

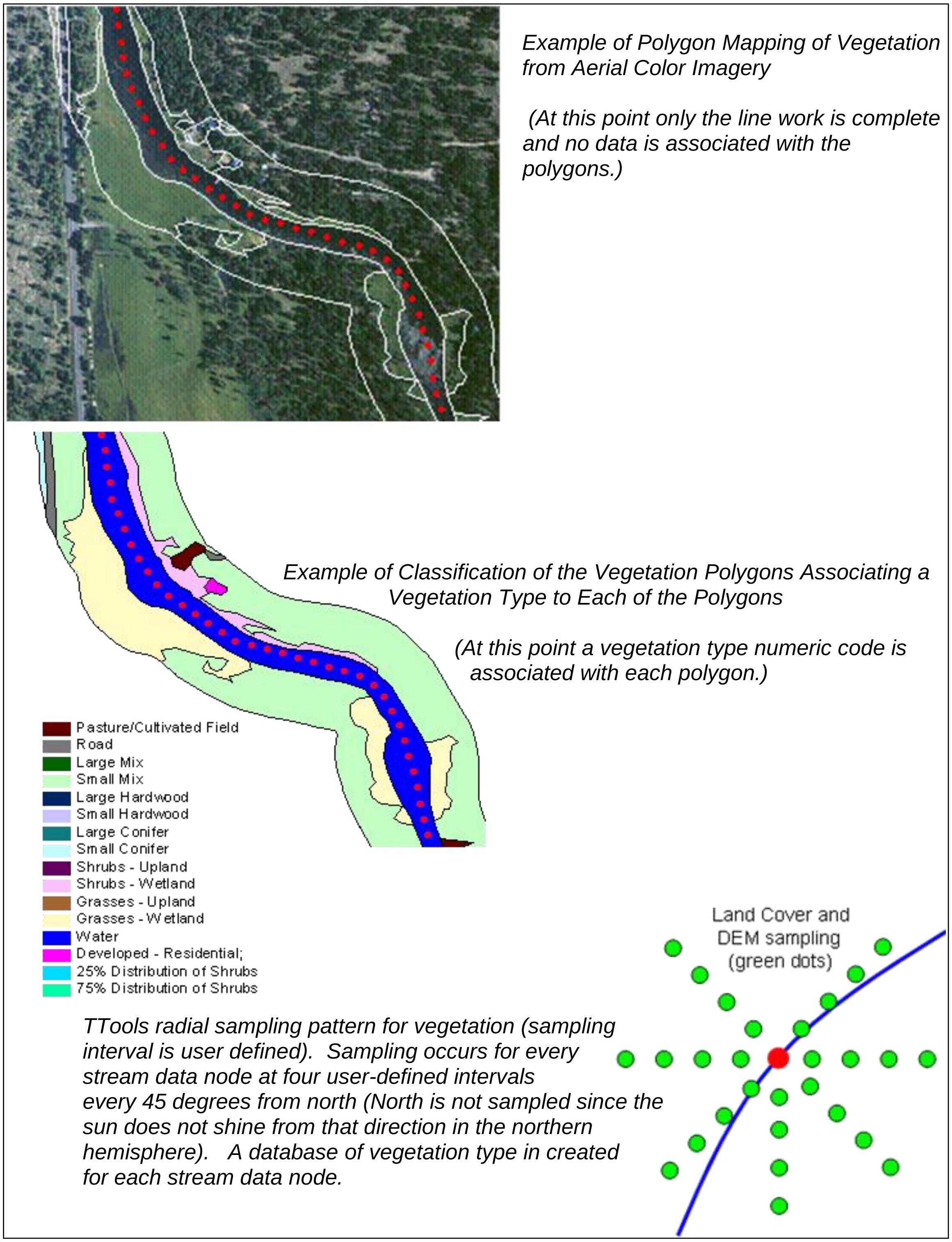


Figure A- 4. Steps for digitizing and classifying vegetation.

A.3.3 Hydrology

A.3.3.1 Mass Balance Development

TIR sampled stream temperature data was used to develop a flow mass balance which was verified with ground level flow measurements. Mass transfer areas (tributaries, springs, return flows, etc.) were identified for each stream. Several unmapped subsurface mass transfer areas were identified and the relative thermal and hydrologic impact to the stream system was quantified.

All stream temperature changes that result from mass transfer processes can be described mathematically using the following relationship:

$$T_{mix} = \frac{(Q_{up} \cdot T_{up}) + (Q_{in} \cdot T_{in})}{(Q_{mix})}$$

where,
Q_{up}: Stream flow rate upstream from mass transfer process
Q_{in}: Inflow volume or flow rate
Q_{mix}: Resulting volume or flow rate from mass transfer process ($Q_{up} + Q_{in}$)
T_{up}: Stream temperature directly upstream from mass transfer process
T_{in}: Temperature of inflow
T_{mix}: Resulting stream temperature from mass transfer process assuming complete mix

All water temperatures (i.e., T_{up}, T_{in} and T_{mix}) were provided by the TIR data. Provided that at least one instream flow rate is known the other flow rates can be calculated.

Following are assumptions and limitations of the flow mass balance methodology:

- **Small mass transfer processes were not accounted for.** Only mass transfer processes with measured flow rates or those that caused a quantifiable change in stream temperature in the receiving waters (identified by TIR data) could be included. *This assumption can lead to an under estimate of influent mass transfer processes.*
- **Ground level flow data was limited**. Errors in the calculations of mass transfer can become cumulative and propagate in the methodology since validation can only be performed at sites with known flow rates. *These mass balance profiles should be considered estimates of a steady state flow condition*.
- **Water withdrawals were not directly quantified**. Instead, water right data is obtained from the POD and WRIS OWRD databases. An assumption is made that these water rights are being used if water availability permits. *This assumption can lead to an over estimate of water withdrawals.*
- **Water withdrawals were assumed to occur only at OWRD mapped points of diversion sites.** There may have been additional diversions occurring throughout the stream network. *This assumption can lead to an underestimate of water withdrawals and an under estimate of potential flow rates.*

A.3.4 Effective Shade

A.3.4.1 Overview

Factors that influence stream surface effective shade are incorporated into the simulation methodology, and include the following:

Season/Time: Date/Time
Stream Morphology: Aspect, Channel Width, Incision
Geographic Position: Latitude, Longitude, Topography
Vegetation: Vegetation Height, Width, Density
Solar Position: Solar Altitude, Solar Azimuth

For detailed information, refer to “Analytical Methods for Dynamic Open Channel Heat and Mass Transfer: Methodology for Heat Source Model Version 7.0” (Boyd and Kasper 2003).

Effective shade was simulated every 50 or 100 longitudinal meters along the stream depending on the stream. Simulation periods were for July and August. Effective shade simulations were performed for a total of 211.93 stream kilometers in the Upper Klamath and Lost Subbasins.

Effective shade simulation validation was conducted by comparing simulated results with ground level measured shade values where data were available. Solar Pathfinder® data were used to collect all ground level data.

A.3.4.2 Total Daily Solar Heat Load Analysis

The total daily solar heat load is the cumulative solar heat received by a stream over one day during the critical period (i.e., July/August period). For the purposes of this analytical effort, the total daily solar heat load is the sum of the products of the daily solar heat flux and surface area of exposure for each stream reach (i.e., for each stream data node every 50 meters).

$$H_{solar} = \sum\left(\Phi_{solar} \cdot A_y\right) = \sum\left(\Phi_{solar} \cdot W_{wetted} \cdot dx\right)$$

Background levels of solar heat estimate the portion of the total daily solar heat load that occurs when anthropogenic nonpoint sources of heat are minimized. The total daily solar load is calculated for both the current condition (H_{solar}) and the potential condition ($H_{solar}^{Backgroun}$). The anthropogenic nonpoint source total daily solar load is the difference between the total daily solar load and the background total daily solar load.

$$H_{solar}^{NPS} = H_{solar} - H_{solar}^{Backgroun}$$

where,

A_y:	Stream surface area unique to each stream segment
Dx:	Stream segment length and distance step in the methodology
Φ_{solar}:	Solar heat flux for unique to each stream segment
H_{solar}:	Total daily solar heat load delivered to the stream

H_{solar}^{NPS}: Portion of the total daily solar heat load delivered to the stream that originates from anthropogenic nonpoint sources of pollution

$H_{solar}^{Backgroun}$: Portion of the total daily solar heat load delivered to the stream that originates from background sources of pollution that are not affected by human activities

W_{wetted}: Wetted width unique to each stream segment

The Upper Klamath and Lost Subbasins Tributary Temperature TMDL displays the solar heat load contributions for each stream where temperature/hydrology was simulated. Longer and wider streams have the most solar heat load. In any case, anthropogenic nonpoint sources account for a fraction of the heat load in most streams simulated (i.e., much of the existing heat load is naturally occurring).

A.3.5 Simulated Temperature Scenarios

Once stream temperature models were calibrated, several scenarios were simulated by changing one or more input parameters for each of the calibrated models. The simulated scenarios focused largely on restored vegetation and natural flow. Some restored scenarios also included changes in channel morphology. A summary of the difference between current conditions and restored conditions results are presented in Table A-1.

Table A- 4. Maximum predicted 7-day average daily maximum temperature difference between current conditions and restored conditions and the location of the maximum difference (point of maximum impact).

Waterbody	Maximum difference between current and restored conditions (Max 7-DADM, °C)	Point of Maximum Impact (river km)
Jenny Creek	6.5	17.4
Spencer Creek	8.8	1.8
Miller Creek	-5.4	4.57

A.4 Model Setup, Calibration and Scenarios

A.4.1 Overview

The Heat Source model (Boyd and Kasper 2003) was used in the Upper Klamath and Lost Subbasins to model solar radiation, effective shade, and stream temperatures. Temperatures were modeled with Heat Source on the following streams:

- Jenny Creek
- Spencer Creek
- Miller Creek (upstream of Pine Creek)

Solar radiation and effective shade were modeled on the following streams:

- Antelope Creek
- Barnes Valley Creek
- Horse Canyon Creek
- Lapham Creek
- Long Branch Creek
- Lost River
- Miller Creek (downstream of Pine Creek)
- North Fork Willow Creek

Specifics for each of the modeled streams follow.

A.4.1.1 Spatial and Temporal Scale

Prediction time steps and spatial scale were limited by stability considerations for the finite difference solution method. Simulations were performed for a total of 211.93 stream kilometers in the Upper Klamath and Lost Subbasins (Table A-2**,** Figure A-4**).**

Table A- 5. Stream simulation periods and extents for temperature models.

River/Stream	Model Period	Time Step (minutes)	Spatial Resolution (meters)	Model spin up (days)	Model Extent	Heat-source version
Jenny Creek	7/4 to 7/23/2001	1	100	5	Confluence with Johnson Cr to OR/CA border: 23.7 km	7.0
Spencer Creek	7/2 to 7/21/2001	1	100	5	Headwaters to mouth: 25.2 km	8.0.2
Miller Creek	7/17 to 8/5/2001	1	100	5	Gerber Reservoir to Pine Creek: 14.57 km	7.0

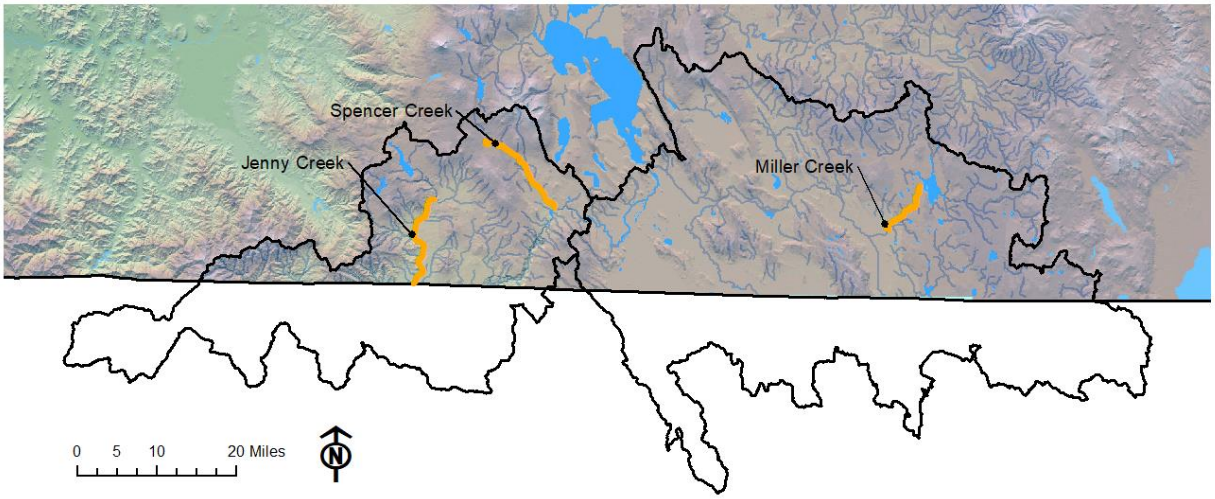


Figure A- 5. Extent of heat source temperature modeled streams.

Table A- 6 Stream simulation periods and extents for solar only models.

River/Stream	Model Period	Time Step (minutes)	Spatial Resolution (meters)	Model Extent	Heat-source version
Antelope	7/15/2005	10	100	Willow Valley Reservoir to river kilometer 1.77	7.0
Barnes Valley	7/15/2005	10	100	Willow Valley Reservoir to headwaters: 23.6 km	7.0
Horse Canyon	7/15/2005	10	100	Dry Prairie Reservoir to the wetland prairie upstream of Horse Canyon Springs: 3.81 km	7.0
Lapham	7/15/2005	10	100	Mouth to headwaters in Holmes Meadow: 7.44 km	7.0
Long Branch	7/15/2005	10	100	Mouth to headwaters at a Spring Seep: 8.11 km	7.0
Lost River	7/15/1999	1	50	Oregon/California border to Malone Diversion Dam: 98.0 km	9.0
Miller Creek	7/17 to 8/5/2001	1	100	Mouth to Gerber Reservoir: 19.75 km	7.0
North Fork Willow	7/15/2005	10	100	OR/CA border to the Yocum Valley wetland complex: 5.43 km	7.0

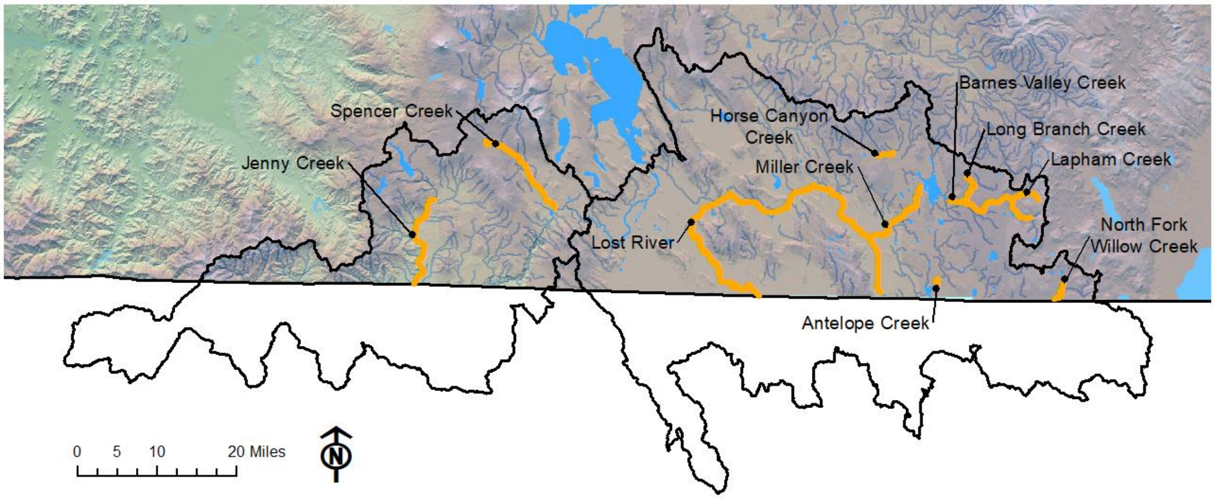


Figure A- 6. Extent of heat source solar radiation and effective shade modeled rivers and streams.

A.4.1.2 Simulation Accuracy

Error statistics were calculated for each calibrated model. Below are the equations used for each type of error statistic.

Mean Error: $$ME = \frac{1}{n}\sum X_{sim} - X_{obs}$$

Mean Absolute Error: $$MAE = \frac{1}{n}\sum \left| X_{sim} - X_{obs} \right|$$

Root Mean Square Error: $$RMSE = \sqrt{\frac{1}{n}\sum (X_{sim} - X_{obs})^2}$$

Nash-Sutcliffe efficiency coefficient: $$E = 1 - \frac{\sum (X_{sim} - X_{obs})^2}{\sum (X_{sim} - \overline{X_{obs}})^2}$$

where,

X_{sim} = the simulated temperature;
X_{obs} = the observed or measured temperature;
$\overline{X_{obs}}$ = the mean of the observed or measured temperatures;
n = the sample size.

Error statistics were calculated for both the spatial (TIR) and temporal (hourly instream measurements) temperatures (see specific stream discussions below).

A.4.2 Jenny Creek

A.4.2.1 Overview

Stream Name: Jenny Creek
Model: Heat Source version 7.0
Beginning date: 7/4/2001
Ending date: 7/23/2001
Time step: 1 minute
Distance step: 100 m
Extent: Confluence with Johnson Creek to Oregon/California border at river km 6.3 (23.7km) (Figure A- 7).

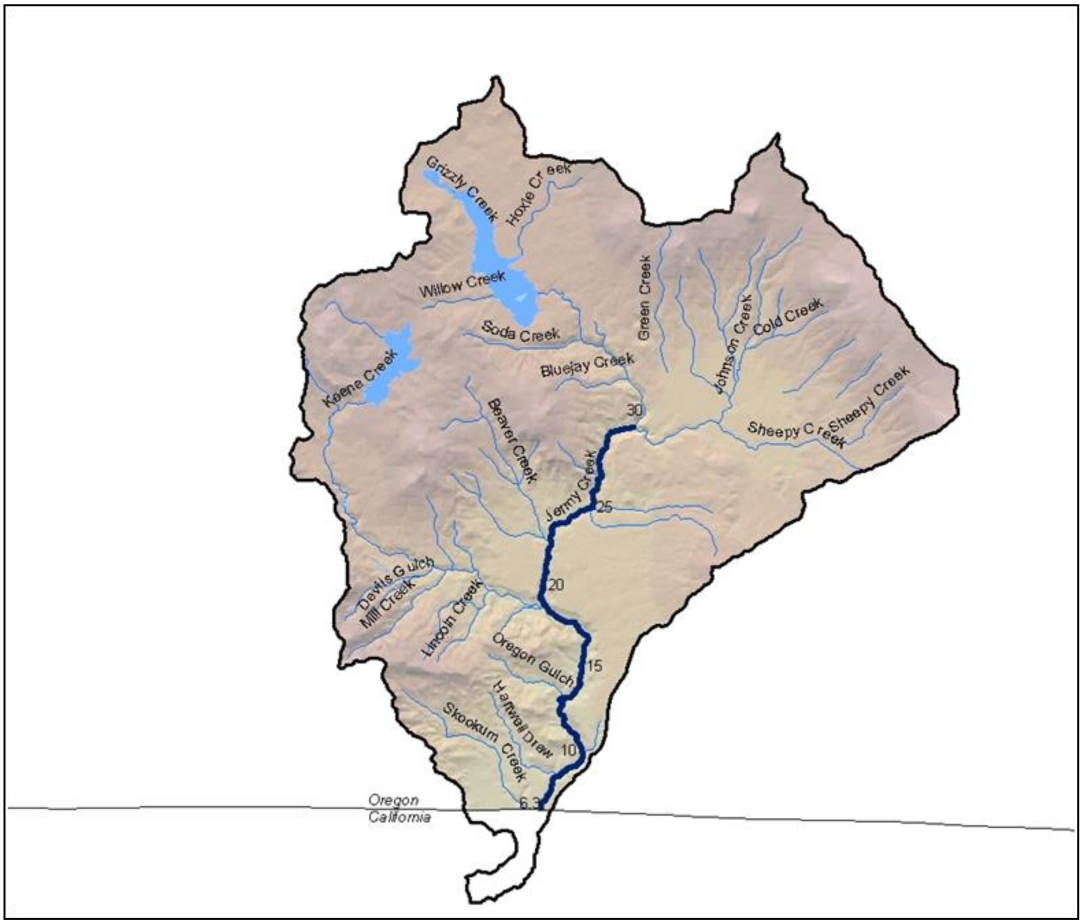


Figure A- 7. Extent of the Jenny Creek temperature model.

A.4.2.2 Reach Properties

The channel properties were determined using the methodology documented previously in this report (see **Section A.3**). Figure A-6 shows the elevation profile and reach gradient. The bottom width was derived using the active channel width measured from aerial photographs. Bottom width was estimated by assuming a trapezoidal channel with variable sloping side slopes and a variable width-to-depth ratio determined through model calibration (Figure A- 9 and Figure A- 10). Non-spatially varying coefficients are presented in Table A- 7. Manning's n values were iteratively altered so that the model temperatures approximately reproduced measured temperatures (Figure A- 10). Topographic and riparian vegetation heights were determined through a GIS analysis (Table A- 8, Figure A- 11 through Figure A- 13). Vegetation was sampled in a radial pattern every 9 meters from the center of stream out to a distance of 36 meters. Using these channel and vegetation inputs, the Jenny Creek model predicted shade is shown in Figure A- 14. Unfortunately, field based effective shade data were not collected so model calibration statistics cannot be generated for model derived effective shade.

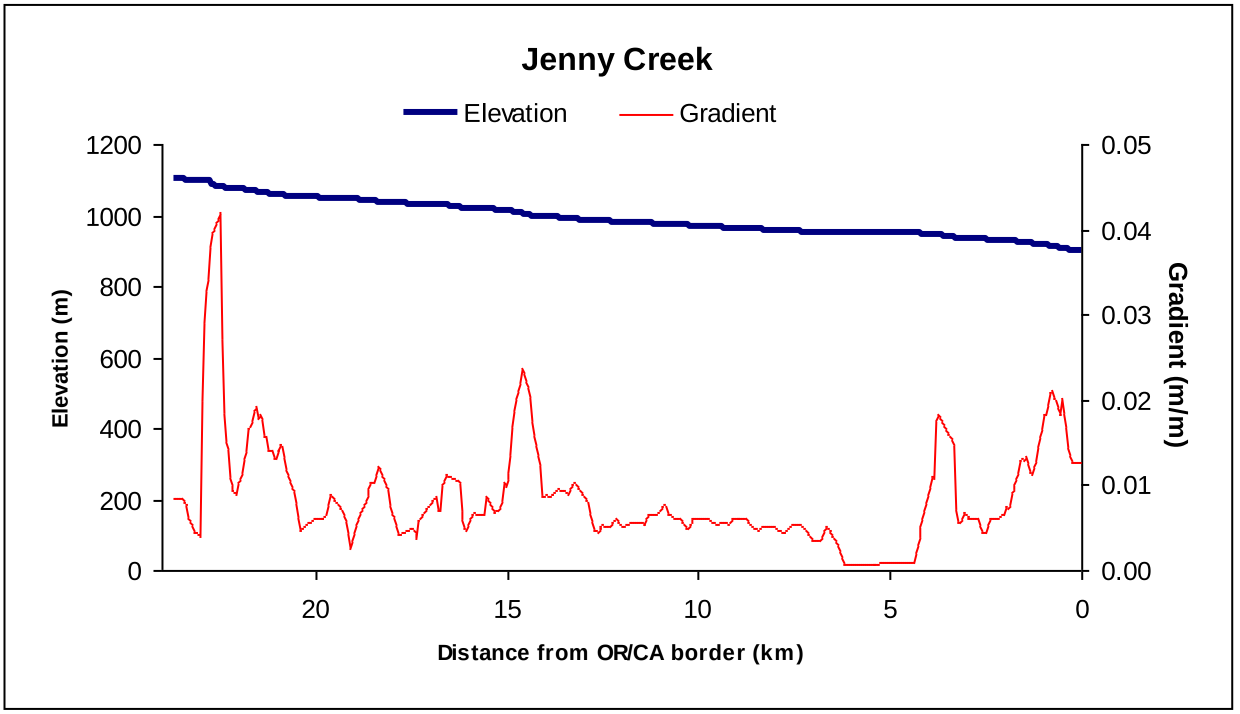


Figure A- 8. Model setup channel elevation and gradient.

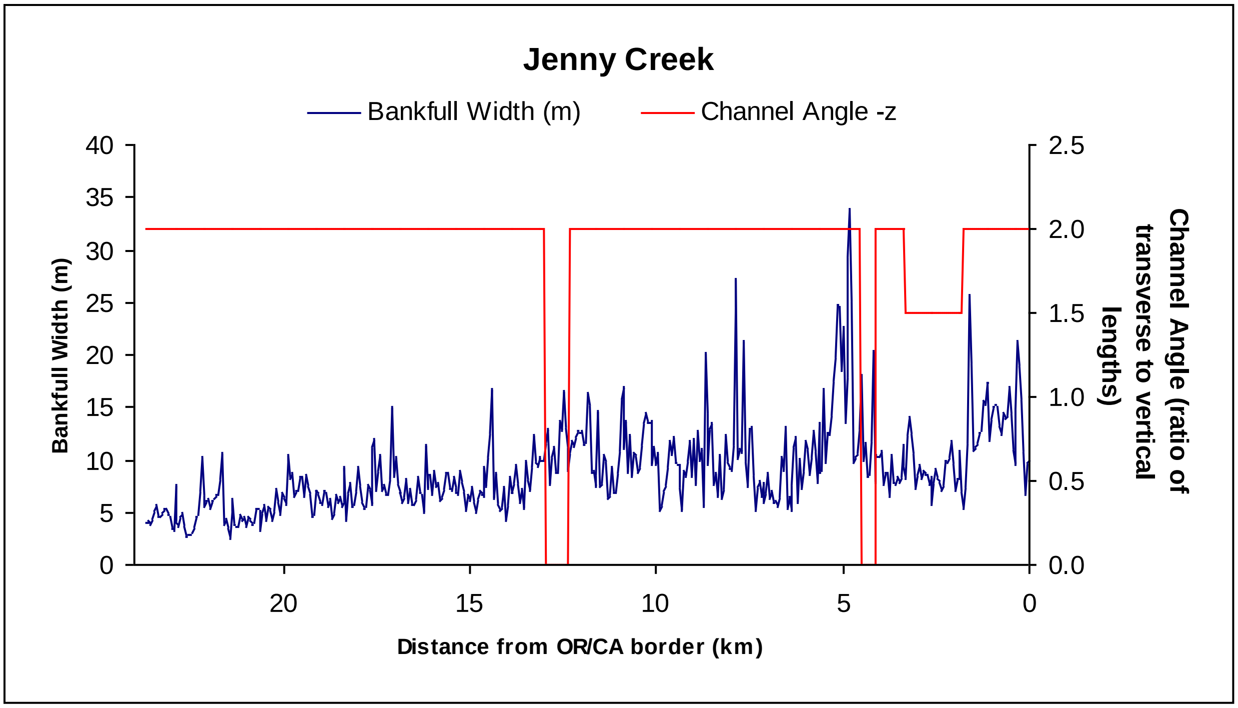


Figure A- 9. Model setup for bankfull width and channel angle.

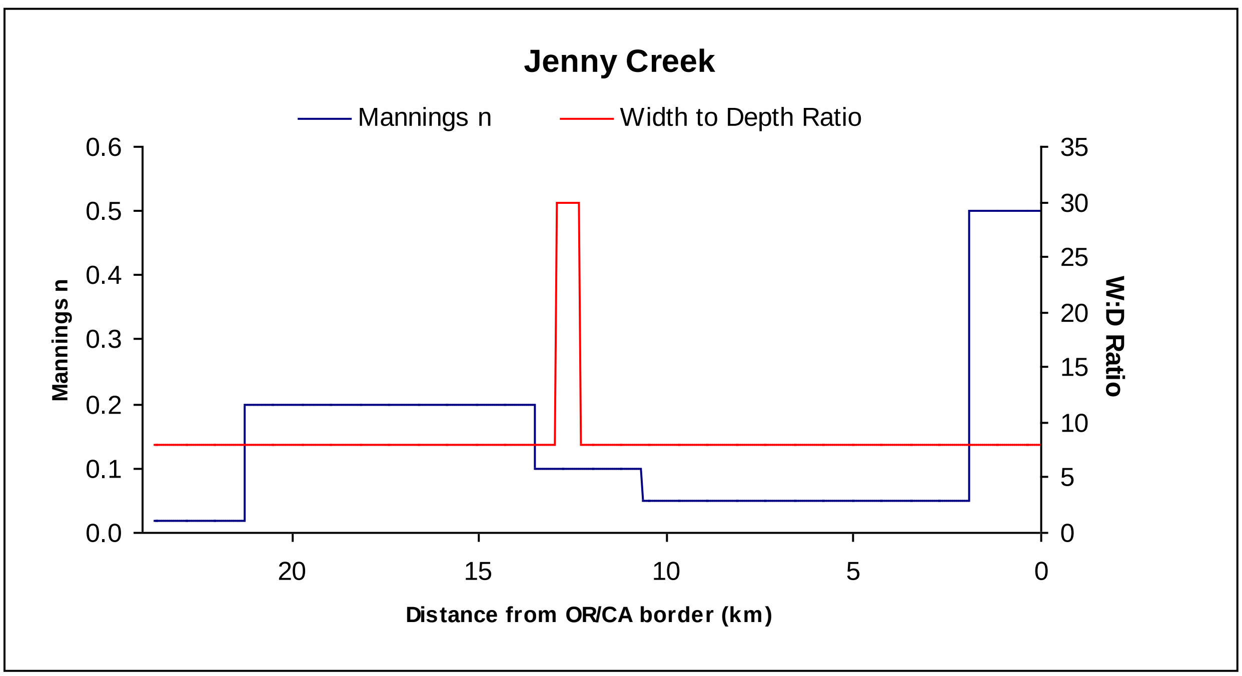


Figure A- 10. Model setup for roughness coefficient and width to depth ratio.

Table A- 7. Model coefficients for non-spatially varying parameters.

Parameter name (units)	Value
Wind Function, coefficient a	1.0×10^{-9}
Wind Function, coefficient b	1.0×10^{-9}
Horizontal Bed Conductivity (mm/s)	20.0
Bed Particle Size (mm)	2
Embeddedness	0.3

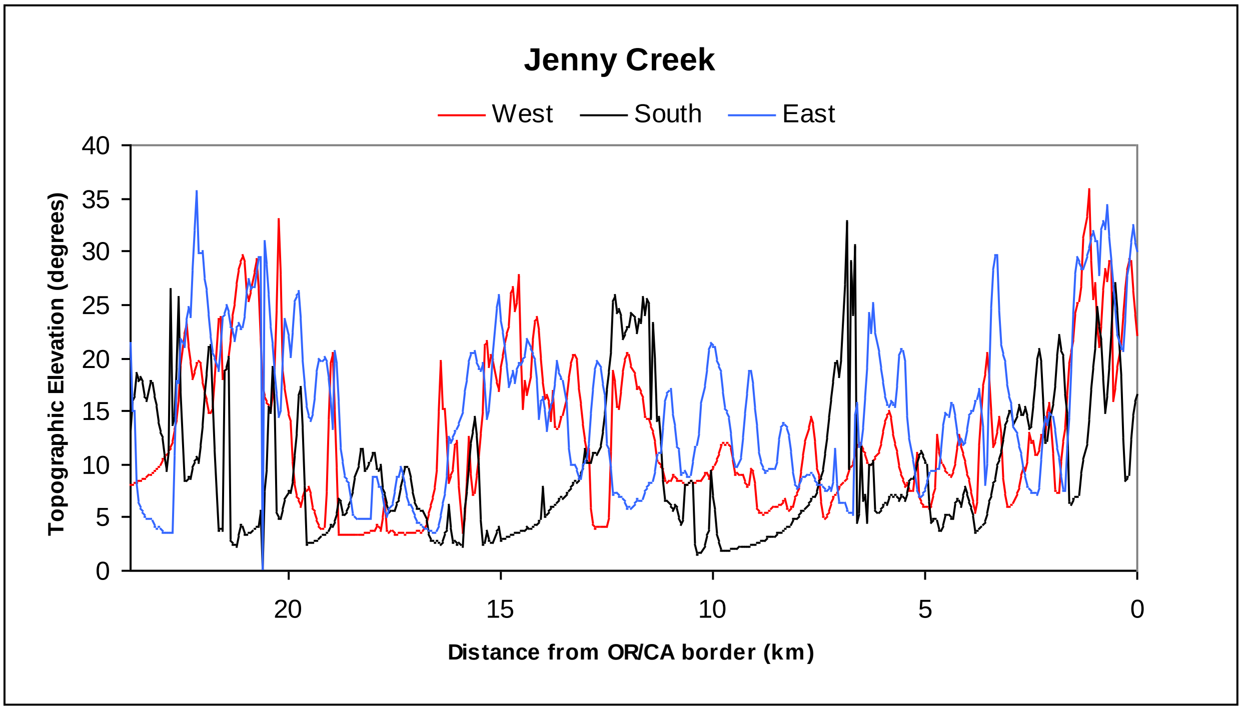


Figure A- 11. Model setup for topographic angle.

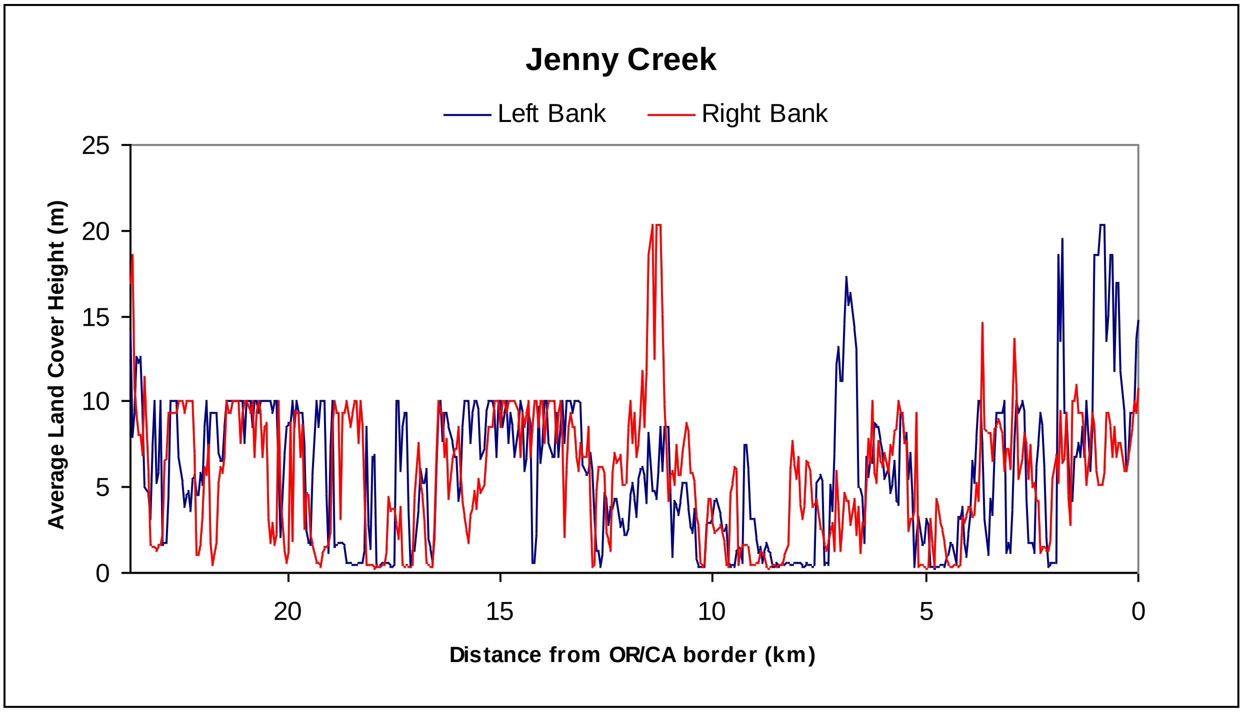


Figure A- 12. Model setup for height of near-stream vegetation.

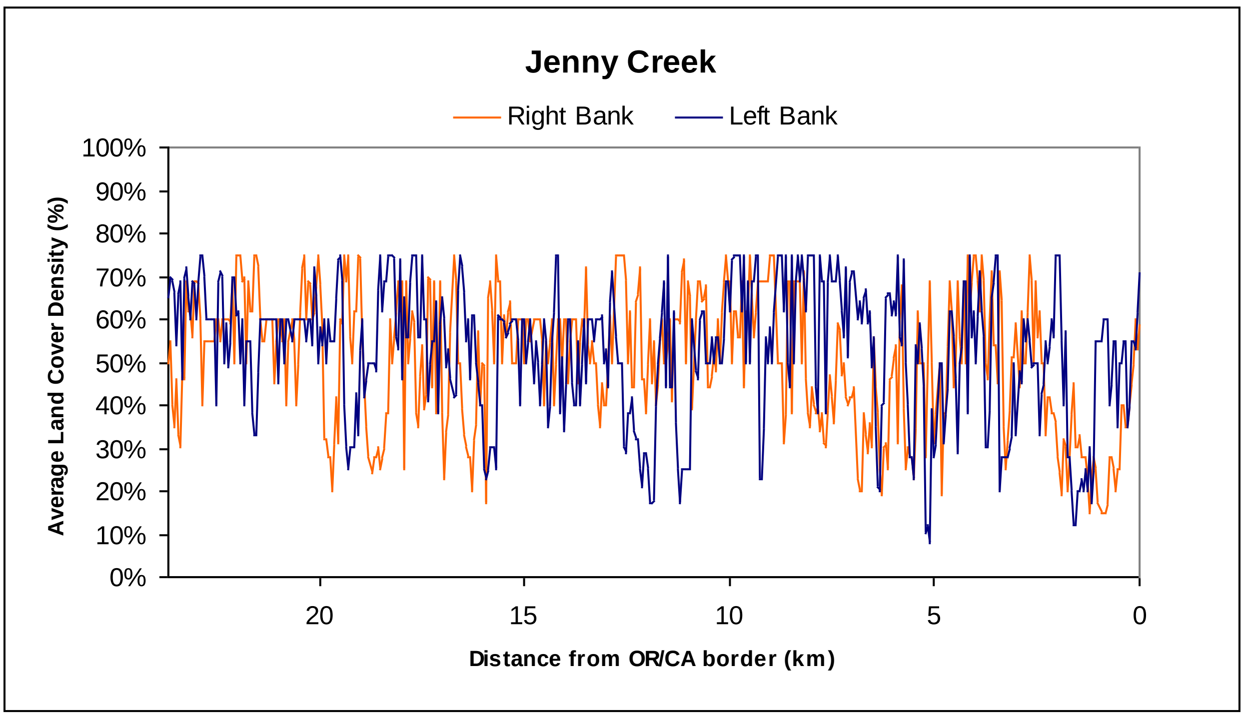


Figure A- 13. Model setup for density of near-stream vegetation.

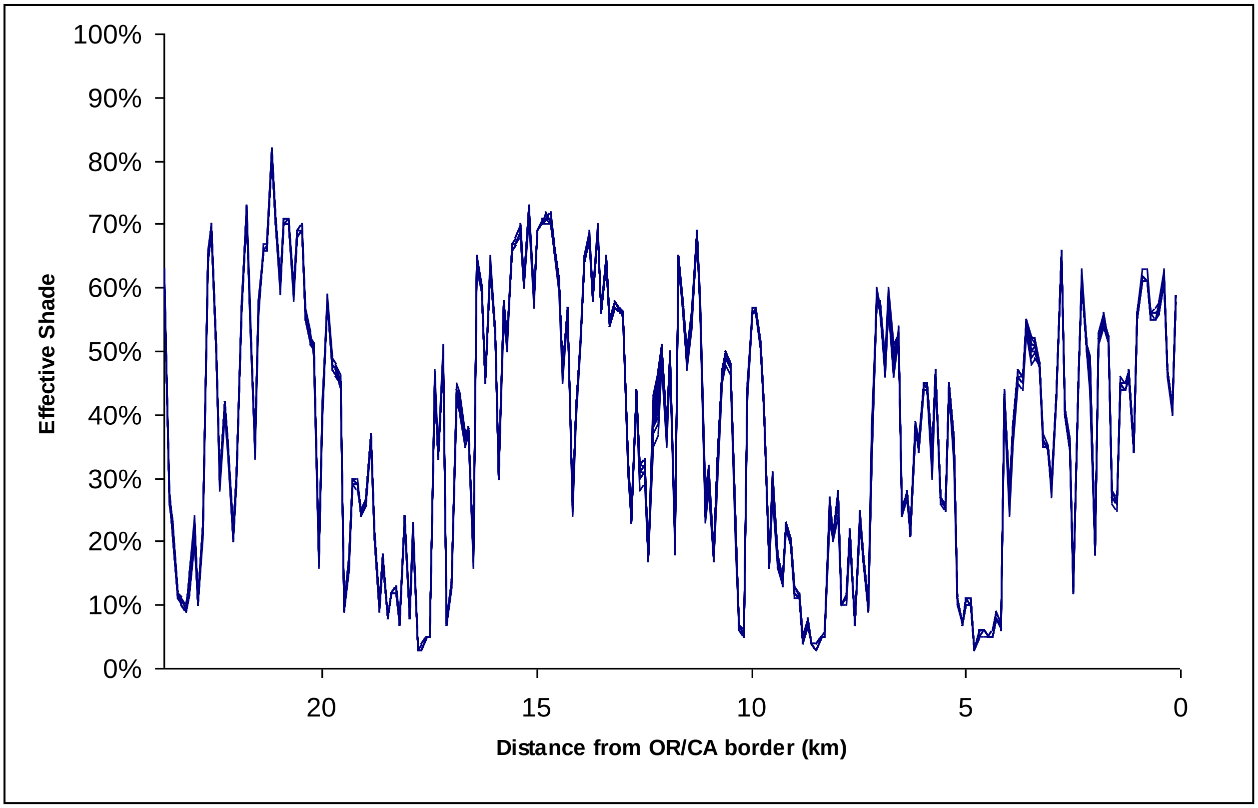


Figure A- 14. Predicted shade on Jenny Creek.

Table A- 8. Spatial Data and Application: GIS data source and the application used in Jenny Creek watershed

Spatial Data	Data Source	Application
10-Meter Digital Elevation Models (DEM)	Oregon Geospatial Data Clearinghouse	Measure Stream Elevation and Gradient Measure Topographic Shade Angles
Aerial Imagery – Digital Orthophoto Quads for years 2001 – 2003	Jackson County	Map Vegetation Map Channel Morphology Map Roads, Development, Structures
Thermal Infrared Radiometry (TIR) Stream Temperature Data	Watershed Sciences 2002, Collected on 7/14/2001	Measure Surface Temperatures Develop Longitudinal Temperature Profiles Identify Subsurface Hydrology, Groundwater Inflow, Springs

A.4.2.3 Meteorology

The Jenny Creek model uses air temperature, relative humidity, wind speed and solar radiation measurements from a BLM monitoring station at Buckhorn Springs (downloaded from RAWS on 1/30/2006). Cloudiness was determined by calculating the deviation of actual solar radiation from expected sunny solar radiation. The wind speed was used without adjustment. The meteorological observations are presented in Figure A-13, a-d.

Figure A- 15, a-d. Meteorology inputs for model setup.

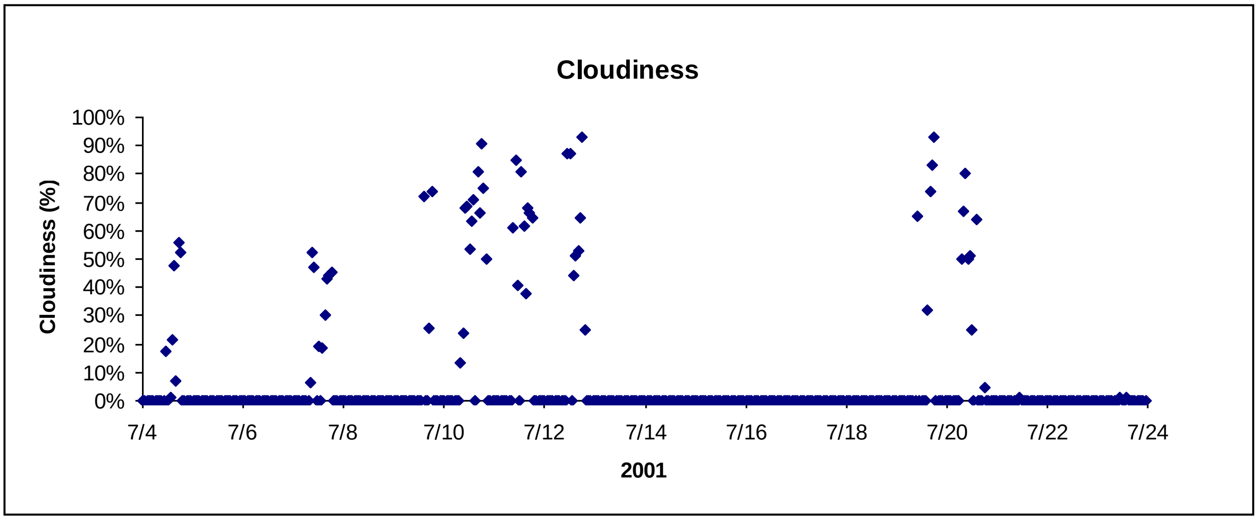


Figure A-13-a.

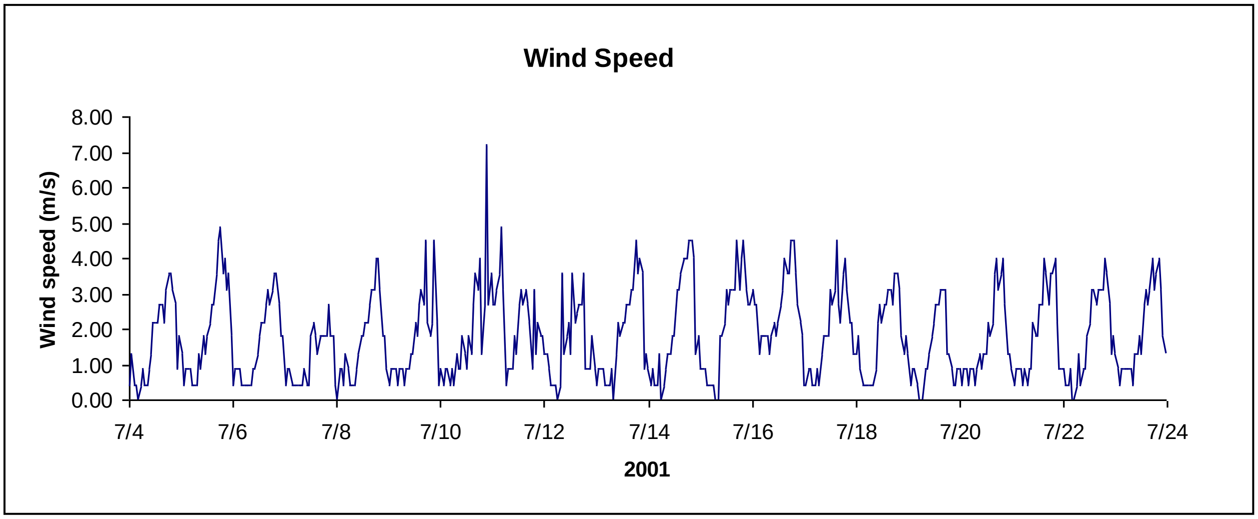


Figure A- 13-b.

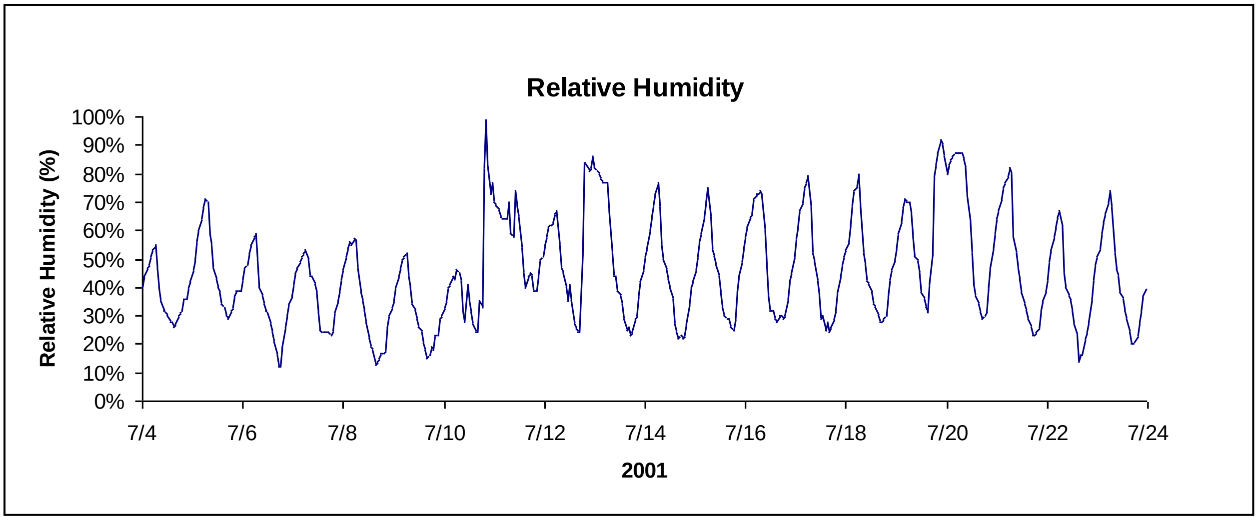


Figure A-13-c.

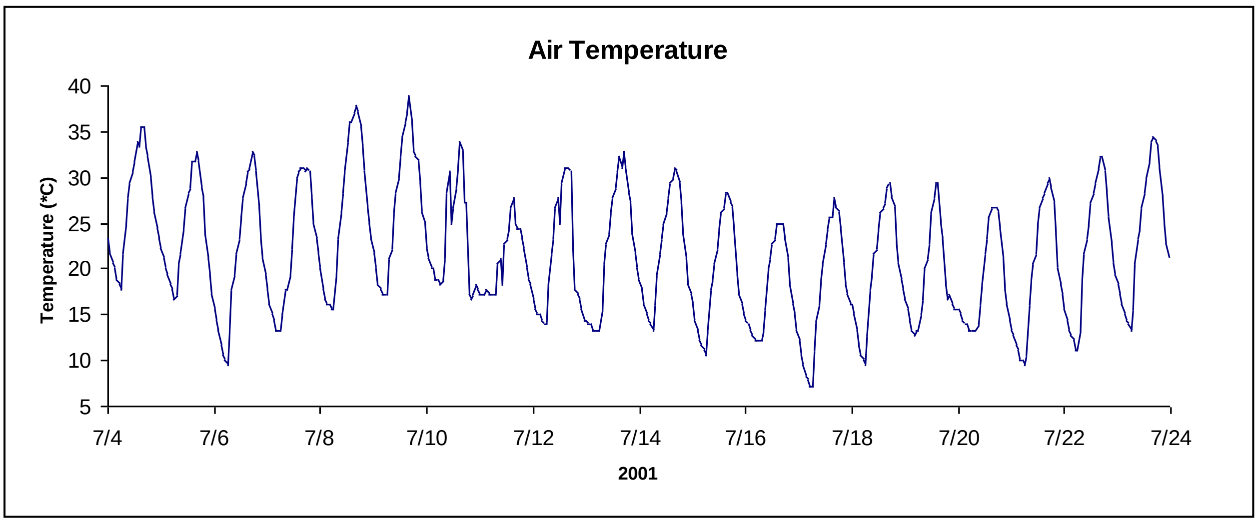


Figure A-13-d.

A.4.2.4 Flow

When available, flow measurements taken in the Jenny Creek watershed were used to generate model input (Table A- 9). Instantaneous flow measurements were collected by BLM at various places and time during the model period. Flow balance was derived through various methods including using the TIR temperatures and upstream flow. The Jenny Creek model assumed there were no significant water withdrawals from the system. Using these flow inputs, the performance of the Jenny Creek model at several times and locations is shown in Figure A- 16**.**

Table A- 9. Flow inputs and rates for the Jenny Creek model.

Location name	Stream km	Flow rate (cms)	Source
Boundary condition	23.7	0.036	Flow balance
Spring (from TIR)	17.35	0.04	Flow balance
Beaver Creek	15.95	0.04	Flow balance
Keene Creek	12.75	0.07	BLM instantaneous flow measurement 7/18/2001
Spring (from TIR)	3.9	0.06	Flow balance
Spring Creek	3.35	0.18	Flow balance

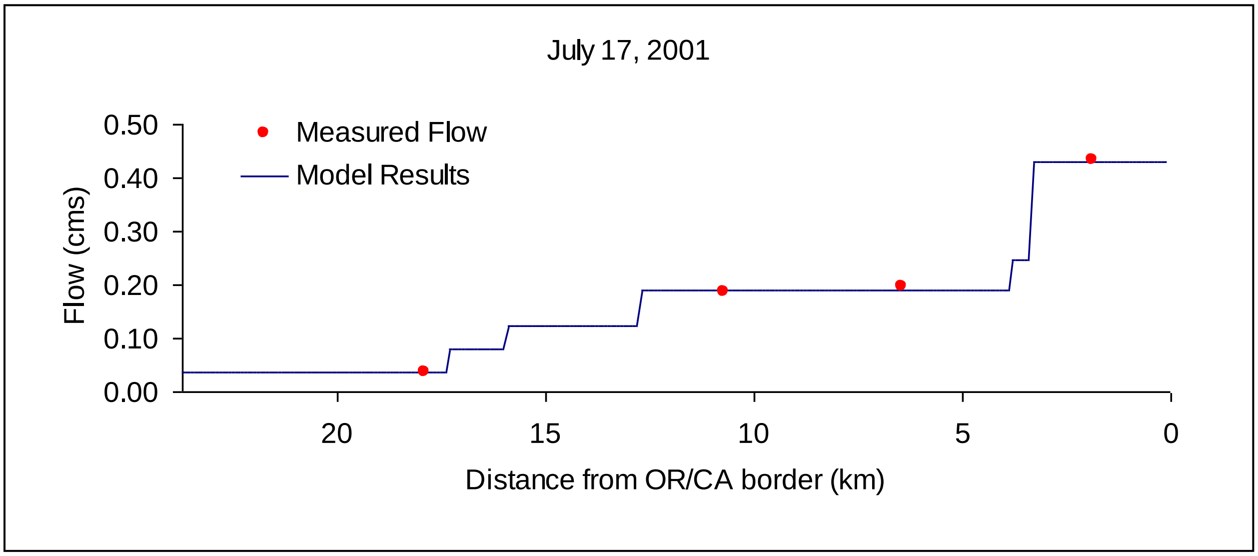


Figure A- 16. Longitudinal profile of model results with measured flow. Model results are represented by lines and measurements by points.

A.4.2.5 Temperature

Table A-6 and Figure A-15 document the temperatures of the tributaries and springs incorporated in the model.

Table A- 10. Source of tributary and boundary condition temperature inputs for Jenny Creek model

Inflow	Stream km	Source of temperature data
Boundary Condition	23.7	Derived from BLM continuous gage Jenny Creek above Johnson Creek (JNYU)
Spring #1 (from TIR)	17.35	TIR temperature
Beaver Creek	15.95	TIR temperature
Keene Creek	12.75	Derived from BLM continuous gage Keene Creek below Lincoln Creek (BXDW)
Spring #2 (from TIR)	3.9	TIR temperature
Spring Creek	3.35	Derived diel from assumed minimum temperature and assumed maximum TIR temperature

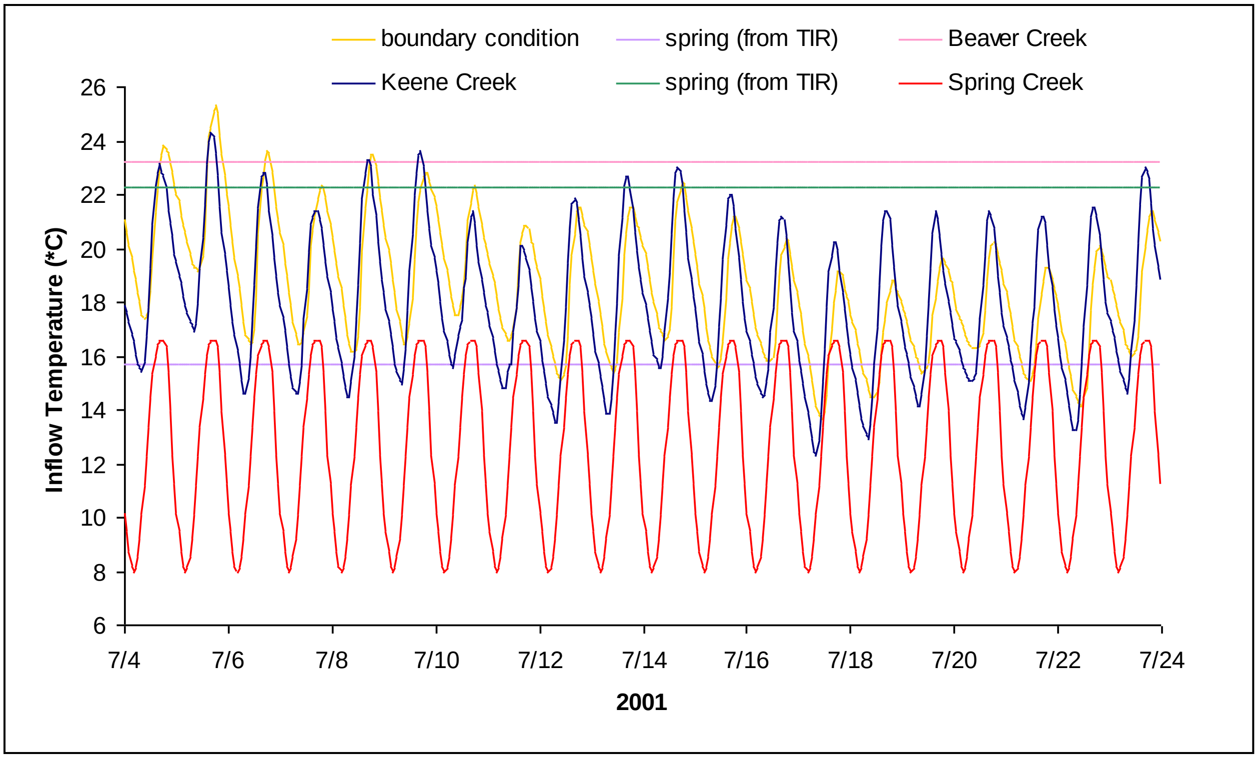


Figure A- 17. Temperature of inflows to the Jenny Creek model.

A.4.2.6 Temperature Calibration

The model generally reproduces spatially and temporal varying temperature measurements (Table A-7 and Table A-8, and Figure A-16 and Figure A-17). The Medford BLM office provided continuous instream temperature data. See previous statistics discussion at the beginning of Section 4 for definitions.

Table A- 11. TIR error statistics

Error type	Value
Mean	-0.28
Absolute mean	0.66
Root mean square	0.70

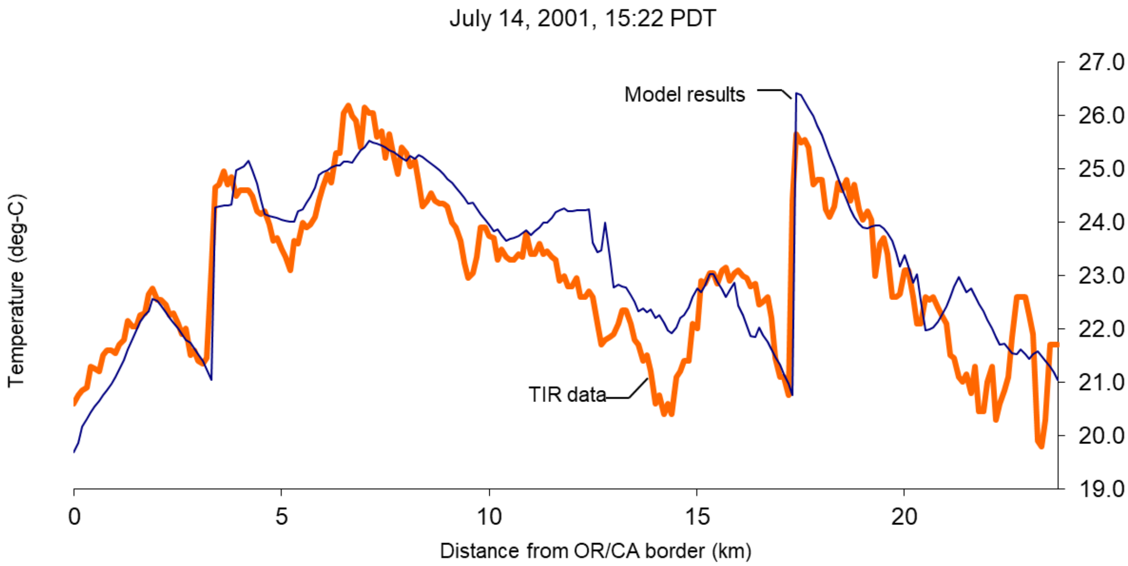


Figure A- 18. Longitudinal profile of measured temperatures using Thermal Infrared Radiometry and model results.

Table A- 12. Continuous monitoring error statistics

Site Name	Site #	Ref	rKM	All data n	Mean Error	Abs Mean Error	RMSE	Nash-Sutcliffe
Jenny Creek below Keene Creek, @ Box O Ranch north boundary	BXON	A	10.7	240	-0.28	0.81	0.97	0.88
Jenny Creek below Oregon Gulch, @ Box O Ranch south boundary	BXOS	B	6.45	240	0.71	0.88	1.03	0.88
Jenny Creek below Spring Creek, @ Road 41-2E-10.1	LWRX	C	1.9	240	-0.68	0.91	1.21	0.80
Average					-0.08	0.87	1.07	0.85

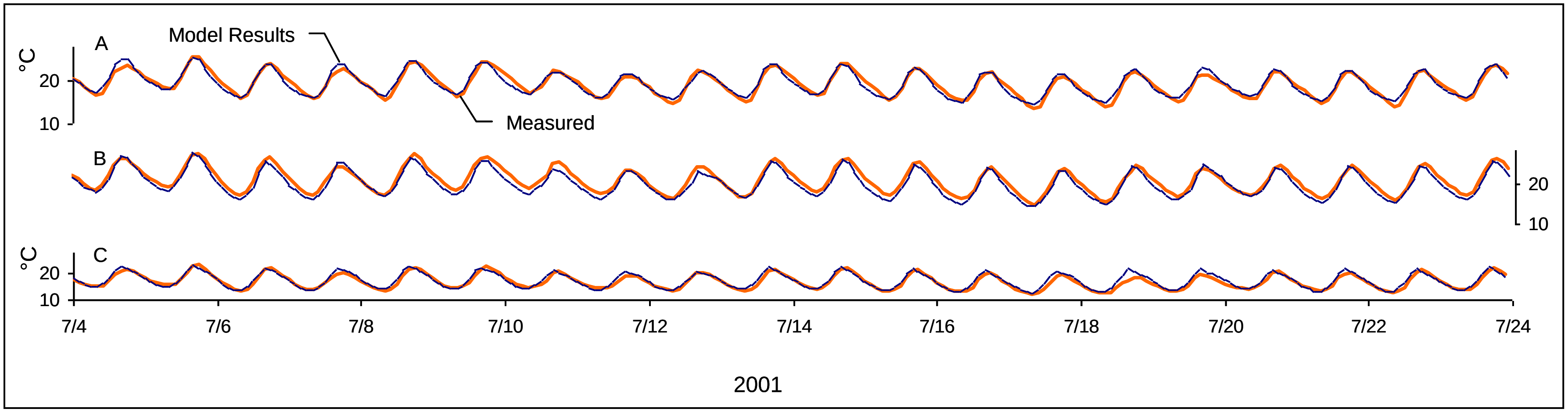


Figure A- 19. Measured steam temperature versus model results.

A.4.2.7 Scenario Results

The Heat Source model was used to predict the influence of various factors on stream temperature (Table A-9). As seen in Figure A- 20, because the restored condition temperatures are greater than the biologically based criterion of 20ºC along a portion of the modeled reach, reductions from background sources are needed to achieve the applicable criteria.

Table A- 13. Simulated Scenario Definitions

0	Topographic TOPO	Same as #1 Current Conditions except all vegetation is removed.
1	Current Calibrated Conditions CCC	Current Calibrated Condition
2	Restored Vegetation VEG	Restored Vegetation (see effective shade figure, potential vegetation table and summary of results in the main text of this document, Chapter 2).
3.1	Natural Flow FLOW	Water withdrawals from points of diversion are maintained as instream flow and the boundary condition flow was adjusted to reflect the natural flow derived by OWRD (see main text, Chapter 3 for a summary of the results) Spring Creek has an additional 7.52 cfs Jenny Creek upstream of Spring has an additional 0.175 cfs Beaver Creek has an additional 1.00 cfs. Keene Creek has an additional 1.36 cfs
3.2	PacCorp withdrawals PACFLOW	Same as #1 Current Conditions except flow from Spring Creek was reduced by five cfs and the stream temperature was increased by two degrees Celsius to reflect Pacificorp's current diversion. The diversion was not occurring during the 2001 model year.
4	Tributary Conditions TRIBS	Flows were adjusted to reflect the #3.1 "Flow" scenario in addition to cooler tributary and boundary condition temperatures. For tributaries with a diel fluctuation, the daily maximums were maintained at less than 20°C (the applicable criteria). The difference between the daily maximum and 20°C was used to scale the temperature and maintain the diel fluctuation. When water temperatures included in the current condition calibrated model were already less than 20°C, they were not changed. Tributary inputs changed included the upstream boundary condition (Johnson Creek and Jenny Creek upstream of Johnson Creek), Beaver Creek, Keene Creek, and Spring #2. Temperatures of Spring #1 and Spring Creek were not changed.
5	Channel Morphology MORPH	Channel morphology changes were focused along 10 kilometers of Jenny Creek upstream from the CA/OR border where portions of the stream exceed the criterion. Along this reach the channel width-to-depth ratio was reduced from 8 to 4.
6	Restored Vegetation & Flow VEGFLOW	Incorporation of the #2 Restored Vegetation and #3.1 Flow scenarios.
7	Restored Conditions RC	Incorporation of #2 Restored Vegetation, #4 Flow/Tributary Conditions, and, #5 Channel Morphology.

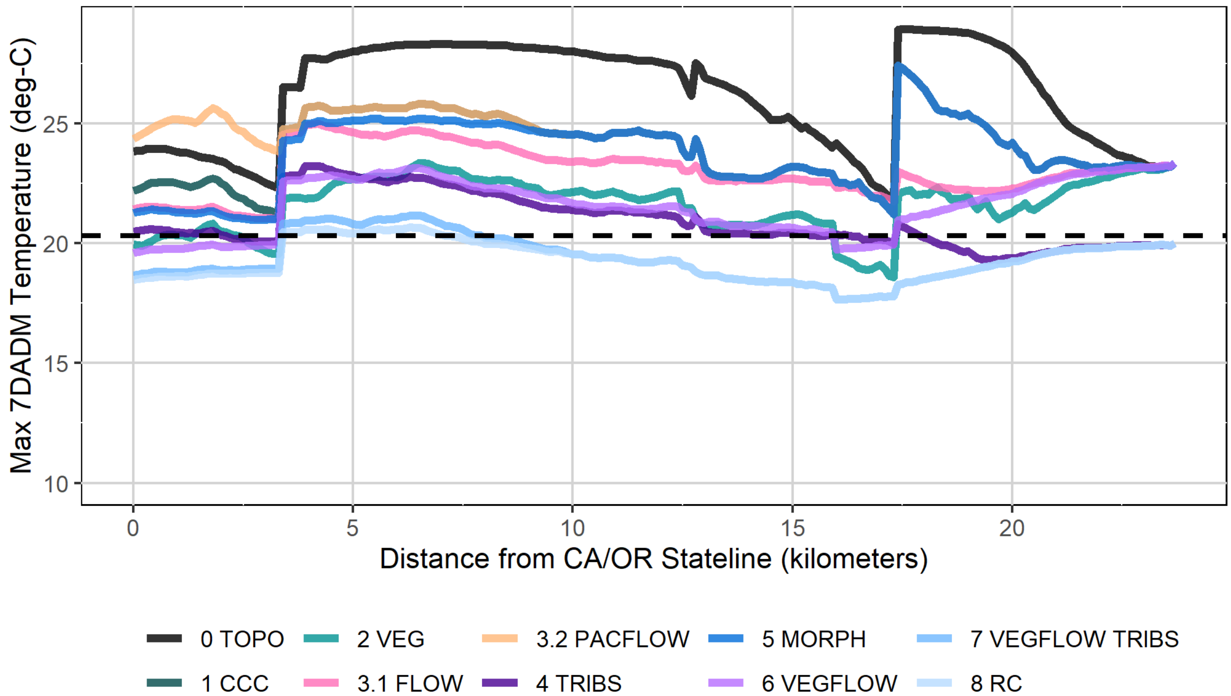


Figure A- 20. Predictions for Jenny Creek scenarios based on the maximum 7-DADM, July 4-23, 2001. Dashed line is the 20-deg C criteria plus 0.3 deg-C human use allowance.

Table A- 14. Summary of maximum 7DADM temperature scenario results for Jenny Creek.

Model Scenario	Location of Point of Maximum Impact (POMI) Stream KM	Maximum 7DADM POMI	Maximum 7DADM Stateline
0 TOPO	17.7	28.9	23.8
1 CCC	17.4	27.4	22.2
2 VEG	23.7	23.4	19.9
3.1 FLOW	4.2	25.0	21.4
3.2 PACFLOW	17.4	27.4	24.4
4 TRIBS	4.0	23.2	20.5
5 MORPH	17.4	27.4	21.3
6 VEGFLOW	23.7	23.4	19.6
7 VEGFLOW TRIBS	6.3	21.2	18.7
8 RC	6.3	20.7	18.5

A.4.2.7.1 Restored Vegetation Scenario

Restored vegetation is the mature species composition, height, density, and overhang width of vegetation that would occur in the absence of human disturbances. Restored vegetation conditions were used in stream temperature modeling scenarios to quantify the impacts of nonpoint source solar radiation loads, and ultimately to develop nonpoint source load allocations for the TMDL.

Restored vegetation values were estimated for the Jenny Creek watershed by examining multiple references. To determine habitat potentials, physical parameters including elevation, gradient, climate, soils, vegetative communities, geology, physiography, hydrology, land use, etc. were assessed. Jenny Creek travels between three EPA Level IV Ecoregions (Thorson et al. 2003), so the habitats were more distinguished by a change in elevation at river kilometer 12.5. The U.S. Environmental Protection Agency (EPA) has identified areas and built a map to depict Level IV Ecoregions throughout the U.S. Ecoregions are areas where ecosystems are generally similar. It is designed to serve as a spatial framework for the research, assessment, and monitoring of ecosystems and ecosystem components, ecoregions denote areas of similarity in the mosaic of biotic, abiotic, terrestrial, and aquatic ecosystem components with humans being considered as part of the biota.To determine potential plant species, narrative reports, especially vegetation descriptions from the Oregon Watershed Assessment Manual (1999), were consulted. Estimates of plant community height, density and overhang width were compiled and averaged by best professional judgment from site indices, tree growth curves, and plant guide books Table A-11. Generally, vegetation is expected to increase or remain the same in average height, density, and overhang distance. The largest Mixed Conifers are also expected to decrease in height, on average, as the species composition changes. Finally, the current land cover vegetation types were assigned a potential (mature) vegetation type, which are also described in Table A-11.

Table A- 15. Summary of the current vegetation type heights, densities, and overhang widths and assigned restored vegetation type.

Vegetation Type	Height (m)	Density (%)	Overhang (m)	Prevalence in model (%)	Restored Vegetation Type	Height (m)	Density (%)	Overhang (m)
Water	0.0	0	0.0	19.3	Water	0.0	0	0.0
Pastures/Cultivated Field/lawn	0.5	75	0.3	15.5	Riparian mixed hardwoods	12.2	75	2.0
Barren - Rock	0.0	0	0.0	0.0	N/A			
Barren - Embankment	0.0	0	0.0	0.0	N/A			
Barren - Clearcut	0.0	0	0.0	0.0	N/A			
Barren - Soil	0.0	0	0.0	0.0	N/A			
Barren - Road	0.0	0	0.0	0.2	Mixed conifers & hardwood	25.0	50	2.0
Barren - Forest Road	0.0	0	0.0	0.0	N/A			
L. Mixed Con/Hard (50-100% CC)	16.4	75	2.1	0.4	Riparian hardwoods	16.4	75	2.1
S. Mixed Con/Hard (50-100% CC)	8.2	75	1.0	2.7	Riparian hardwoods	16.4	75	2.1
L. Mixed Con/Hard (<50% CC)	16.4	25	2.1	0.0	N/A			
S. Mixed Con/Hard (<50% CC)	8.2	25	1.0	0.6	Riparian hardwoods	16.4	75	2.1
L. Mixed Con/Hard (10% CC)	16.4	10	2.1	0.0	N/A			
Large Hardwood	12.5	75	1.9	0.0	N/A			
Small Hardwood	6.2	75	0.9	9.4	Riparian mixed hardwoods	12.2	75	2.0
Large Hardwood - Low Density	12.5	10	1.9	0.0	N/A			
Small Hardwood - Low Density	6.2	30	0.9	2.3	Riparian mixed hardwoods	12.2	75	2.0
Large Conifer	35.0	60	2.0	24.5	Mixed conifers	30.0	60	2.0
Medium Conifer – Upper watershed	20.3	60	2.0	3.6	Mixed conifers	30.0	60	2.0

Vegetation Type	Height (m)	Density (%)	Overhang (m)	Prevalence in model (%)	Restored Vegetation Type	Height (m)	Density (%)	Overhang (m)
Medium Conifer – Lower watershed	20.3	60	2.0	3.6	Mixed conifers & hardwood	25.0	50	2.0
Small Conifer	10.2	60	1.0	0.0	N/A			
Large Conifer - Low Density	35.0	30	2.0	0.0	N/A			
Medium Conifer - Low Density	20.3	30	2.0	10.5	Mixed conifers & hardwood	25.0	50	2.0
Small Conifer - Low Density	10.2	30	1.0	0.0	N/A			
Western Juniper	5.4	10	0.5	0.0	N/A			
Upland shrubs	1.8	50	0.3	3.0	Mixed conifers & hardwood	25.0	50	2.0
Shrubs on wet floodplain	1.8	75	0.3	5.8	Shrubs on wet floodplain	2.3	75	0.3
Grasses - upland	0.5	75	0.3	2.0	Mixed conifers & hardwood	25.0	50	2.0
Active Channel Bottom	0.0	0	0.0	0.0	N/A			
Development - Residential	6.1	100	0.0	0.0	Mixed conifers & hardwood	25.0	50	2.0
Development - Industrial	9.1	100	0.0	0.0	N/A			
Dam/Wier	0.0	0	0.0	0.0	N/A			
Canal	0.0	0	0.0	0.0	N/A			
Dike	0.0	0	0.0	0.0	N/A			

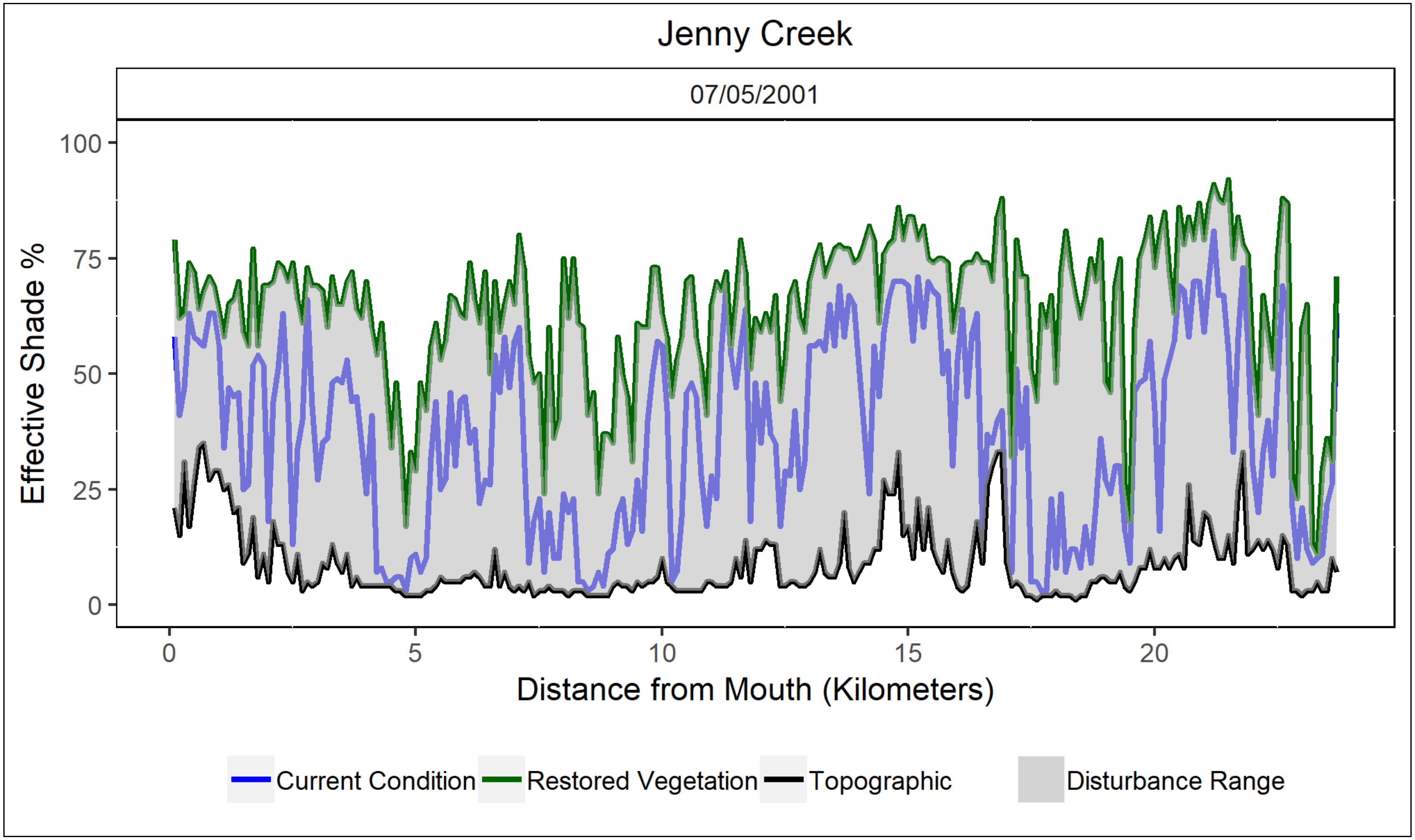


Figure A- 21. Longitudinal profiles of effective shade on Jenny Creek.

Table A- 16. Jenny Creek mean effective shade.

Analysis Date	Mean Effective Shade Current Condition	Mean Effective Shade Restored Condition	Mean Effective Shade Deficit
07/05/2001	38%	64%	26%

A.4.2.7.2 Restored Flow Scenario

Restored flow is the volumetric flow of water estimated to be in the modeled reach if there were no anthropogenic influences. In the Jenny Creek watershed, OWRD provided estimates of the 50th percentile natural flow at several points (OWRD 2002). The OWRD estimate was incorporated in to the model only at the boundary condition (Table A-13 and Figure A-20). According to the Current Calibrated model, the increase in flow at the boundary increases the flow downstream to greater than flows estimated by OWRD. Instead, in the “Restored Flow” model, flow was added to tributaries to reflect the water that is currently withdrawn from the mainstem Jenny Creek and Spring Creek according to the OWRD points-of-diversion database. This flow was added to the closest tributary node. The “Restored Flow” scenario represents a greater volumetric flow at the mouth than was estimated by the OWRD report. During the model year, 2001, a significant water withdrawal from Spring Creek was not used. The scenario “PacCorp withdrawals” incorporates the current estimated consumptive water use from Spring Creek and is a reflection of the current water flow in Jenny Creek.

Table A- 17. Flow inputs and rates for the Jenny Creek flow modified model.

Location name	Stream km	Current flow rate (cms)	Restored flow rate (cms)	Source
Boundary condition	23.7	0.036	0.224	OWRD report
Spring (from TIR)	17.35	0.04	0.049	OWRD POD consumptive use
Beaver Creek	15.95	0.04	0.072	OWRD POD consumptive use
Keene Creek	12.75	0.07	0.104	OWRD POD consumptive use
Spring (from TIR)	3.9	0.06	0.06	
Spring Creek	3.35	0.18	0.396	OWRD POD consumptive use

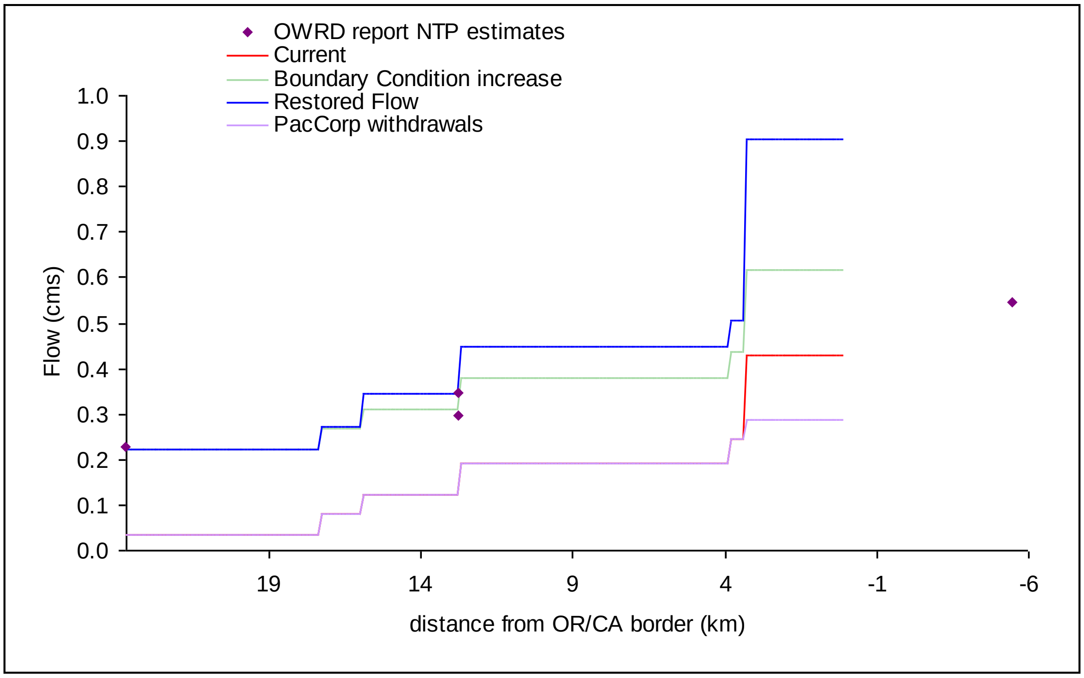


Figure A- 22. Longitudinal profiles of predicted flows for scenarios which considered flow alterations on Jenny Creek, July 24, 2001.

A.4.3 Spencer Creek

A.4.3.1 Overview

Stream Name: Spencer Creek
Model: Heat Source version 8.0.2
Beginning date: 7/2/2001
Ending date: 7/21/2001
Time step: 1 minute
Distance step: 100 m
Extent: Headwaters (25.2 km) to mouth (Figure A- 23).

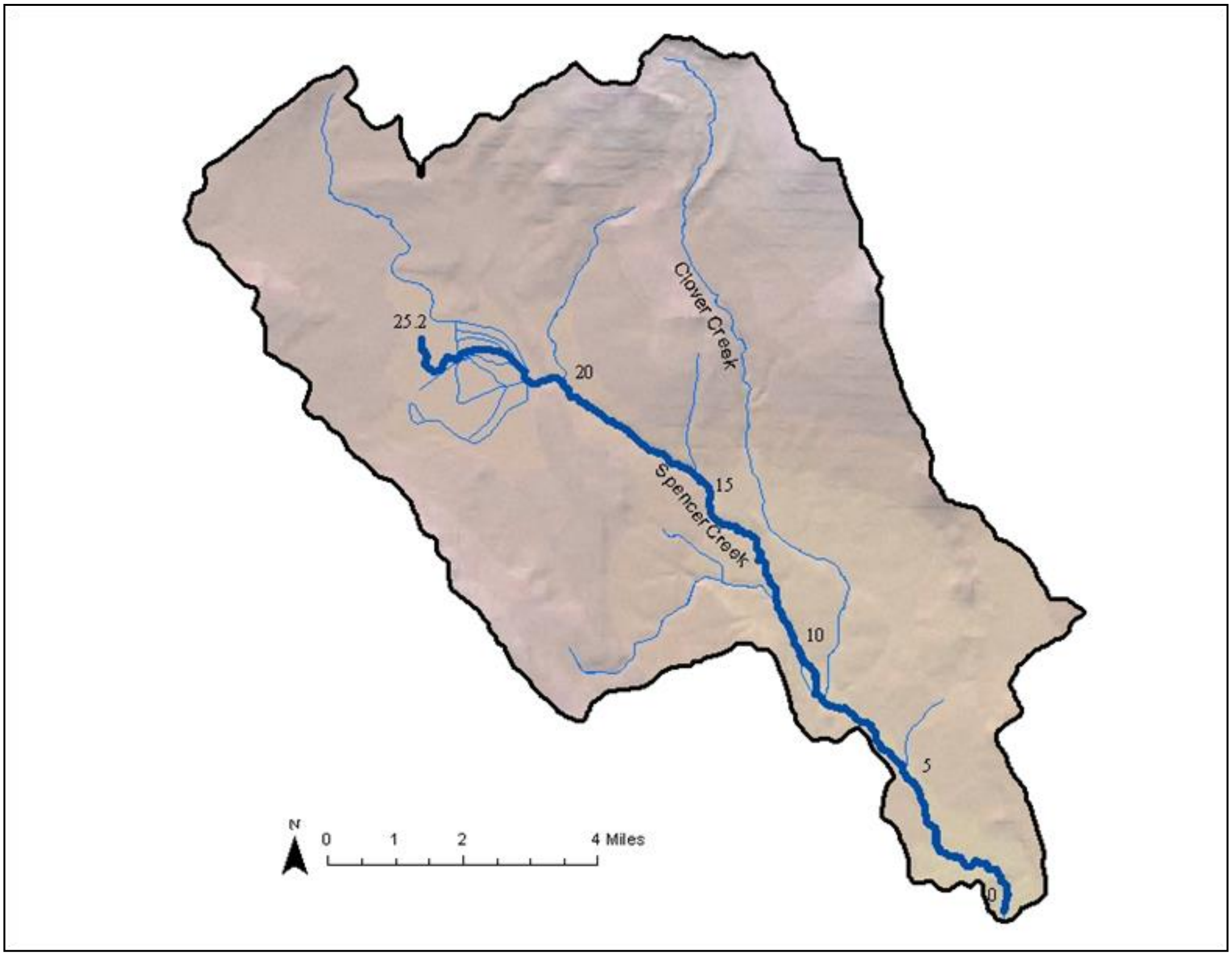


Figure A- 23. Extent of the Spencer Creek temperature model.

A.4.3.2 Reach Properties

The channel properties were determined using the methodology documented previously in this report (see Section 3). Figure A-22 shows the elevation profile and reach gradient. The bottom width was derived using the active channel width measured from aerial photographs. Bottom width was estimated by assuming a trapezoidal channel with variable sloping side slopes and a variable width-to-depth ratio determined through model calibration (Figure A-22). Non-spatially varying coefficients are presented in Table A- 18. Manning's n was iteratively altered so that the model temperatures approximately reproduced measured temperatures (Table A- 18). Topographic and riparian vegetation heights were determined through a GIS analysis (Table A- 19, Figure A- 27 through Figure A- 29). Vegetation was sampled in a radial pattern every 5 meters from the center of stream out to a distance of 25 meters. Using these channel and vegetation inputs, the performance of the Spencer Creek model in predicting shade is shown in Figure A- 30.

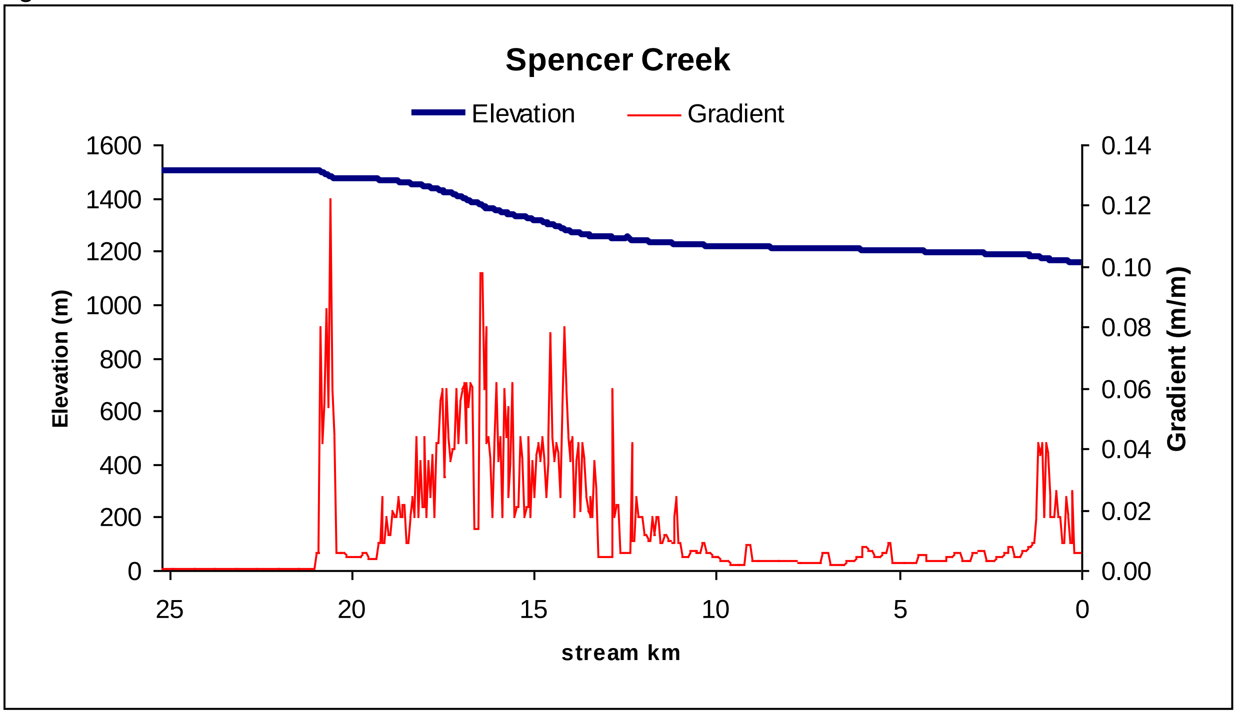


Figure A- 24. Model setup channel elevation and gradient.

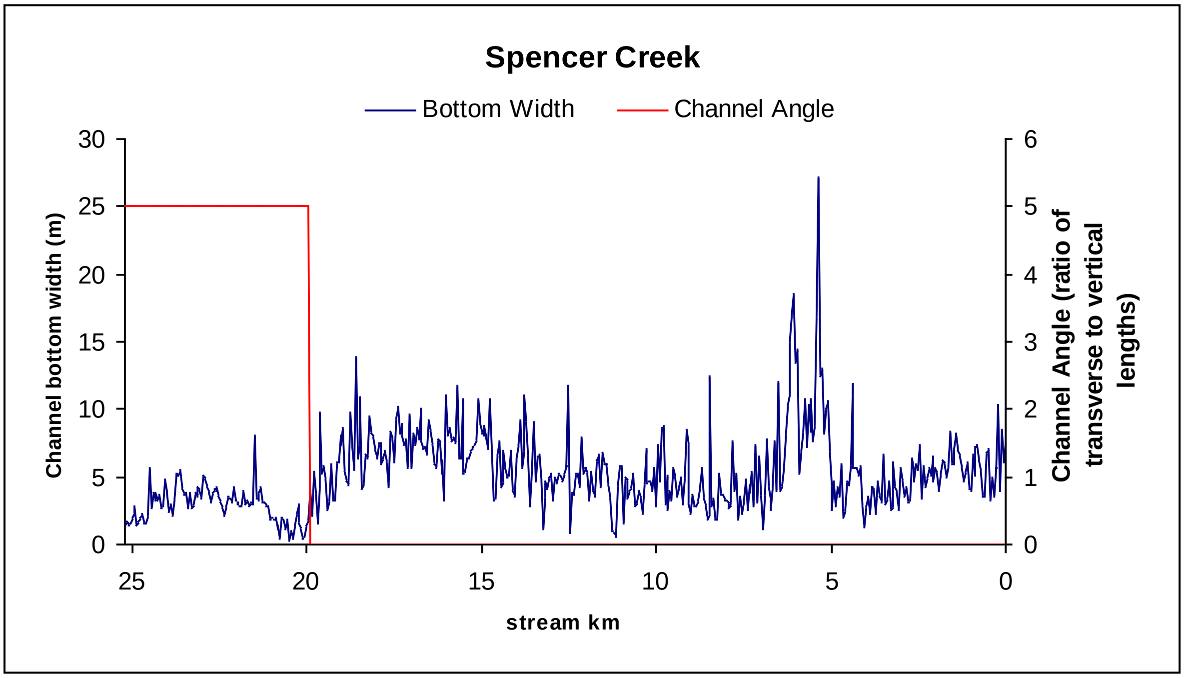


Figure A- 25. Model setup for channel bottom width and channel angle.

Table A- 18. Model coefficients for non-spatially varying parameters.

Parameter name (units)	Value
Wind Function, coefficient a	1.51×10^{-9}
Wind Function, coefficient b	1.60×10^{-9}
Width:Depth Ratio	26.0
Sediment Thermal Conductivity (W/m/°C)	1.57
Sediment Thermal Diffusivity (cm^2/sec)	0.0064
Sediment/Hyporheic Zone Thickness (m)	0.20
Percent Hyporheic Exchange	0%
Porosity	33%

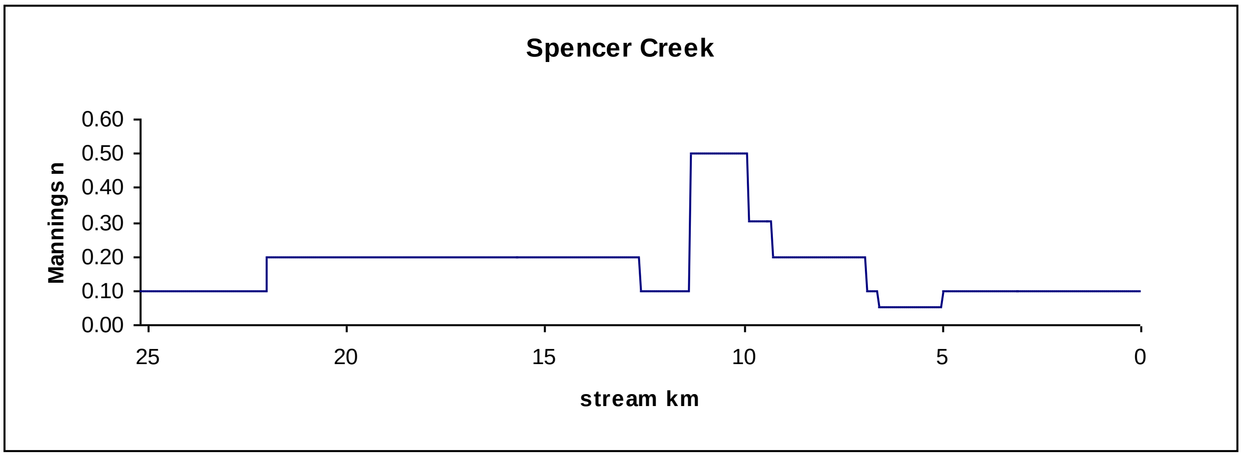


Figure A- 26. Model setup for roughness coefficient.

Table A- 19. Spatial Data and Application: GIS data source and the application used in Spencer Creek watershed

Spatial Data	Data Source	Application
10-Meter Digital Elevation Models (DEM)	Oregon Geospatial Data Clearinghouse	Measure Stream Elevation and Gradient Measure Topographic Shade Angles
Aerial Imagery – Digital Orthophoto Quads for year 2000	BLM	Map Vegetation Map Channel Morphology Map Roads, Development, Structures
Thermal Infrared Radiometry (TIR) Stream Temperature Data	Watershed Sciences 2002, collected on 7/15/2001	Measure Surface Temperatures Develop Longitudinal Temperature Profiles Identify Subsurface Hydrology, Groundwater Inflow, Springs

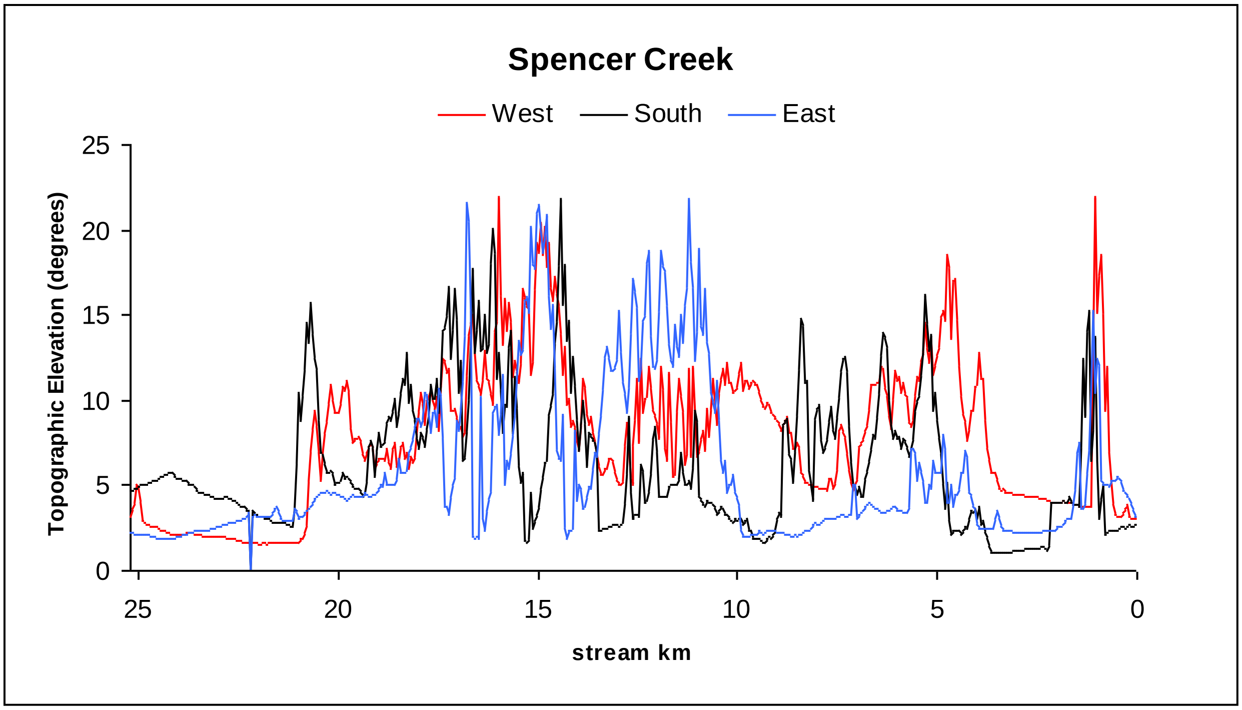


Figure A- 27. Model setup for topographic angle.

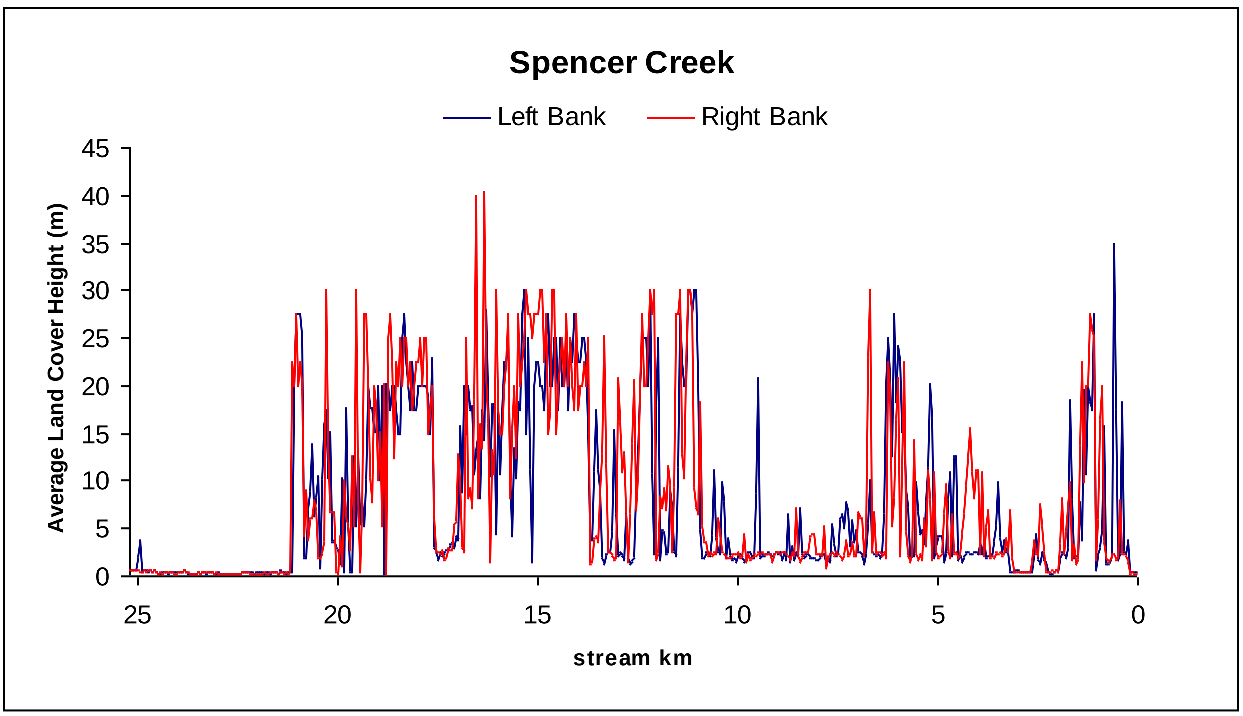


Figure A- 28. Model setup for height of near-stream vegetation.

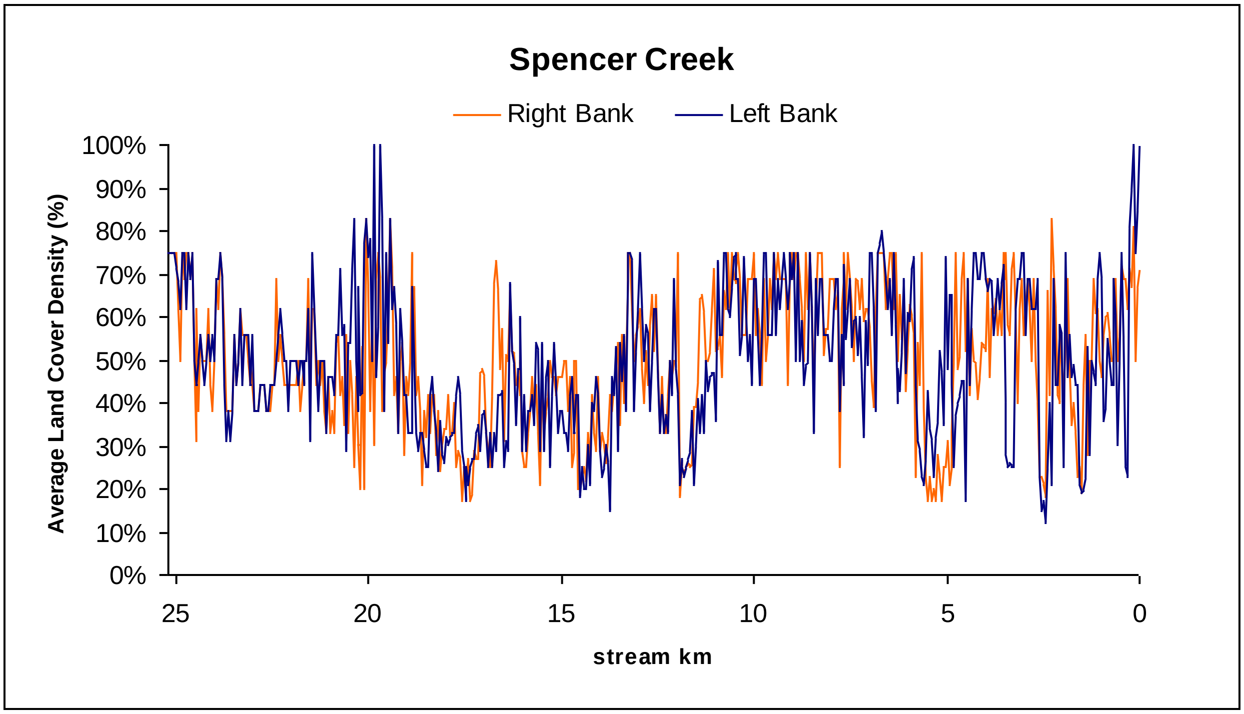


Figure A- 29. Model setup for density of near-stream vegetation.

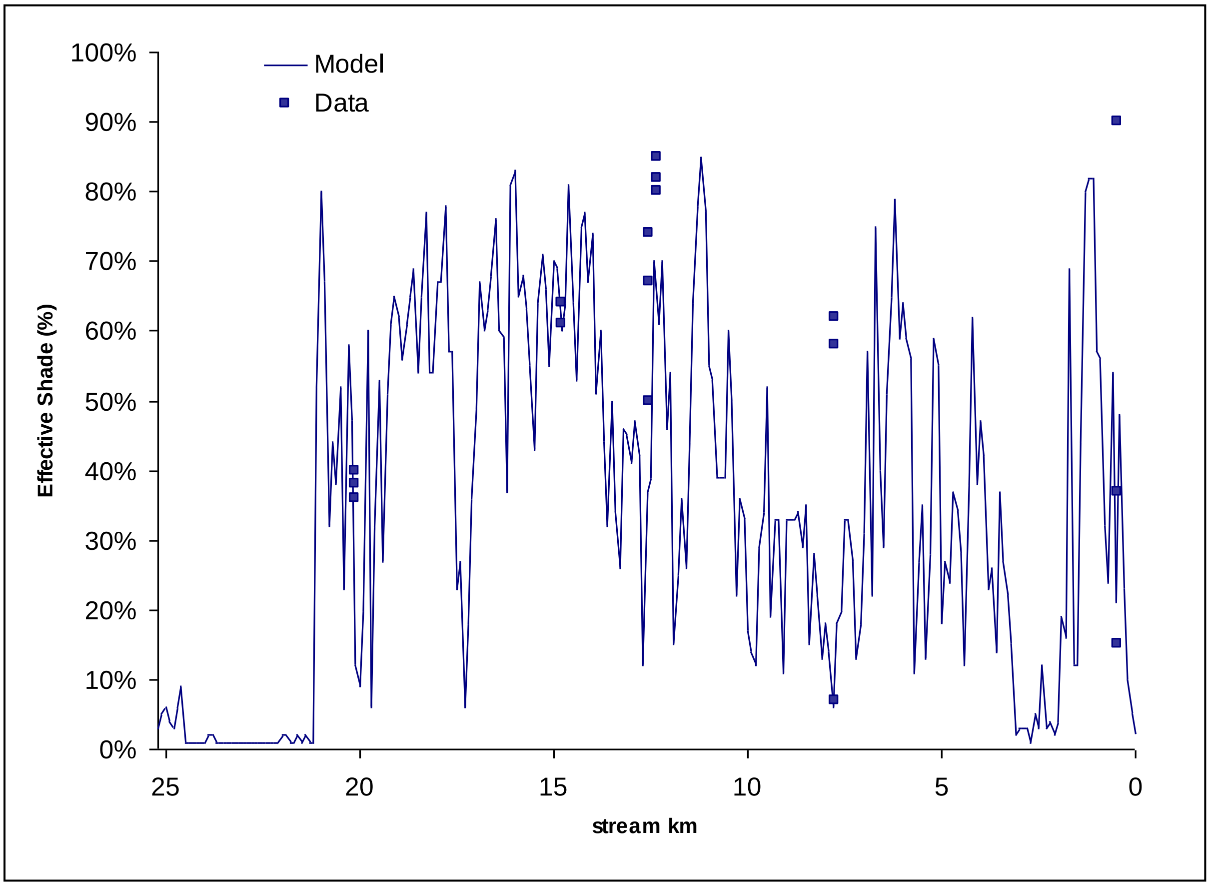


Figure A- 30. Predicted versus measured effective shade.

A.4.3.3 Meteorology

The Spencer Creek model uses air temperature, relative humidity, and wind speed data from a BLM meteorology station in the Spencer Creek watershed (US BLM 2004). Solar radiation data was obtained from the Medford airport meteorology site (NOAA 2001a) and used to derive cloudiness. The meteorological observations are presented in Figure A-29, a-d.

Figure A- 31, a-d. Meteorology inputs for model setup.

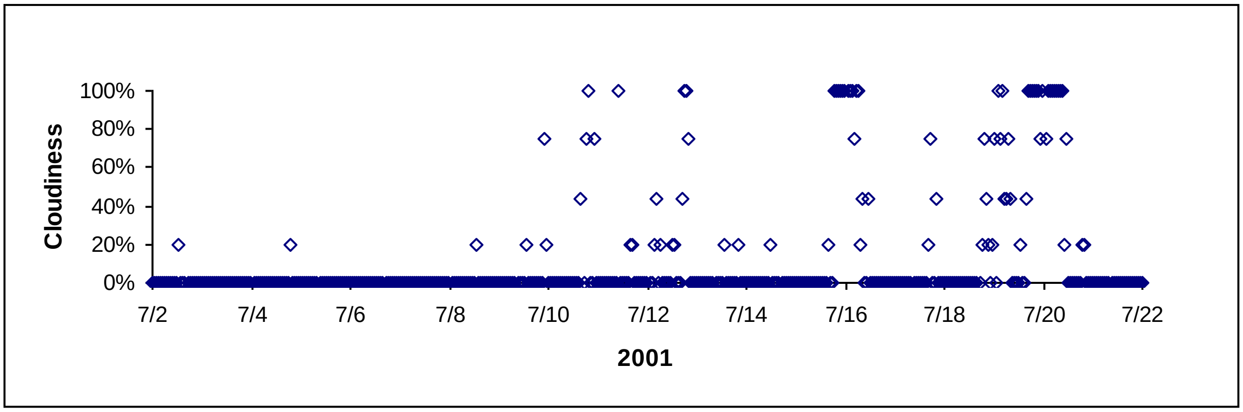


Figure A-29-a.

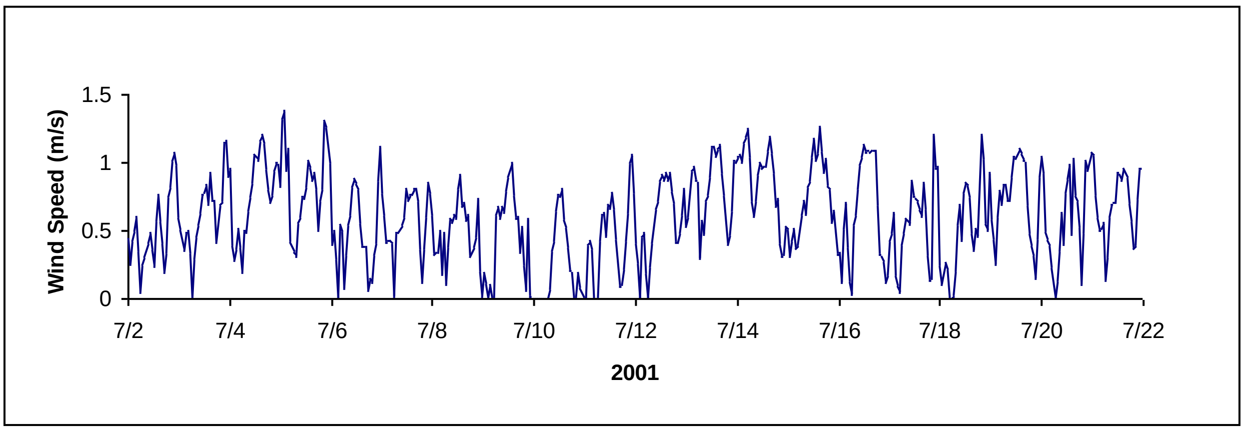


Figure A- 29-b.

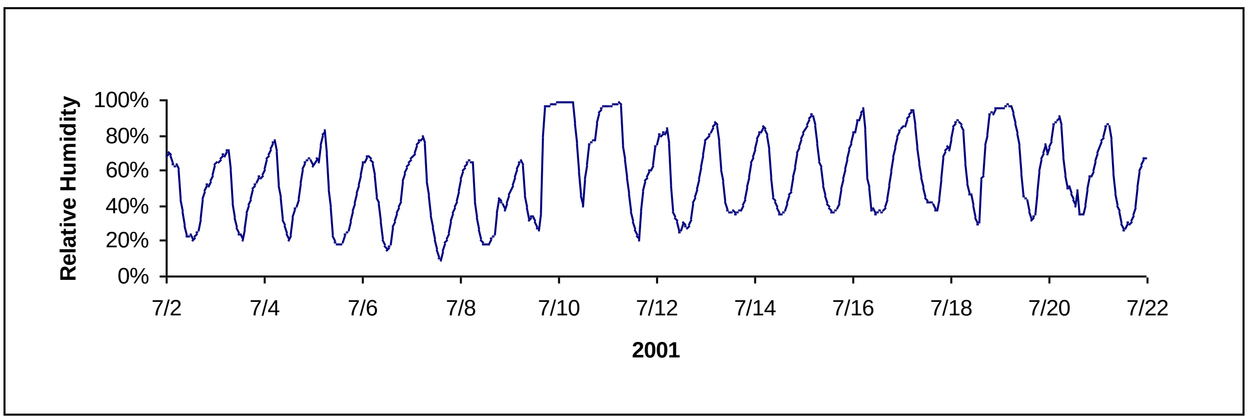


Figure A- 29-c.

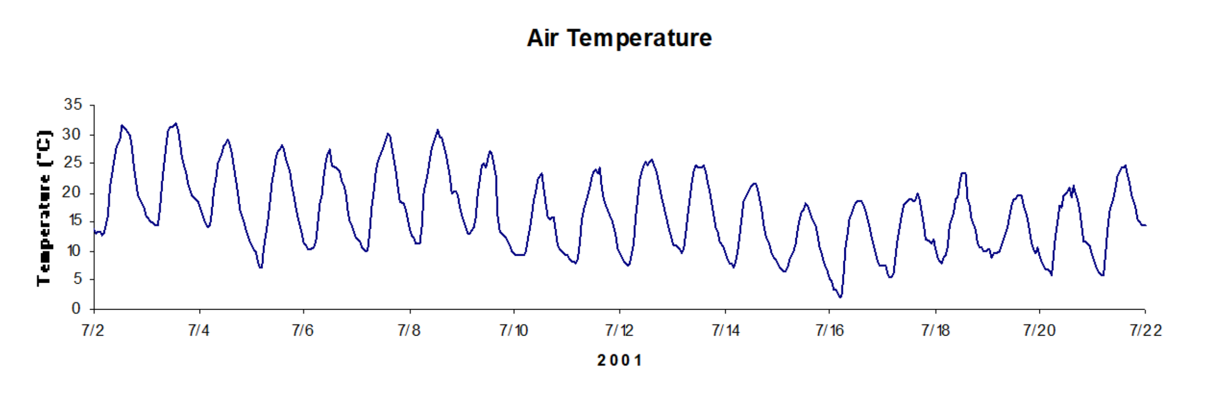


Figure A- 29-d.

A.4.3.4 Flow and Temperature

No continuous gage or instantaneous flow data for were available in the Spencer Creek watershed for 2001, so flows were assumed based on best professional judgment and field transects provided by BLM (Elizabeth Berger, personal communication, 2001). In order to match TIR temperatures, supplemental water was added for calibration between river km 24.4 and 25.2 at a rate of 0.0135 cms every 0.05 km. The supplemental water was assumed to be groundwater inflow at 12ºC. There were no other tributaries added to the model. The model assumed a constant inflow at the headwaters (25.2km) of 0.05 cms. Using these flow inputs, the Spencer Creek model predicted flow is shown in Figure A-30.

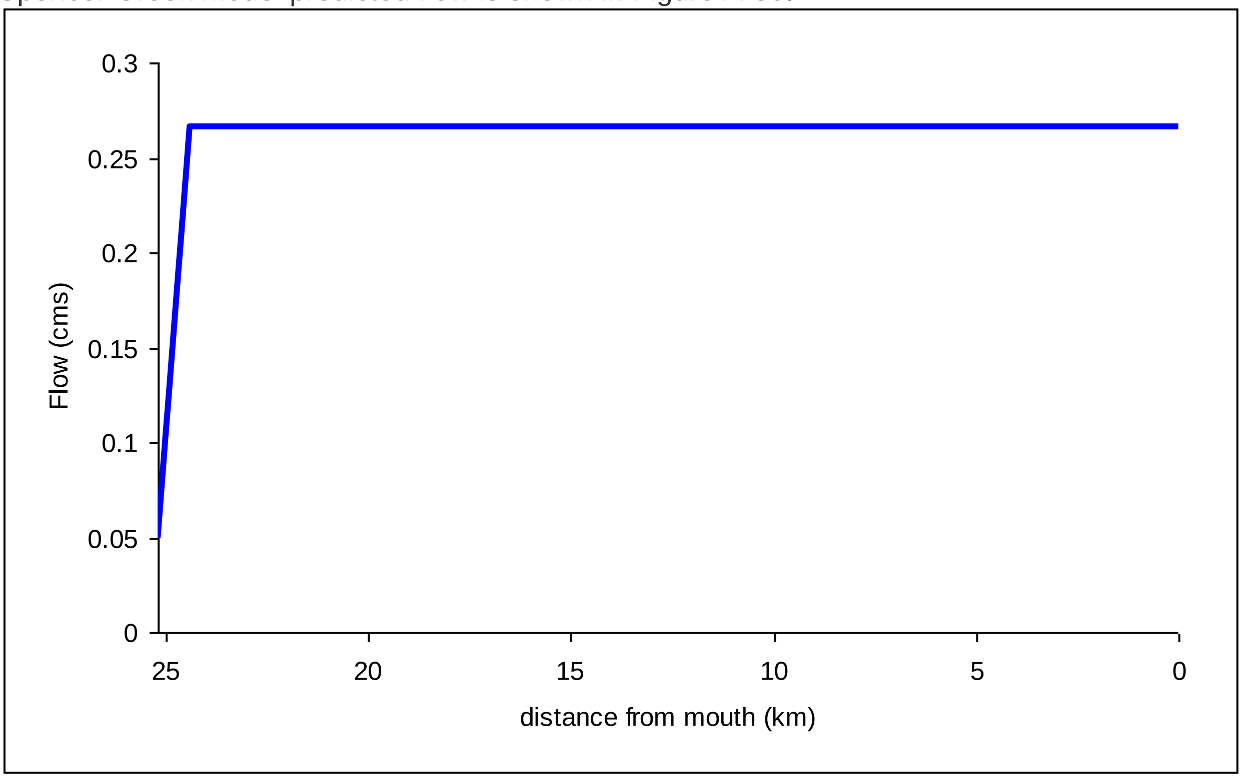


Figure A- 32. Longitudinal profile of measured flow.

A.4.3.5 Temperature Calibration

The model generally reproduces spatially and temporal varying temperature measurements (Table A-16 and Table A- 21 and Figure A-31 and Figure A- 34). See previous statistics discussion at the beginning of **Section A.4** for definitions.

Table A- 20. TIR error statistics

Error type	Value
Mean	-0.46
Absolute mean	1.04
Root mean square	1.29
Nash-Sutcliffe	0.41

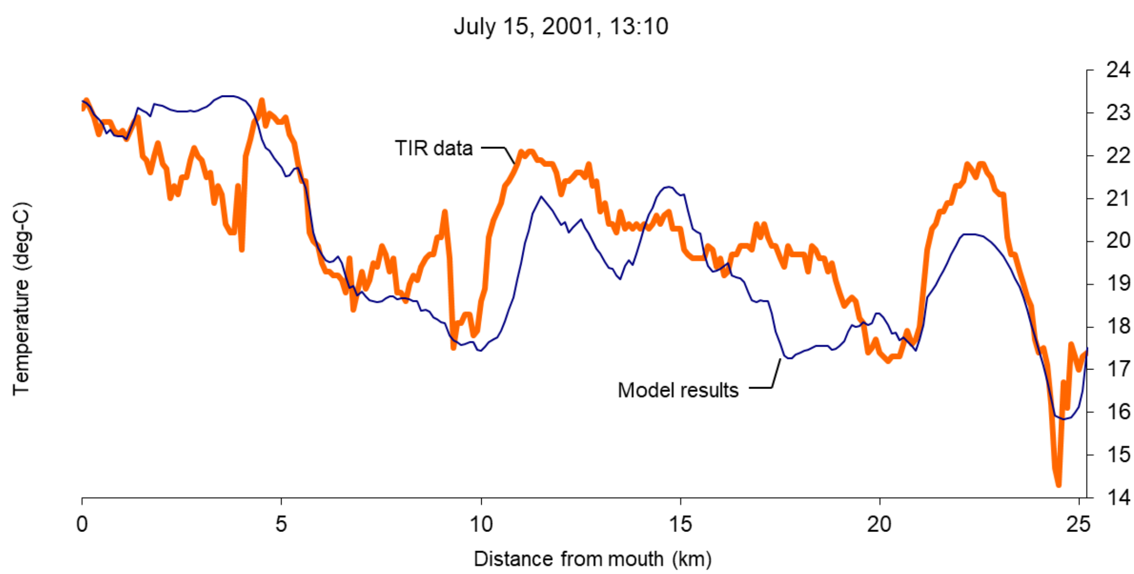


Figure A- 33. Longitudinal profile of measured temperatures using Thermal Infrared Radiometry and model results.

Table A- 21. Continuous monitoring error statistics

Site Name	Site #	Ref	rKM	n	Mean Error	Abs Mean Error	RMSE	Nash-Sutcliffe
				All data				
Spencer Cr. at outlet of Buck Lake	4920	A	21.1	480	-0.37	1.32	1.63	0.84
Spencer Cr. (section 17)	4800	B	18.8	480	0.38	1.26	1.62	0.60
Spencer Cr. (section 21)	4600	C	16.95	480	1.09	1.52	1.85	0.50
Spencer Cr. (section 28)	4300	D	14.7	480	0.89	1.41	1.71	0.57
Spencer Cr. upstream from Hook-Up Road (section 34)	4100	E	12.7	480	0.75	1.33	1.60	0.70
Spencer Cr. at upstream end of meadow (Broken Bridge)	4000	F	9.95	480	1.06	1.67	2.04	0.06
Spencer Cr. at downstream end of meadow	3985	G	7.4	480	1.78	1.95	2.32	-0.20
Spencer Cr. at mouth	3800	H	0.5	480	1.14	1.77	2.32	0.57
Average					0.84	1.53	1.88	0.46

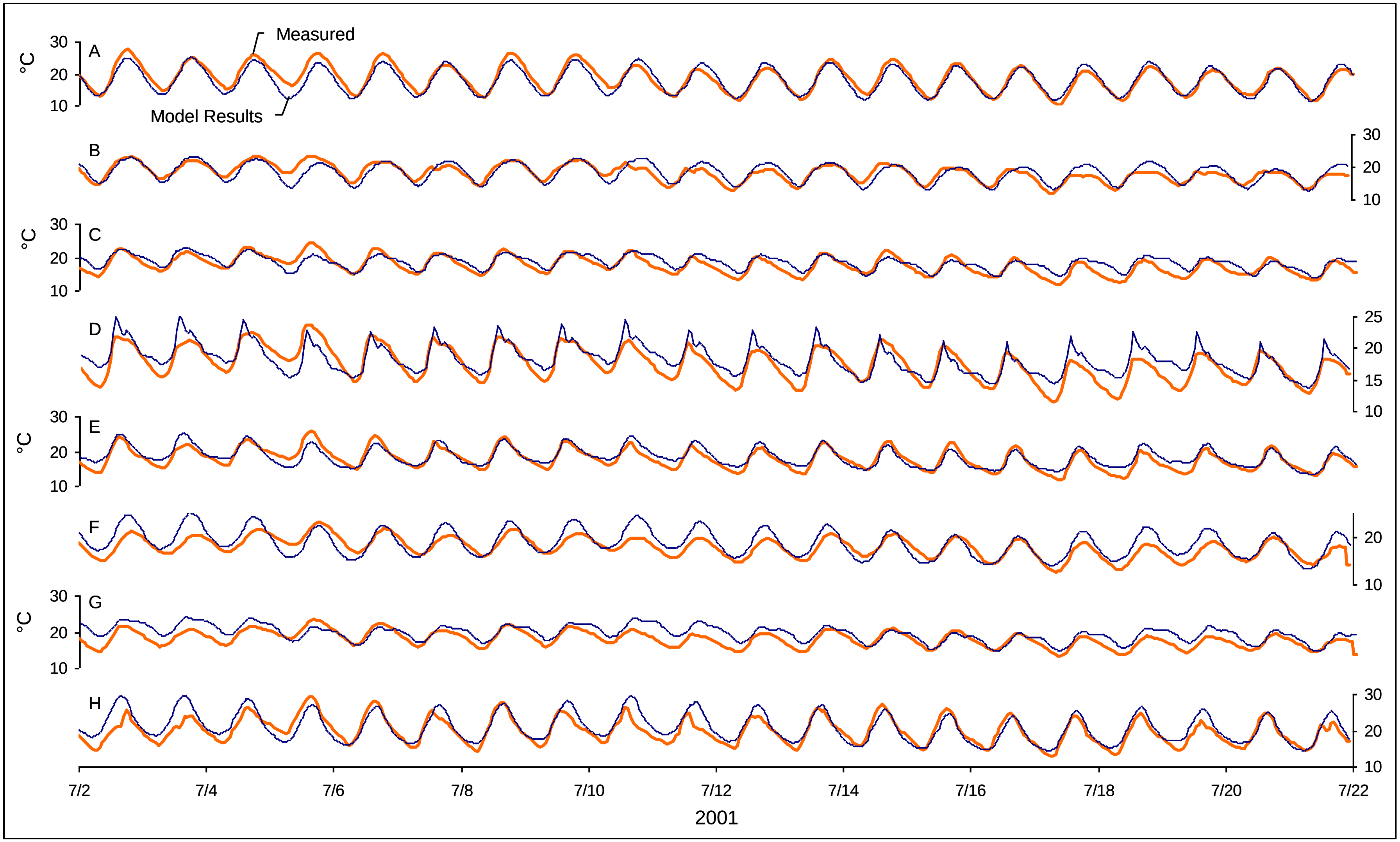


Figure A- 34. Measured steam temperature versus model results.

A.4.3.6 Scenario Results

The Heat Source model was used to predict the influence of various factors on stream temperature (Table A-18).

Table A- 22. Simulated Scenario Definitions.

0	Topographic TOPO	Same as #1 Current Conditions except all vegetation is removed.
1	Current Calibrated Condition CCC	Current Calibrated Condition
2	Restored Vegetation VEG	Restored Vegetation
3	Natural Flow FLOW	Water withdrawals from points of diversion are maintained as instream flow and the boundary condition flow was adjusted to reflect the natural flow derived by OWRD.
4	Restored Conditions RC	Incorporation of inputs of #2 restored vegetation and #3 flow scenarios. No other adjustments were made to tributary inputs.

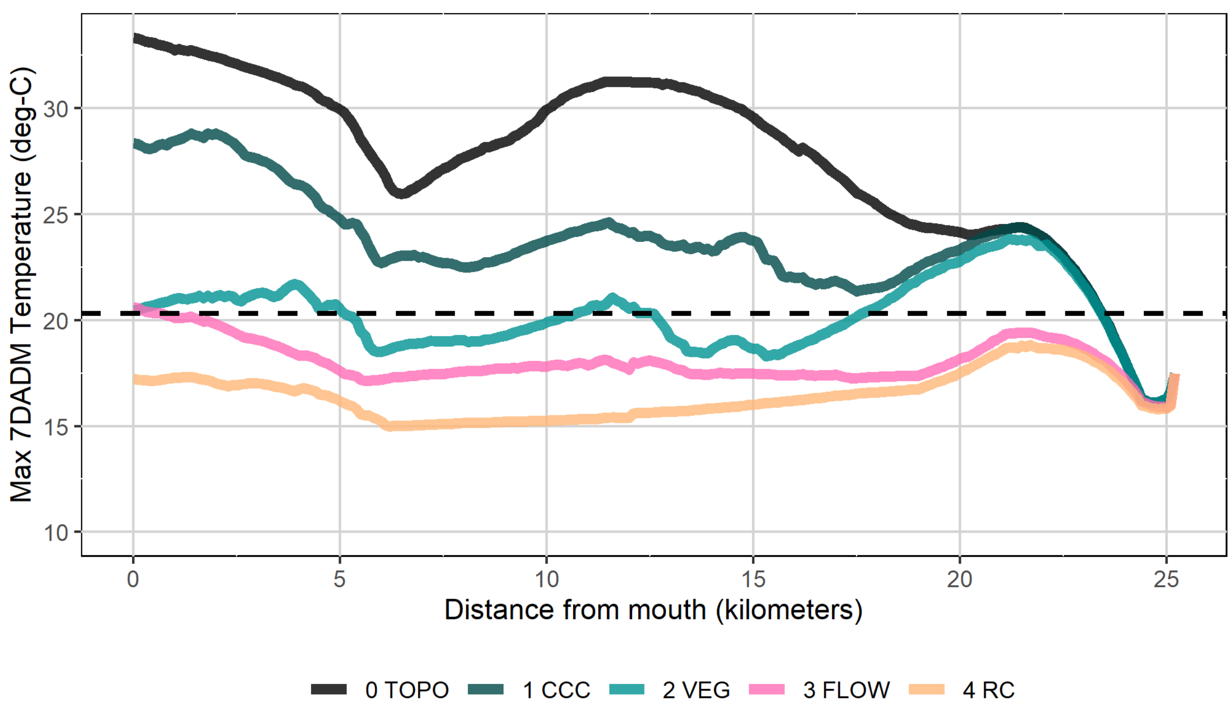


Figure A- 35. Predictions for Spencer Creek scenarios based on the maximum 7DADM, July 2-21, 2001. Dashed line is the 20-deg C criteria plus 0.3 deg-C human use allowance.

Table A- 23. Summary Spencer Creek maximum 7DADM temperature scenarios, July 2-21, 2001.

Model Scenario	Location of Point of Maximum Impact (POMI) Stream KM	Maximum 7DADM POMI	Maximum 7DADM Mouth
0 TOPO	0	33.3	33.3
1 CCC	1.8	28.8	28.3
2 VEG	21.2	23.8	20.5
3 FLOW	0	20.6	20.6
4 RC	21.7	18.8	17.2

A.4.3.6.1 Restored Vegetation

Restored vegetation is essentially the mature species composition, height, density, and overhang width of vegetation that would occur in the absence of human disturbances. Restored vegetation conditions were used in stream temperature modeling scenarios to quantify the impacts of nonpoint source solar radiation loads, and ultimately to develop nonpoint source load allocations for the TMDL.

Restored vegetation values were estimated for the Spencer Creek watershed by examining multiple references. To determine habitat potentials, physical parameters including elevation, gradient, climate, soils, vegetative communities, geology, physiography, hydrology, land use, etc. were assessed. Habitats were distinguished by changes in elevation at river kilometers 20.0 and 11.0. The habitats were called “Buck Lake”, “Upper watershed”, & “Lower watershed” in order of average elevation. The potential habitat scenario assumes the watershed has been morphologically restored. Buck Lake is assumed to be returned to a more natural hydrological state of a wetland meadow. The water in the current channel will be filled with emergent vegetation. The HeatSource program has an "emergent vegetation" function that was used to calculate the potential temperature impacts due to this shading. To determine potential plant species, narrative reports, especially vegetation descriptions from the Oregon Watershed Assessment Manual (1999), were consulted. Estimates of plant community height, density and overhang width were compiled and averaged by best professional judgment from site indices, tree growth curves, and plant guide books (Table A- 24). Generally, vegetation is expected to increase or remain the same in average height, density, and overhang distance. The potential height of the largest Ponderosa Pines is expected to decrease in height, on average. The current height of the largest Ponderosa Pines is 5 meters taller than the estimated potential height (30 meters). The current height is likely an over-estimate of actual conditions. The restored height for Ponderosa Pine is based on local site indices and field data (Oliver and Powers 1978, Seeds 2007, Sokol 2007). The largest Mixed Conifers are also expected to decrease in height, on average, as the species composition changes. Finally, the current land cover vegetation types were assigned a potential (mature) vegetation type, which are described in Table A- 24.

Table A- 24. Summary of the current vegetation type heights, densities, and overhang widths and assigned restored vegetation type.

Vegetation Type	Height (m)	Density (%)	Overhang (m)	Prevalence in model (%)	Restored Vegetation Type	Potential Height (m)	Potential Density (%)	Potential Overhang (m)
Water (Buck Lake)	0.0	0	0.0	6	Emergent Vegetation - Buck Lake	0.5	50	0.0
Water	0.0	0	0.0	18	Water	0.0	0	0.0
Pastures/Cultivated Field/lawn (Buck Lake)	0.5	75	0.3	11	Wetland Complex - Buck Lake	2.3	75	0.3
Pastures/Cultivated Field/lawn (Upper watershed)	0.5	75	0.3	0	Mixed Conifer - Large	55.6	80	2.0
Pastures/Cultivated Field/lawn (Lower watershed)	0.5	7	0.3	3	Ponderosa Pine - Large	30.0	60	2.0
Barren - Rock	0.0	0	0.0	0	Barren - Rock	0.0	0	0.0
Barren - Embankment	0.0	0	0.0	0	Barren - Embankment	0.0	0	0.0
Barren - Clearcut /recent re-plant	0.0	0	0.0	0	Ponderosa Pine - Large	30.0	60	2.0
Barren - Soil	0.0	0	0.0	0	Ponderosa Pine - Large	30.0	60	2.0
Dead Stand	15.0	5	0.0	0	Ponderosa Pine - Large	30.0	60	2.0
Barren - Road (Buck Lake)	0.0	0	0.0	0	Wetland Complex - Buck Lake	2.3	75	0.3
Barren - Road (Upper watershed)	0.0	0	0.0	0	Mixed Conifer - Large	55.6	80	2.0
Barren - Road (Lower watershed)	0.0	0	0.0	0	Ponderosa Pine - Large	30.0	60	2.0
Aspen	5.0	50	0.3	0	Aspen	15.0	50	1.0
Ponderosa Pine - Large	35.0	60	2.0	0	Ponderosa Pine - Large	30.0	60	2.0
Ponderosa Pine - Medium	20.0	60	2.0	1	Ponderosa Pine – Large	30.0	60	2.0

Vegetation Type	Height (m)	Density (%)	Overhang (m)	Prevalence in model (%)	Restored Vegetation Type	Potential Height (m)	Potential Density (%)	Potential Overhang (m)
Ponderosa Pine - Small	10.0	60	1.0	0	Ponderosa Pine - Large	30.0	60	2.0
Ponderosa Pine - Large - Low Density	35.0	30	2.0	0	Ponderosa Pine - Large	30.0	60	2.0
Ponderosa Pine - Medium - Low Density	20.0	30	2.0	1	Ponderosa Pine - Large	30.0	60	2.0
Ponderosa Pine - Small - Low Density	10.0	30	1.0	0	Ponderosa Pine - Large	30.0	60	2.0
Mixed Conifer - Large	60.0	80	2.0	0	Mixed Conifer - Large	55.6	80	2.0
Mixed Conifer - Medium	30.0	50	0.0	16	Mixed Conifer - Large	55.6	80	2.0
Mixed Conifer - Small	10.0	80	0.0	0	Mixed Conifer - Large	55.6	80	2.0
Mixed Conifer - Smaller (recent replant)	5.0	50	0.5	1	Mixed Conifer - Large	55.6	80	2.0
Mixed Conifer - Medium - Low Density	30.0	30	2.0	2	Mixed Conifer - Large	55.6	80	2.0
Mixed Conifer - Small - Low Density	10.0	30	2.0	0	Mixed Conifer - Large	55.6	80	2.0
Upland shrubs	1.8	50	0.3	0	Ponderosa Pine - Large	30.0	60	2.0
Upland shrubs	1.8	20	0.3	0	Ponderosa Pine - Large	30.0	60	2.0
Shrubs and grasses floodplain / riparian (Buck Lake)	2.5	75	1.0	1	Wetland Complex - Buck Lake	2.3	75	0.3
Shrubs and grasses floodplain / riparian (Upper watershed)	2.5	75	1.0	4	Riparian shrubs- Upper watershed	3.6	75	1.0
Shrubs and grasses floodplain / riparian (Lower watershed)	2.5	75	1.0	20	Riparian shrubs- Lower watershed	12.2	75	2.0
Shrubs and grasses floodplain / riparian (Buck Lake)	2.5	25	1.0	0	Wetland Complex - Buck Lake	2.3	75	0.3

Vegetation Type	Height (m)	Density (%)	Overhang (m)	Prevalence in model (%)	Restored Vegetation Type	Potential Height (m)	Potential Density (%)	Potential Overhang (m)
Shrubs and grasses floodplain / riparian (Upper watershed)	2.5	25	1.0	2	Riparian shrubs-Upper watershed	3.6	75	1.0
Shrubs and grasses floodplain / riparian (Lower watershed)	2.5	25	1.0	4	Riparian shrubs-Lower watershed	12.2	75	2.0
Grasses - upland	0.5	75	0.3	0	Ponderosa Pine - Large	30.0	60	2.0
Grasses - wetland (Buck Lake)	0.5	100	0.0	1	Wetland Complex - Buck Lake	2.3	75	0.3
Grasses - wetland (Upper watershed)	0.5	100	0.0	2	Riparian shrubs-Upper watershed	3.6	75	1.0
Grasses - wetland (Lower watershed)	0.5	100	0.0	1	Riparian shrubs-Lower watershed	12.2	75	2.0
Active Channel Bottom	0.0	0	0.0	0	Active Channel Bottom	0.0	0	0.0
Pine plantation	10.0	75	1.0	0	Ponderosa Pine - Large	30.0	60	2.0
Dense pine on floodplain	30.0	75	1.0	2	Ponderosa Pine - Large	30.0	60	2.0

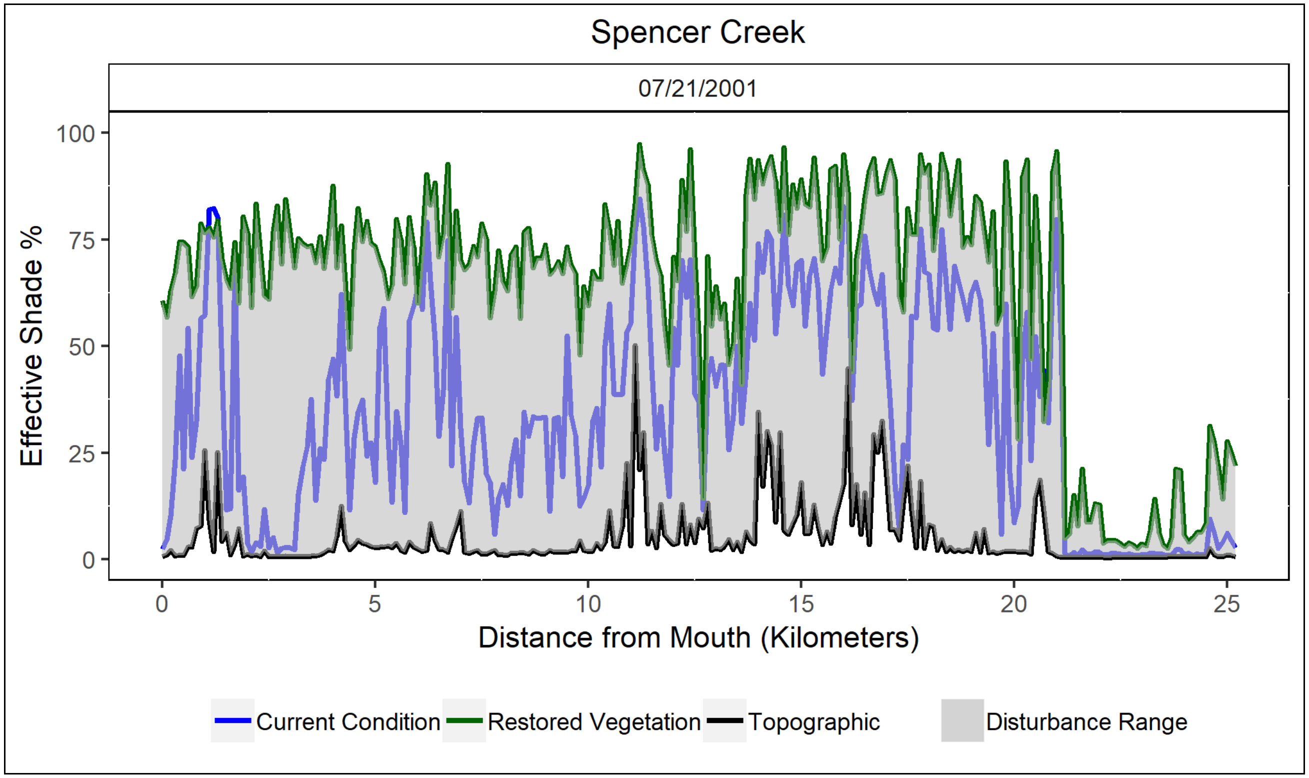


Figure A- 36. Longitudinal profiles of effective shade on Spencer Creek.

Table A- 25. Spencer Creek mean effective shade.

Analysis Date	Mean Effective Shade Current Condition	Mean Effective Shade Restored Condition	Mean Effective Shade Deficit
07/21/2001	35%	63%	28%

A.4.3.6.2 Restored Flow

Restored flow is the volumetric flow of water estimated to be in the modeled reach if there were no anthropogenic influences. On the Spencer Creek mainstem, OWRD provided estimates of the 50th percentile natural flow at two points (OWRD 2002). In the Spencer Creek model, accretion flow was added to approximate the OWRD estimate at the National Forest boundary and represents spring inflow around Buck Lake. However, OWRD notes that there was very little accretion flow downstream of the National Forest boundary (Jonathon LaMarche, personal communication, 2008). The OWRD estimate of flow at the mouth of Spencer Creek necessitated adding a tributary representing Miller Creek to balance the increase in flow. These estimates were incorporated into the model as “Restored Flow” (Figure A-35).

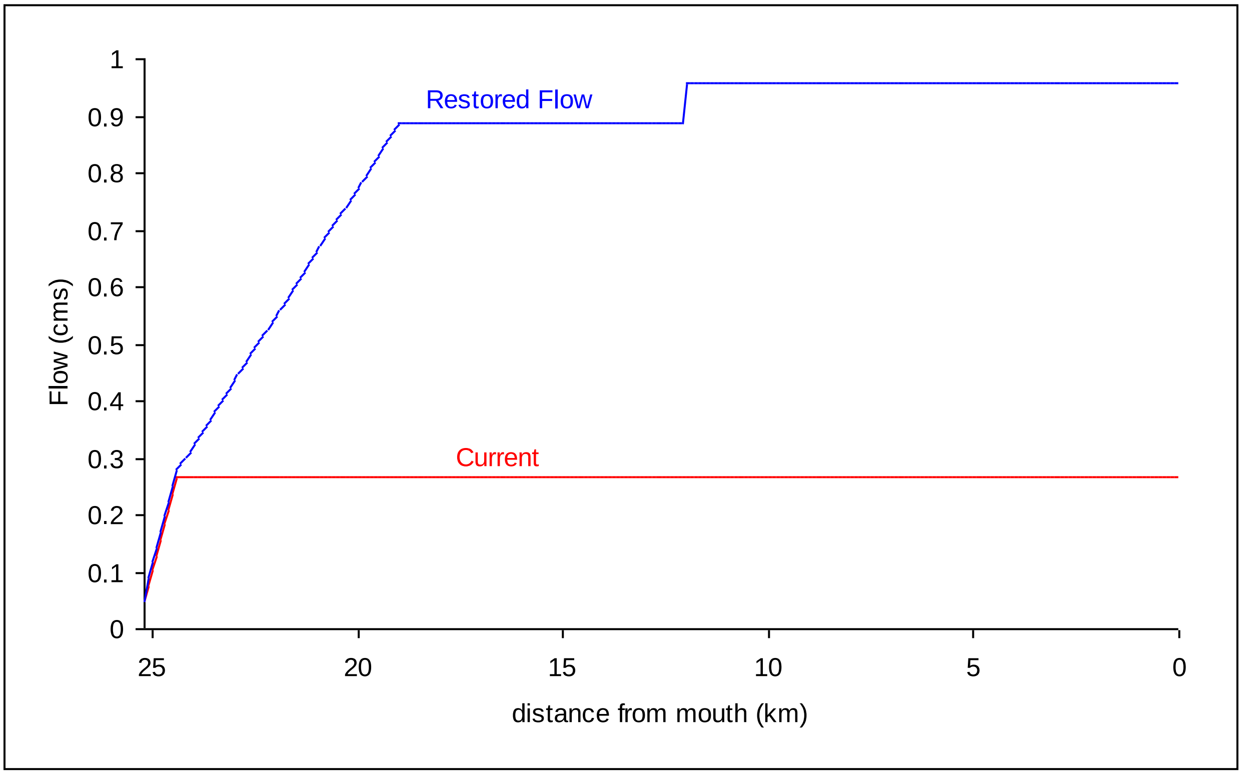


Figure A- 37. Longitudinal profiles of predicted flows for scenarios which considered flow alterations on Spencer Creek, July 21, 2001.

A.4.4 Miller Creek

A.4.4.1 Overview

Stream Name: Miller Creek
Model: Heat Source version 7.0
Beginning date: 7/17/2001
Ending date: 8/5/2001
Time step: 1 minute
Distance step: 30.48 m
Extent: Temperature modeling: Gerber Reservoir to confluence with Pine Creek (14.57 km) (Figure A- 38). Effective Shade modeling: Gerber Reservoir to Miller Creek mouth at

confluence with Lost River (19.75 km). The temperature model stops at the confluence with Pine Creek because there was too little flow downstream to calibrate the model.

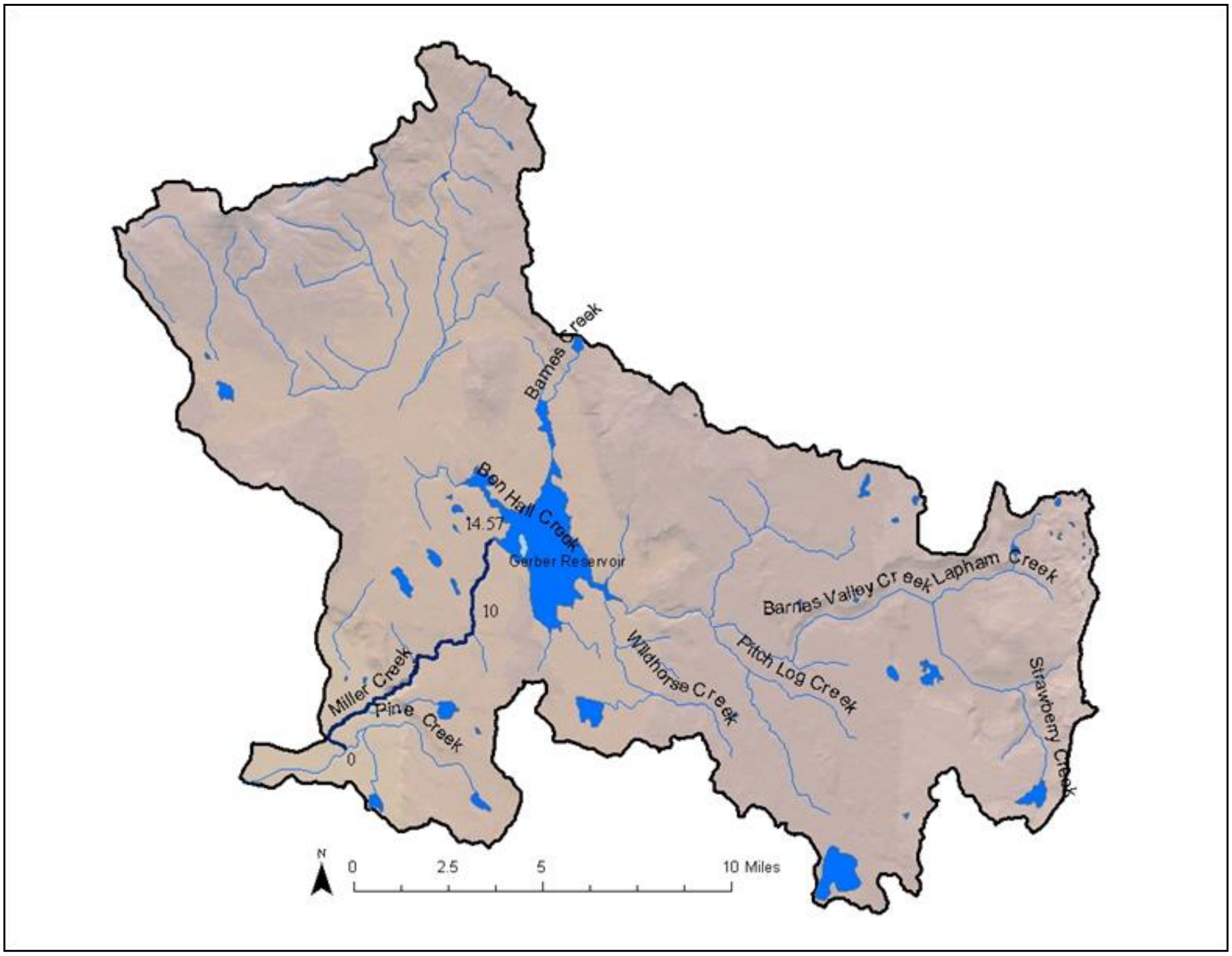


Figure A- 38. Extent of the Miller Creek temperature model.

A.4.4.2 Reach Properties

The channel properties were determined using the methodology documented previously in this report (see **Section A.3**).Figure A- 39 shows the elevation profile and reach gradient. The bankfull width (Figure A- 40) was derived using the active channel width measured from relatively low resolution black and white aerial photographs (all that was available when the model was developed). The active channel width appeared to be underestimated in a number of reaches. Therefore, if the estimated stream width was less than 12m, it was corrected using the formula: $width_{adj} = width + \frac{12 - width}{2}$

Bottom width (Figure A- 40) was estimated by assuming a rectangular channel with perpendicular side slopes (channel angle –z of 0) upstream of kilometer 3.8. Downstream of kilometer 3.8 a side slope was introduced (channel angle –z of 0.95) to reflect the angle of the dredged channel on the valley floor (Figure A- 40). A constant width-to-depth ratio of 4 was used and determined through model calibration. Non-spatially varying coefficients are presented in Table A- 26. Manning's n (Figure A- 41) was iteratively adjusted so that the model temperatures approximately reproduced measured temperatures The sharp increase near kilometer 6.3 is the location of a large pool upstream of a road culvert. Manning's n is not shown below kilometer 5.15 because that is where the temperature modeling stops.

Topographic and riparian vegetation heights were determined through a GIS analysis (Figure A-42 through Figure A- 44**,** and Table A- 27). Vegetation was sampled in a radial pattern every 10 meters from the center of stream out to a distance of 40 meters. Using these channel and vegetation inputs, the Miller Creek model predicted shade is shown in Figure A- 45. Unfortunately, field based effective shade data were not collected so model calibration statistics cannot be generated for model derived effective shade (Figure A- 45). Due to diversions of water from Miller Creek, there was too little flow downstream of the confluence with Pine Creek to calibrate the model.

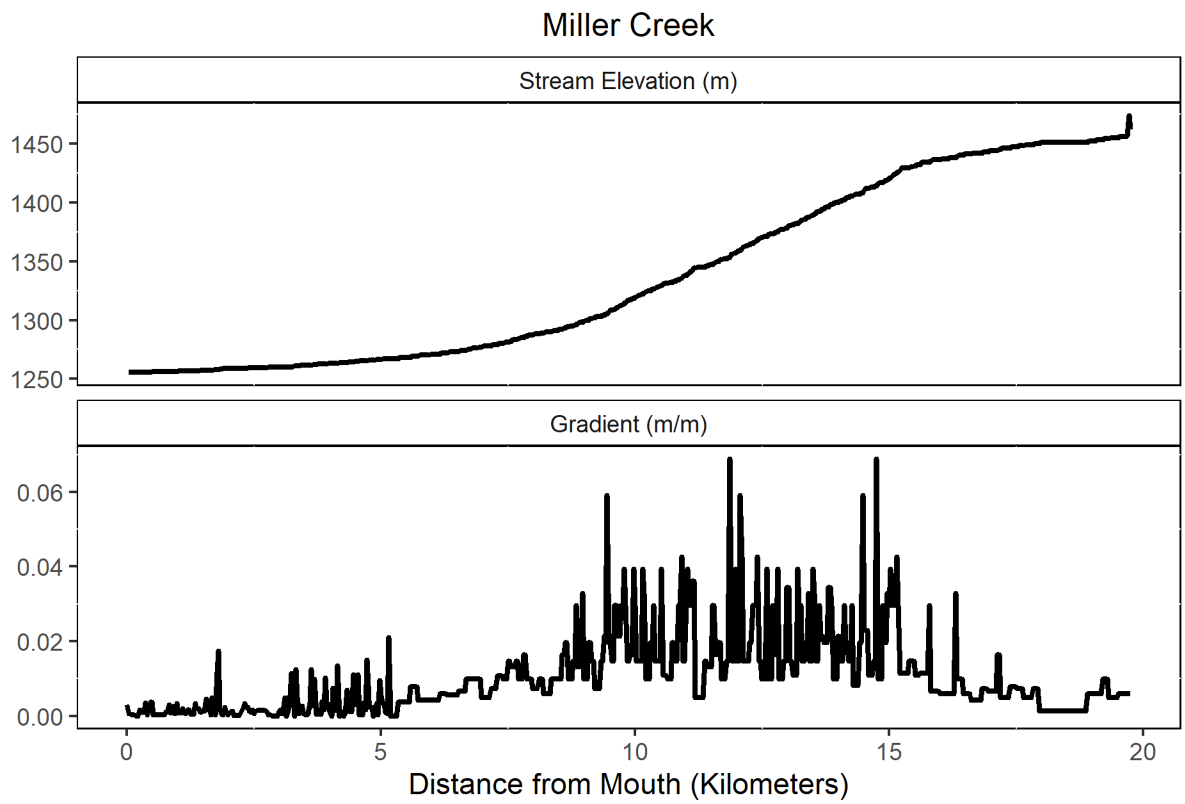


Figure A- 39. Model setup channel elevation and gradient.

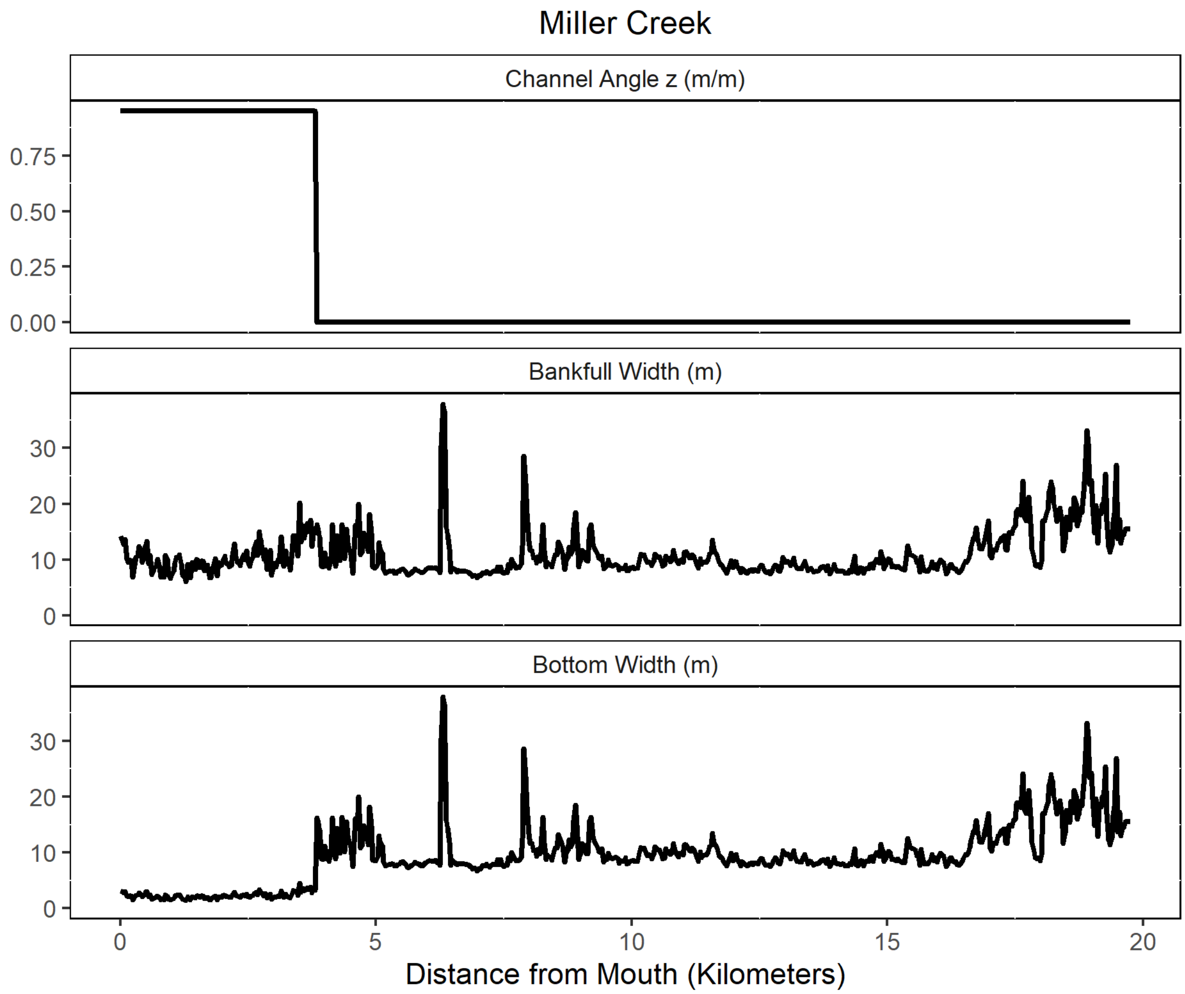


Figure A- 40. Model setup for bankfull width.

Table A- 26. Model coefficients for non-spatially varying parameters.

Parameter name (units)	Value
Wind Function, coefficient a	0.5×10^{-9}
Wind Function, coefficient b	0.5×10^{-9}
Width to Depth Ratio	4.00
Horizontal Bed Conductivity (mm/s)	2.00
Bed Particle (mm)	1
Embedded-ness	0.5

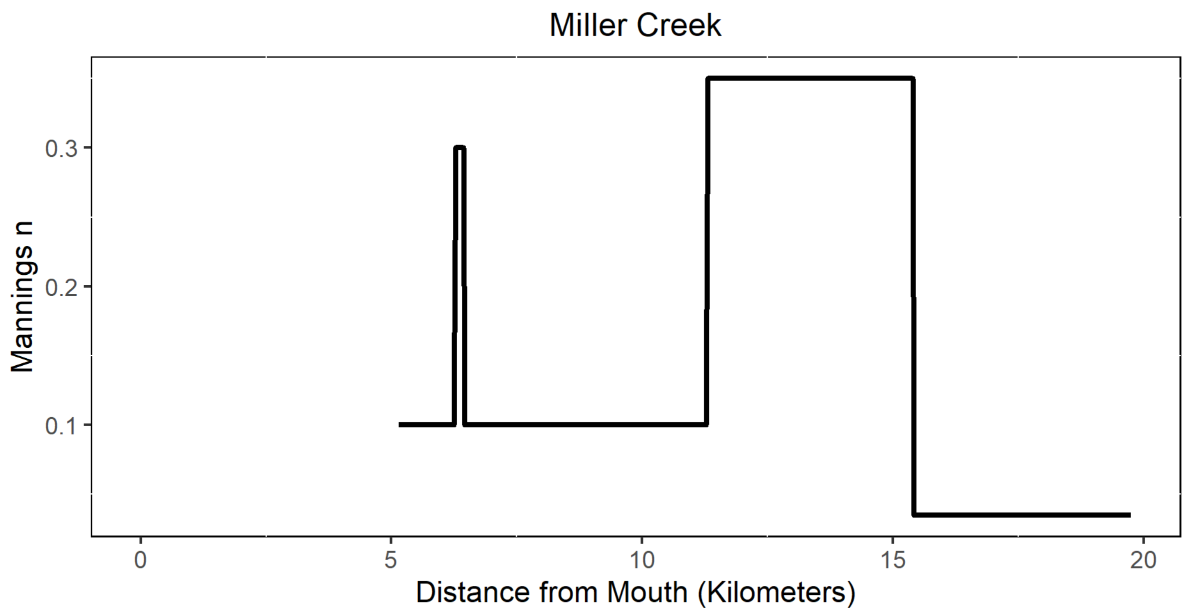


Figure A- 41. Model setup for roughness coefficient.

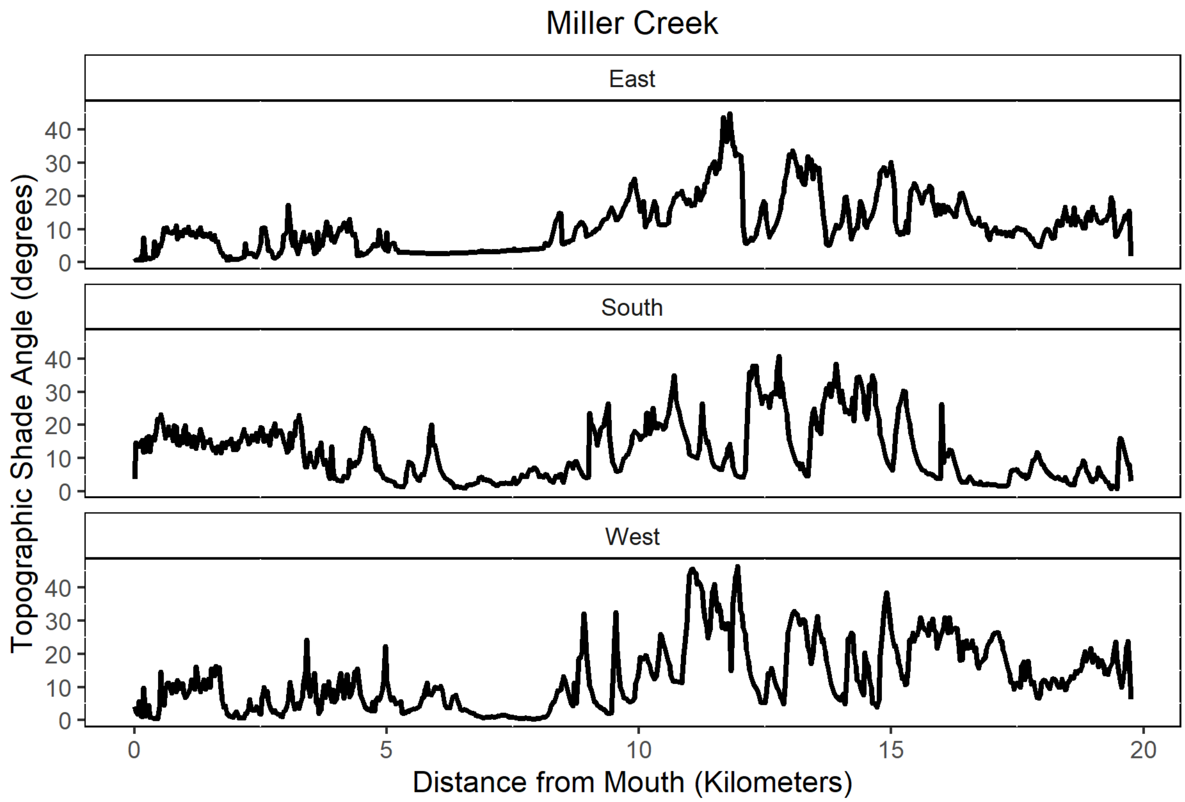


Figure A- 42. Model setup for topographic angle.

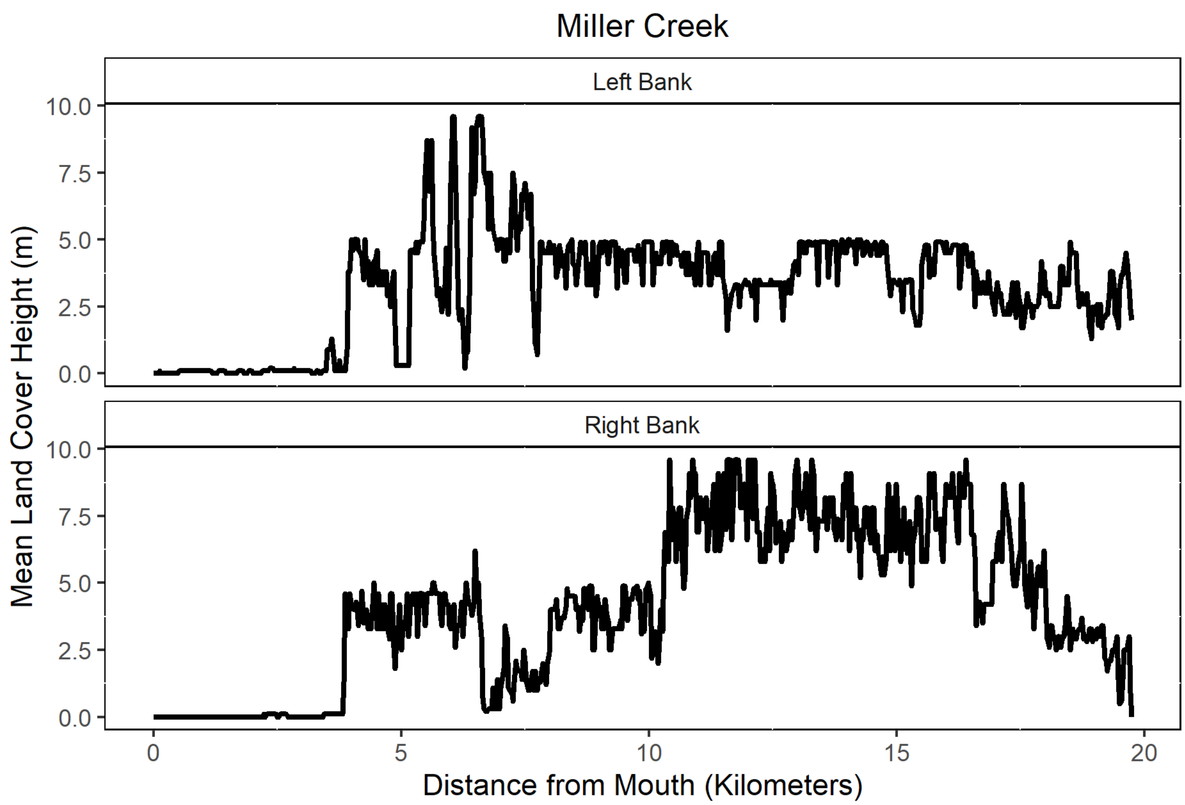


Figure A- 43. Model setup for height of near-stream vegetation.

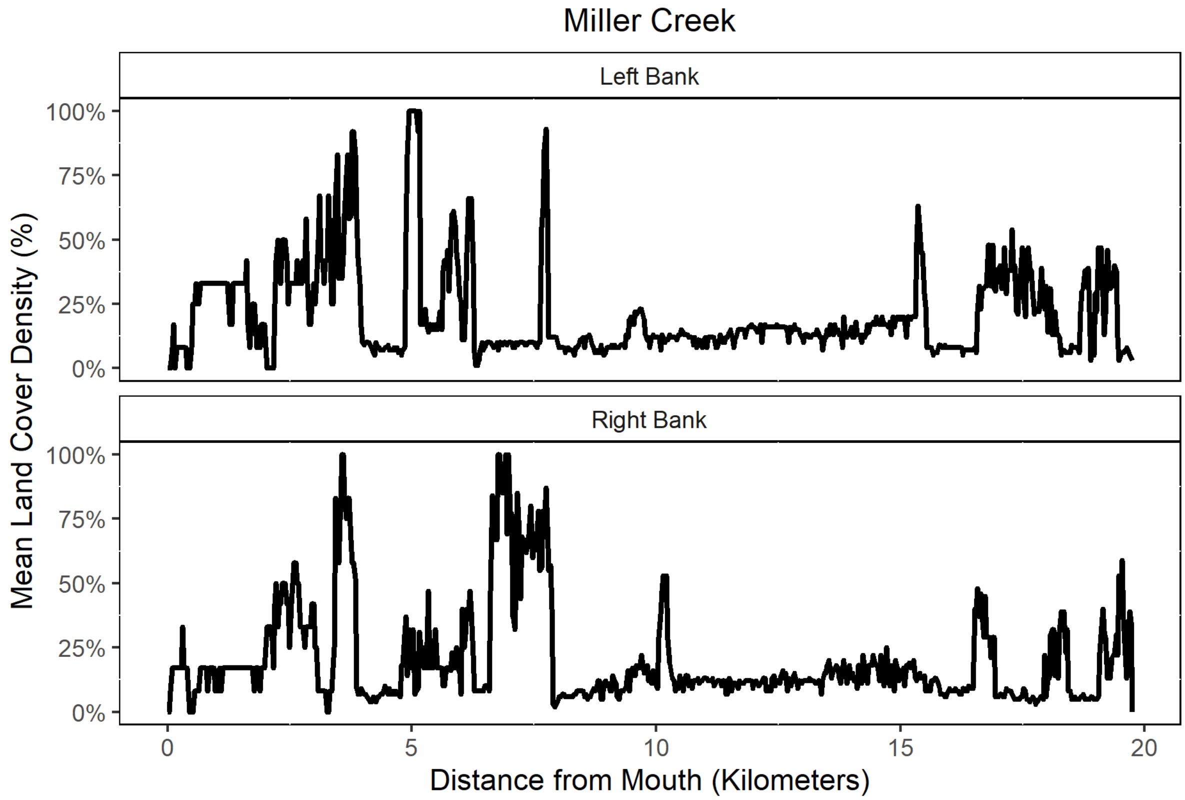


Figure A- 44. Model setup for density of near-stream vegetation.

Table A- 27. Spatial Data and Application: GIS Data Source and the application used in Miller Creek Watershed.

Spatial Data	Data Source	Application
1-meter LiDAR derived Digital Elevation Models (DEM) and Digital Surface Models (DSMs)	Oregon LiDAR Consortium (WS 2011)	Measure Stream Elevation and Gradient Measure Topographic Shade Angles Map Vegetation Map Channel Morphology Map Roads, Development, Structures
Aerial Imagery – Digital Orthophoto Quads for 1994 and 2000.	US Geological Survey BLM	Map Vegetation Map Channel Morphology Map Roads, Development, Structures
Thermal Infrared Radiometry (TIR) Stream Temperature Data	Watershed Science 2002, Collected on 7/17/2001	Measure Surface Temperatures Develop Longitudinal Temperature Profiles Identify Subsurface Hydrology, Groundwater Inflow, Springs

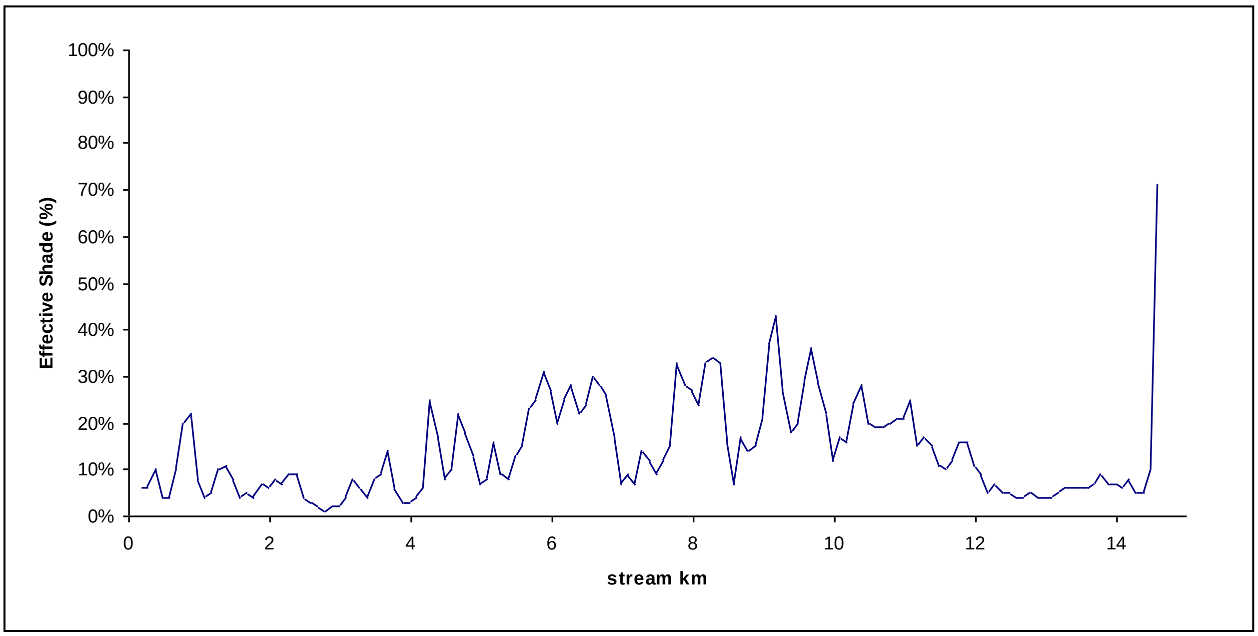


Figure A- 45. Predicted effective shade. The effective shade near the headwaters of the model was influenced by Gerber dam.

A.4.4.3 Meteorology

The model uses hourly air temperature, relative humidity, and wind speed from the Agrimet station at Loralla, Oregon. Cloudiness was assumed to be zero during the summer period. The meteorological observations are presented in Figure A- 46**,** a-c.

Figure A- 46, a-c. Meteorology inputs for model setup

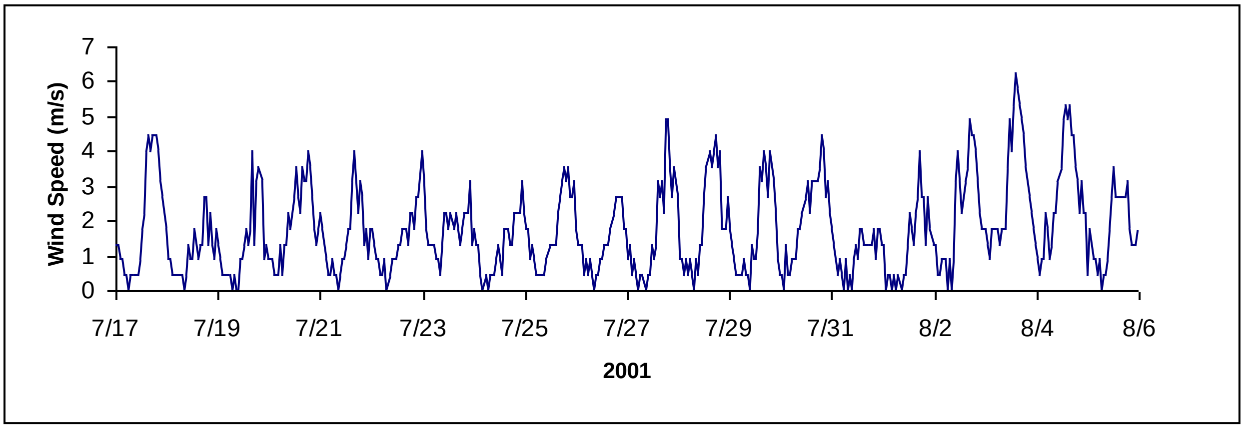


Figure A-44-a.

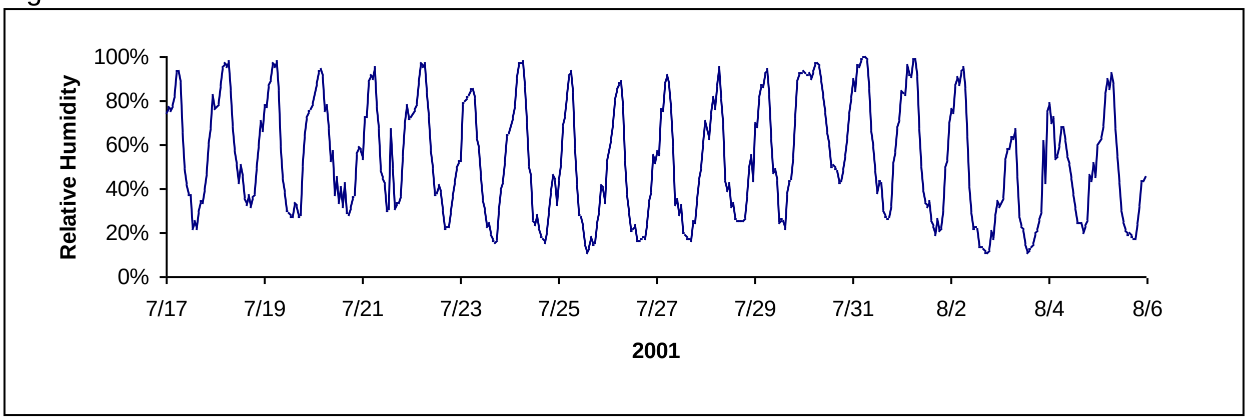


Figure A-44-b.

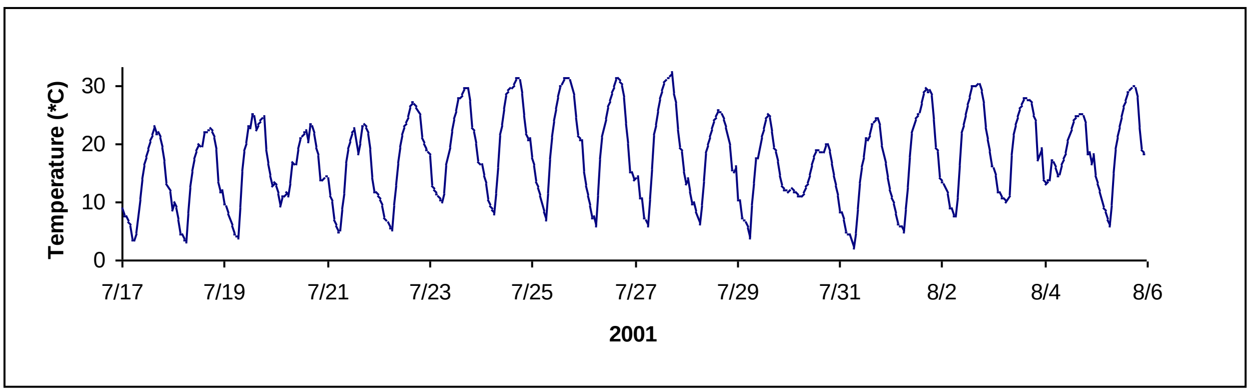


Figure A-44-c.

A.4.4.4 Flow

Estimates of the flow out of Gerber Reservoir were provided by USBOR and used as the boundary input to the model (John Hicks, personal communication, 2005). The reported flow varied greatly from day to day and caused model instabilities. Therefore, the data was averaged over the model period. These were the only flow inputs to the model (Figure A- 47).

Figure A- 47. Inflow boundary condition (14.57 km).

A.4.4.5 Temperature

The headwater temperature data were provided by BLM (A Hamilton, personal communication, 2005) (Table A-24 and Figure A- 48 **)**.

Table A- 28. Source of inflow temperature inputs for Miller Creek model.

Site	Stream km	Source of temperature data
Boundary Condition	19.75	BLM

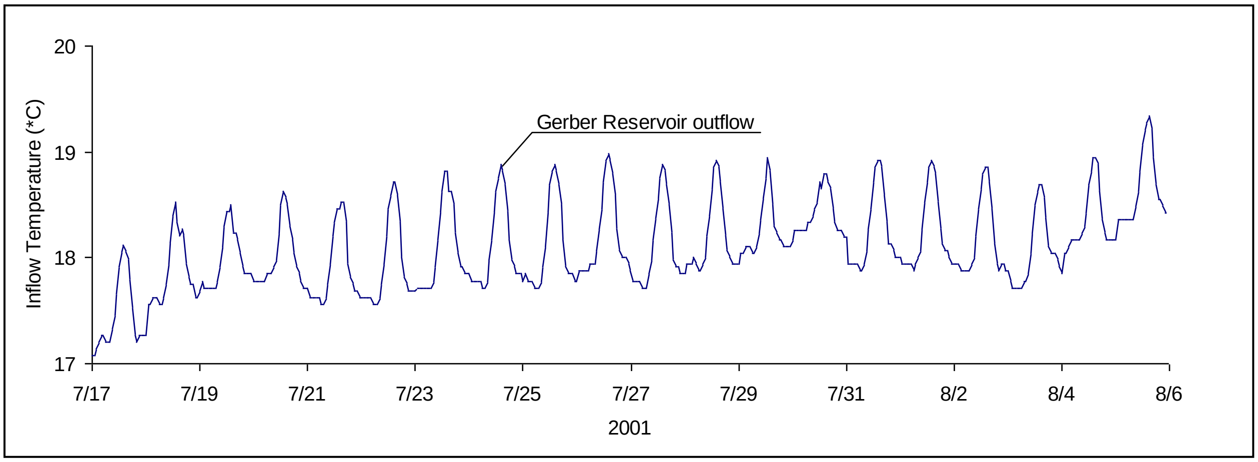


Figure A- 48. Temperature of inflows to the Miller Creek model.

A.4.4.6 Temperature Calibration

The model generally reproduces spatially and temporally varying temperature measurements (Table A-25 and Table A-26 and Figure A- 49 **and** Figure A- 50). See previous statistics discussion at the beginning of **Section A.4** for definitions.

Table A- 29. TIR error statistics.

Error type	value
mean	-0.37
Absolute mean	0.49
Root mean square	0.70
Nash-Sutcliffe	0.79

Table A- 30. Continuous monitoring error statistics.

Site Name	Site #*	Ref	Model KM	n	Mean Error	Abs Mean Error	RMSE	Nash-Sutcliffe
Miller Creek at Bridge	MR4760	A	17.77	240	0.13	0.32	0.37	0.83

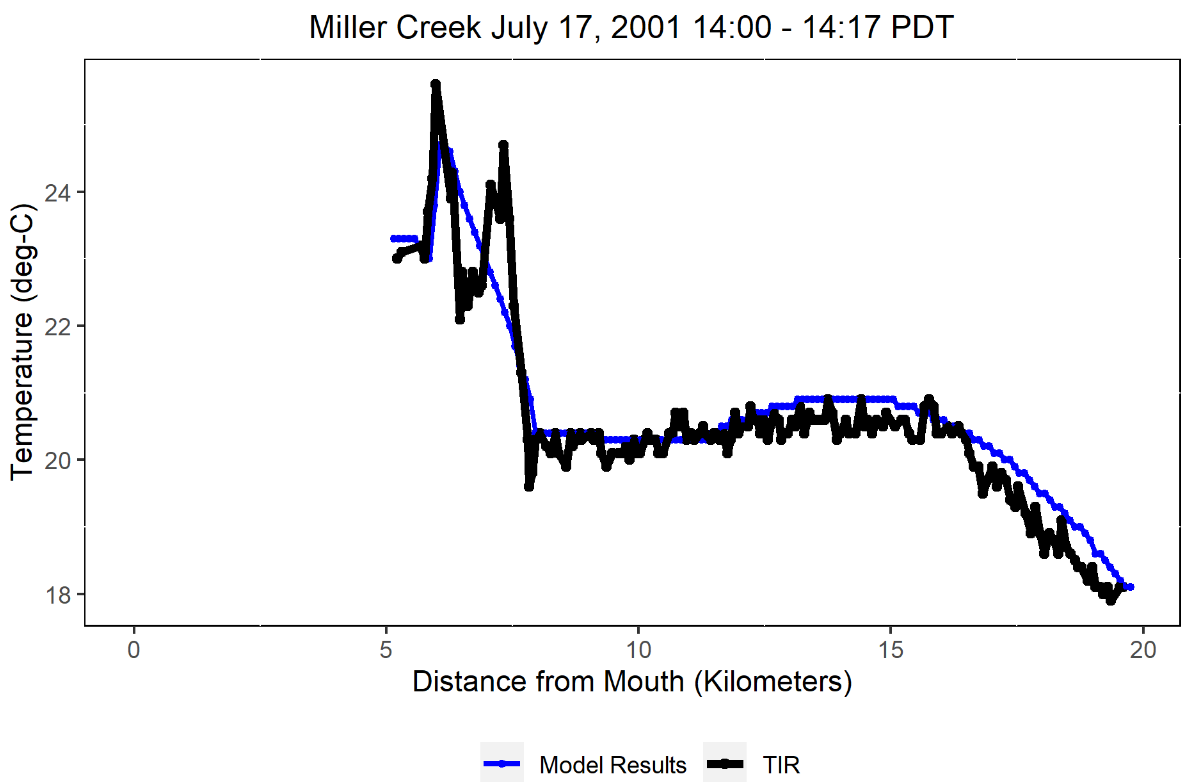


Figure A- 49. Longitudinal profile of measured temperatures using Thermal Infrared Radiometry and model results.

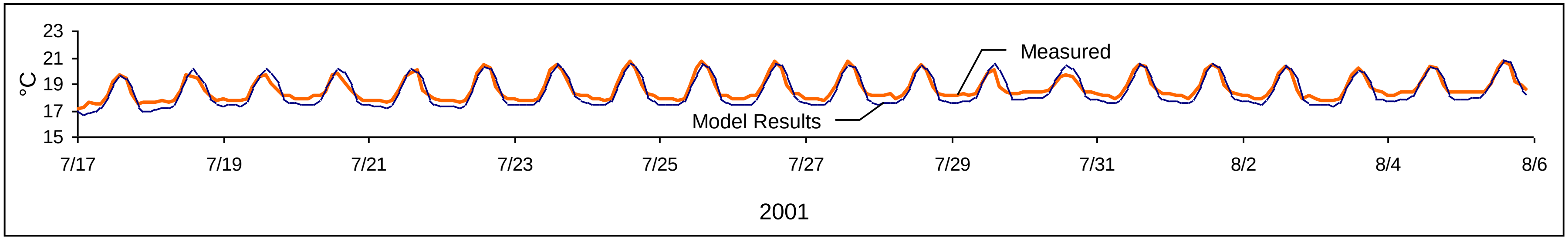


Figure A- 50. Measured steam temperature versus model results.

A.4.4.7 Scenario Results

The Heat Source model was used to predict the influence of flow and vegetation on stream temperature (Table A-27). The predicted restored conditions is warmer than the biologically based criterion for most of the stream and therefore, restored is the applicable criteria (Figure A-48).

Table A- 31. Simulated Scenario Definitions.

0	Topographic TOPO	Same as #1 Current Conditions except all vegetation is removed.
1	Current Calibrated Condition CCC	Current Calibrated Condition
2	Restored Vegetation VEG	Restored Vegetation (see Section A.4.4.7.1 for details)
3	Natural Flow FLOW	Estimated natural flow downstream of Gerber Dam based on professional judgment and no diversions. Natural flows are much less than current because the storage of water in Gerber Reservoir. Miller Creek is used as an irrigation conveyance during irrigation season increasing flows compared to natural. Channel morphology was modified to accommodate the dramatic decrease in flow: Manning's n = 0.07, channel angle = 0.95.
4	"Restored Conditions" "RC"	Restored vegetation from 2 VEG and flows and channel morphology from 3 FLOW. In this scenario the spatial extent of the vegetation was modified so it was adjacent to the smaller wetted widths reflecting the reduction in flow.

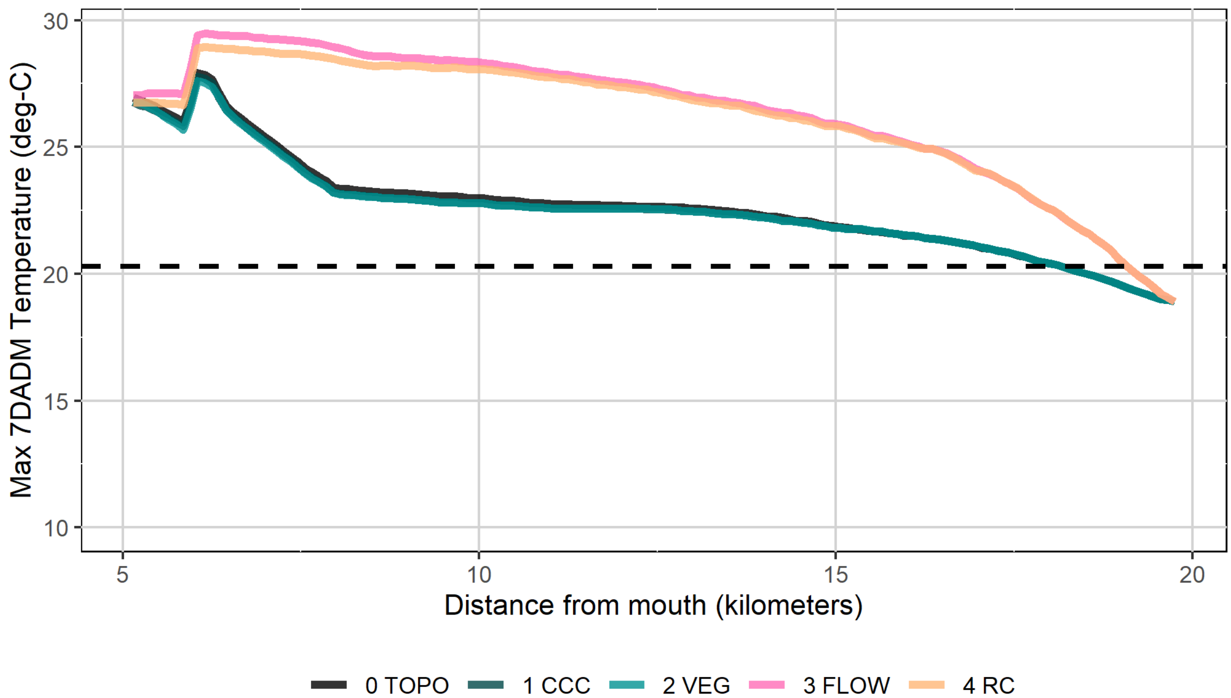


Figure A- 51. Predictions of Miller Creek scenarios based on the maximum 7-DADM, 7/17 to 8/5/2001. Dashed line is the 20-deg C criteria plus 0.3 deg-C human use allowance.

Table A- 32. Summary Miller Creek maximum 7DADM temperature scenarios, July 17-August 5, 2001.

		Maximum 7DADM	
Model Scenario	**Location of Point of Maximum Impact (POMI) Stream KM**	**POMI**	**Confluence with Pine Creek**
0 TOPO	6.05	27.9	27.0
1 CCC	6.05	27.8	26.8
2 VEG	6.05	27.6	26.8
3 FLOW	6.15	29.5	27.1
4 RC	6.15	29.0	26.8

A.4.4.7.1 Restored Vegetation

Restored vegetation is the mature species composition, height, density, and overhang width of vegetation that would occur in the absence of human disturbances. Restored vegetation conditions were used in stream temperature modeling scenarios to quantify the impacts of nonpoint source solar radiation loads, and ultimately to develop nonpoint source surrogate measure load allocations for the TMDL.

The restored vegetation on private lands was determined using methodology similar to Jenny and Spencer Creeks. The restored vegetation communities on public land were determined and delineated on false color, infrared aerial imagery by the BLM and USFS (Elizabeth Berger and Karen Zamudio, respectively, personal communication, 2005). This information was digitized and sampled by TTools. Table A-29 illustrates how the current condition vegetation was updated in the restored vegetation scenario. Table A- 34 shows the relative prevalence of vegetation types used in the current condition and restored vegetation model scenarios. The Miller Creek model does not predict much influence of restoring riparian vegetation on stream temperatures (at current flow rates).

Table A- 33. Miller Creek restored vegetation crosswalk.

Current Condition Code	Restored Vegetation Code	Restored Vegetation Code on BLM Lands
301	301	BLM spot checked (802, 851, 900, 902, 905)
400	400	400
401	903	903
402	851	851
755	755	BLM spot checked: (760, 765, 802, 851, 900, 902, 905)
760	760	BLM spot checked: (802, 851, 900, 905)
765	765	BLM spot checked: (802, 851)
800	800	800
802	802	802
851	851	851
900	903	BLM spot checked: (802, 851)
901	901	901
902	905	BLM spot checked: (802, 851, 900, 905)
903	905	905
905	905	802

3252	3252	3252

Table A- 34. Miller Creek vegetation types and prevalence in the current condition and restored vegetation model scenarios.

					Prevalence in Scenario (%)	
Code	**Land Cover Name**	**Height (m)**	**Density (%)**	**Overhang (m)**	**Current Condition**	**Restored Vegetation**
301	Water	0	0%	0	NA	NA
400	Barren-Road	0	0%	0	0.2%	0.2%
401	Agriculture or Grazing Use	0.1	100%	0	4%	0%
402	Embankment	0.0	0%	0	12%	0%
755	Western Juniper	5.0	10%	0	33%	27%
760	Juniper and some pine	10.0	10%	0	15%	13%
765	Mainly shrub with scattered pine and juniper	3.0	15%	0	4%	5%
800	Upland Shrubs	2	75%	0	1%	1%
802	Water Sedge	0.3	100%	0	2%	3%
851	Wetland Shrubs	4.6	30%	0	5%	15%
900	Wetland grasses	0.3	100%	0	6%	1%
901	Dryland Grasses	0.3	100%	0	2%	2%
902	Wetland grasses/shrubs mix (majority grasses/minority shrubs)	4.6	5%	0	6%	0.2%
903	Wetland grasses/shrubs mix (50/50)	4.6	15%	0	0.4%	9%
905	Wetland shrubs/grasses mix (majority shrubs/minority grasses)	4.6	20%	0	9%	25%
3252	Dam/Weir	0	0%	0	0.1%	0.1%

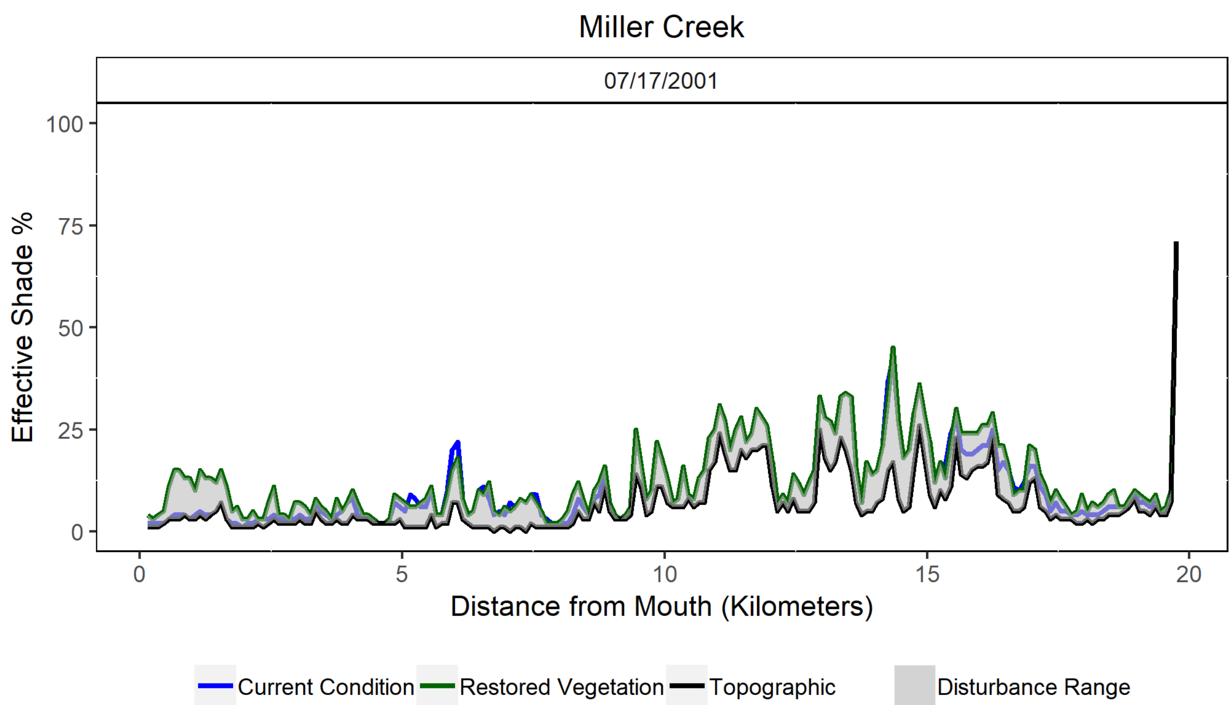


Figure A- 52. Longitudinal profiles of effective shade on Miller Creek.

Table A- 35. Miller Creek mean effective shade.

Reach	Reach Length (km)	Mean Effective Shade Current Condition	Mean Effective Shade Restored Condition	Mean Effective Shade Deficit
Gerber Dam to Pine Creek	14.57	14%	15%	1%
Pine Creek to Lost River	5.15	4%	7%	3%
Gerber Dam to Lost River	19.75	11%	13%	1%

A.4.4.7.2 Restored Flow

Upstream of Miller Diversion Dam, the current condition flow is dominated by release of stored water in Gerber Reservoir for irrigation. The stream is used as a conveyance for the water and therefore current flows are much greater compared to estimated restored flows without the storage at Gerber Reservoir (Figure A- 53). Because of the high volume of water in the creek, stream temperatures upstream of the Miller Creek Diversion Dam are currently cooler than predicted under restored conditions.

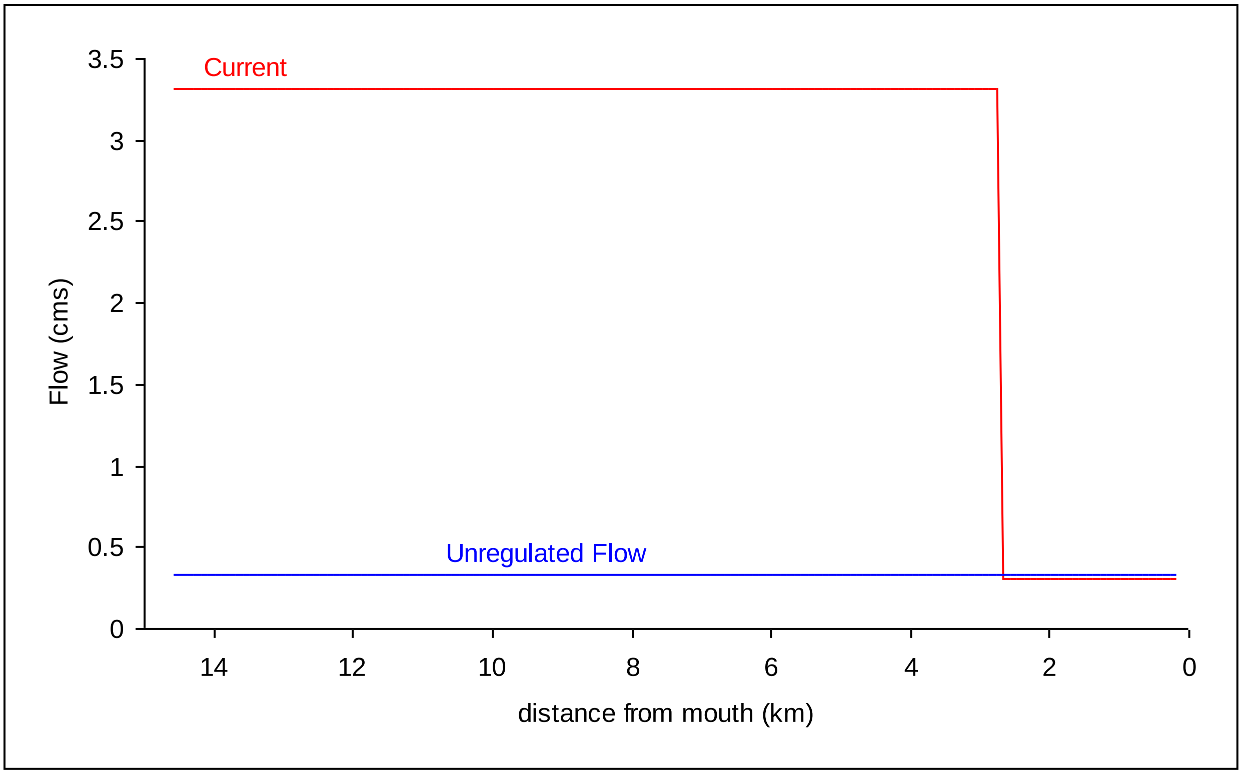


Figure A- 53. Longitudinal profiles of predicted flows for scenarios which considered flow alterations on Miller Creek for 7/17/2001.

A.4.5 Antelope Creek

Stream Name: Antelope Creek
Model: Heat Source version 7.0, solar only
Beginning date: 7/15/2005
Ending date: 7/15/2005
Time step: 10 minute
Distance step: 30.48 m
Extent: Willow Valley Reservoir to river kilometer 1.77 (Figure A- 54).

The following figures and tables document the shade analysis on Antelope Creek. The reach that was examined is completely within BLM managed lands (Figure A- 54). Vegetation was sampled along the stream in a radial pattern every 3 meters from the center of stream out to a distance of 12 meters. Shade due to restored vegetation is less than current shade (Figure A- 55). This effect is because the predicted restored vegetation for near stream juniper and pine is less dense than the current stands due to fire suppression. Table A- 36 shows the relative prevalence of vegetation types used in the current condition and restored vegetation model scenarios.

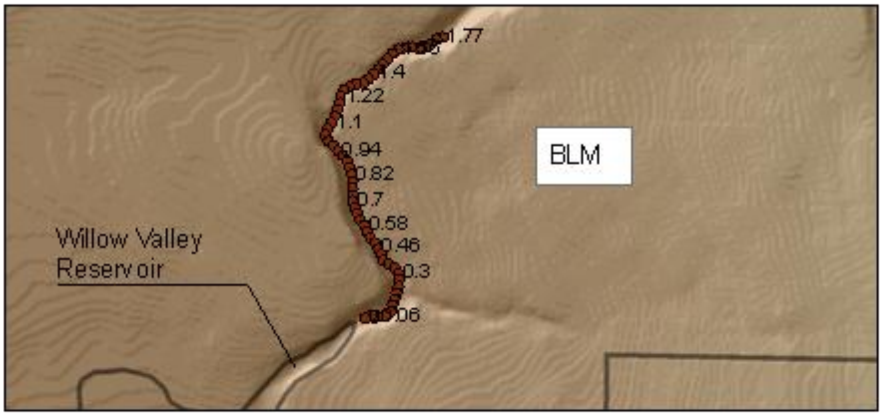
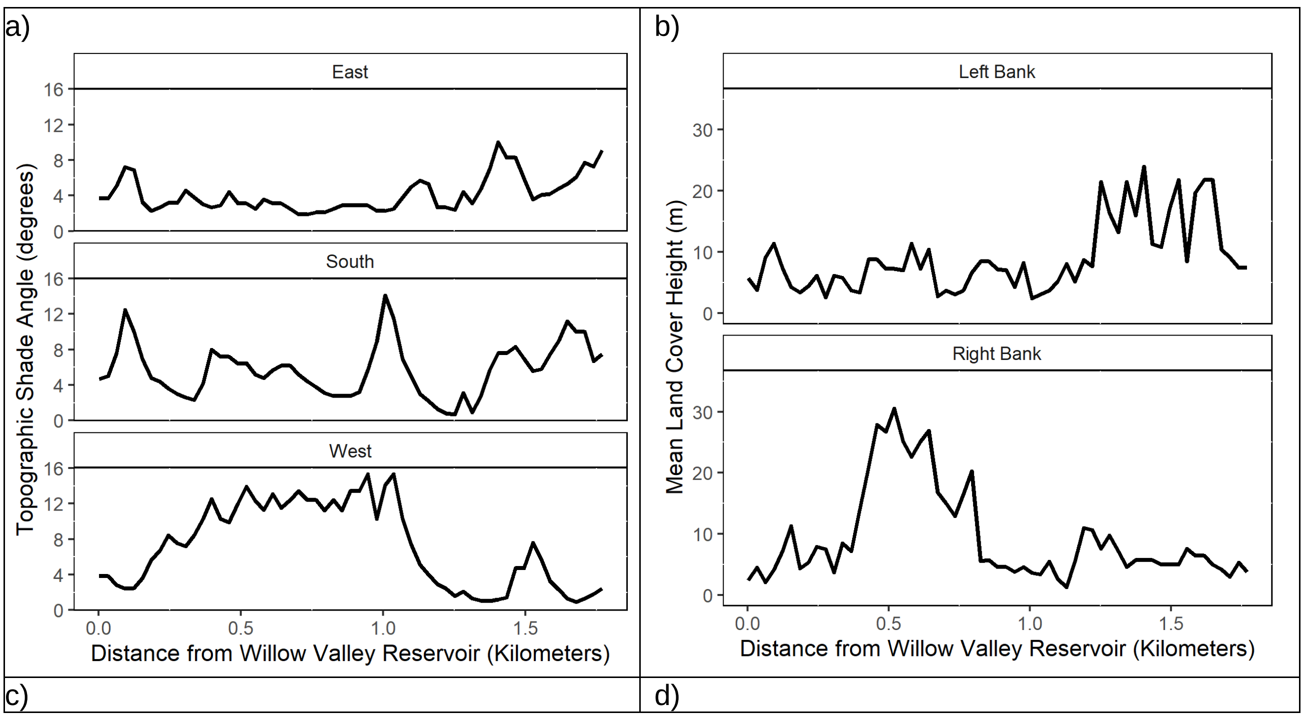


Figure A- 54. Antelope Creek analysis extent with ownership and distance upstream from Willow Valley Reservoir (km).



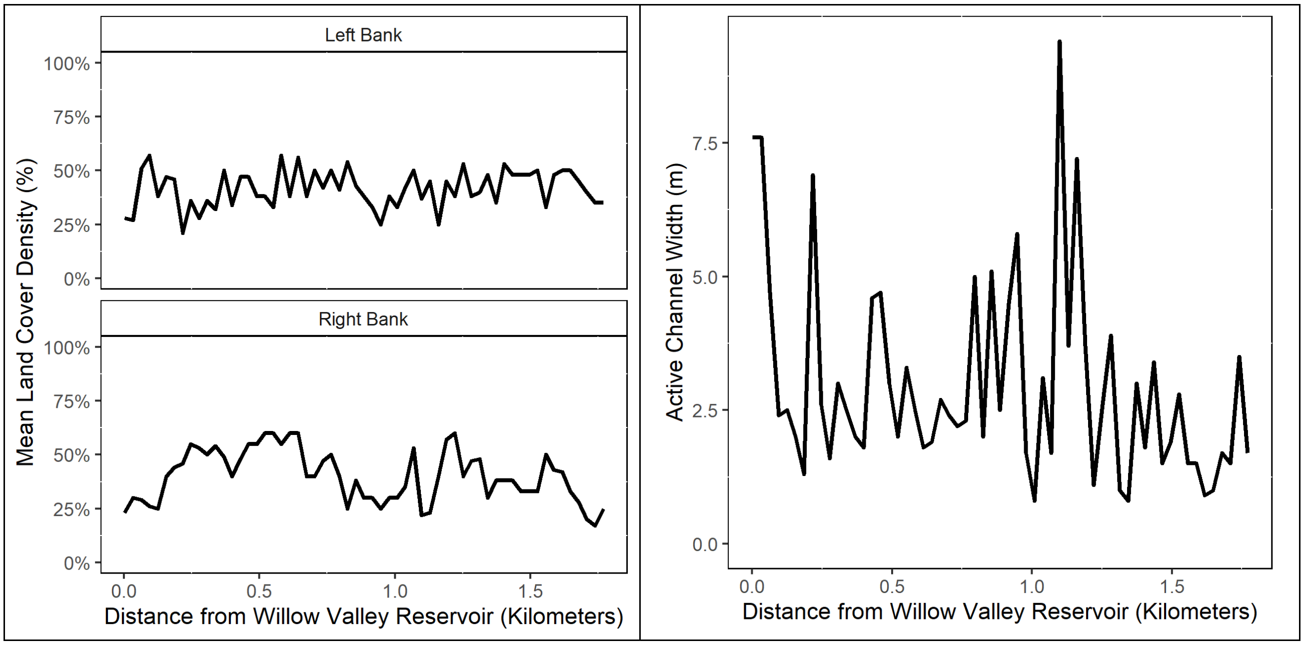


Figure A- 55. Antelope Creek existing conditions as configured in the model (a – d).

Table A- 36. Antelope Creek riparian area vegetation.

Land Cover Name	Height (m)	Density (%)	Overhang (m)	Prevalence in Scenario (%) Current Condition	Prevalence in Scenario (%) Restored Vegetation
Wetland grasses/shrubs mix	3.7	50%	0.3	26%	26%
Wetland Shrubs	4.6	30%	0.3	20%	20%
Large Conifer	30.5	60%	2.1	17%	17%
Western Juniper/Pine Mix	15.2	30%	0.9	1%	16%
Non-Riparian Juniper	9.1	30%	0.5	2%	13%
Warm Willow	4.6	30%	0.9	4%	4%
Wetland grasses	0.9	30%	0.3	2%	2%
Western Juniper/Pine Mix	15.2	60%	0.9	16%	1%
Non-Riparian Juniper	9.1	60%	0.5	11%	0%

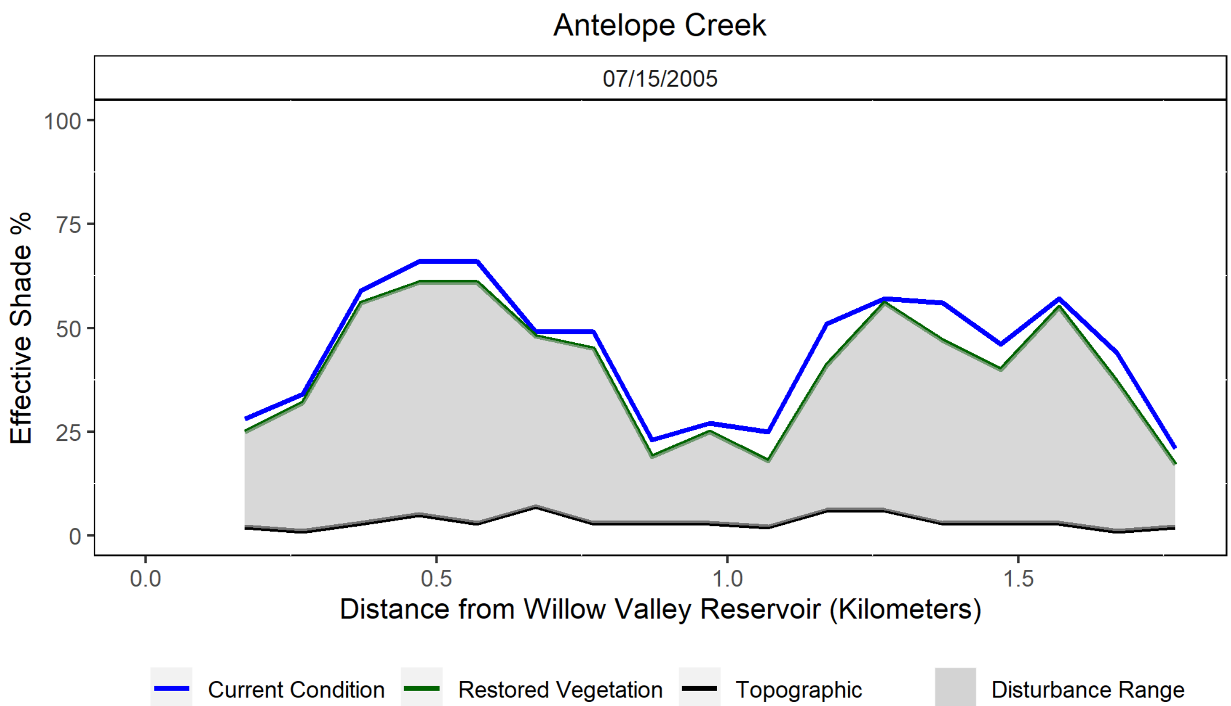


Figure A- 56. Antelope Creek shade analysis results.

Table A- 37. Antelope Creek mean effective shade results.

Analysis Date	Reach Length (km)	Mean Effective Shade Current Condition	Mean Effective Shade Restored Condition	Mean Effective Shade Deficit
07/15/2005	1.6	44%	40%	-4%

A.4.6 Barnes Valley Creek

Stream Name: Barnes Valley Creek
Model: Heat Source version 7.0, solar only
Beginning date: 7/15/2005
Ending date: 7/15/2005
Time step: 10 minute
Distance step: 30.48 m
Extent: Willow Valley Reservoir to headwaters (river kilometer 23.9) (Figure A- 54).

The following figures and tables document the shade analysis on Barnes Valley Creek. The reach that was examined flows through private, USFS and BLM lands (Figure A-53). Vegetation was sampled along the stream in a radial pattern every 5 meters from the center of stream out to a distance of 20 meters. Most of the increases in shade are predicted to occur on private land due to the predicted increase in wetland shrubs (Figure A- 59). In addition, an average 4% increase in effective shade is predicted through the most downstream 9 km. Table A- 38 shows the relative prevalence of vegetation types used in the current condition and restored vegetation model scenarios.

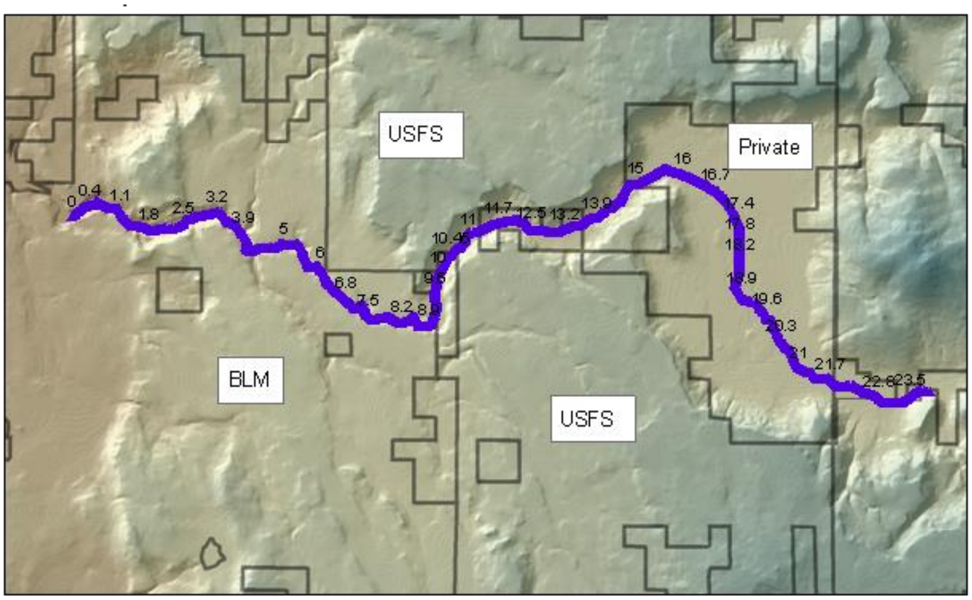


Figure A- 57. Barnes Valley Creek analysis extent with ownership and distance upstream from Gerber Reservoir (km).

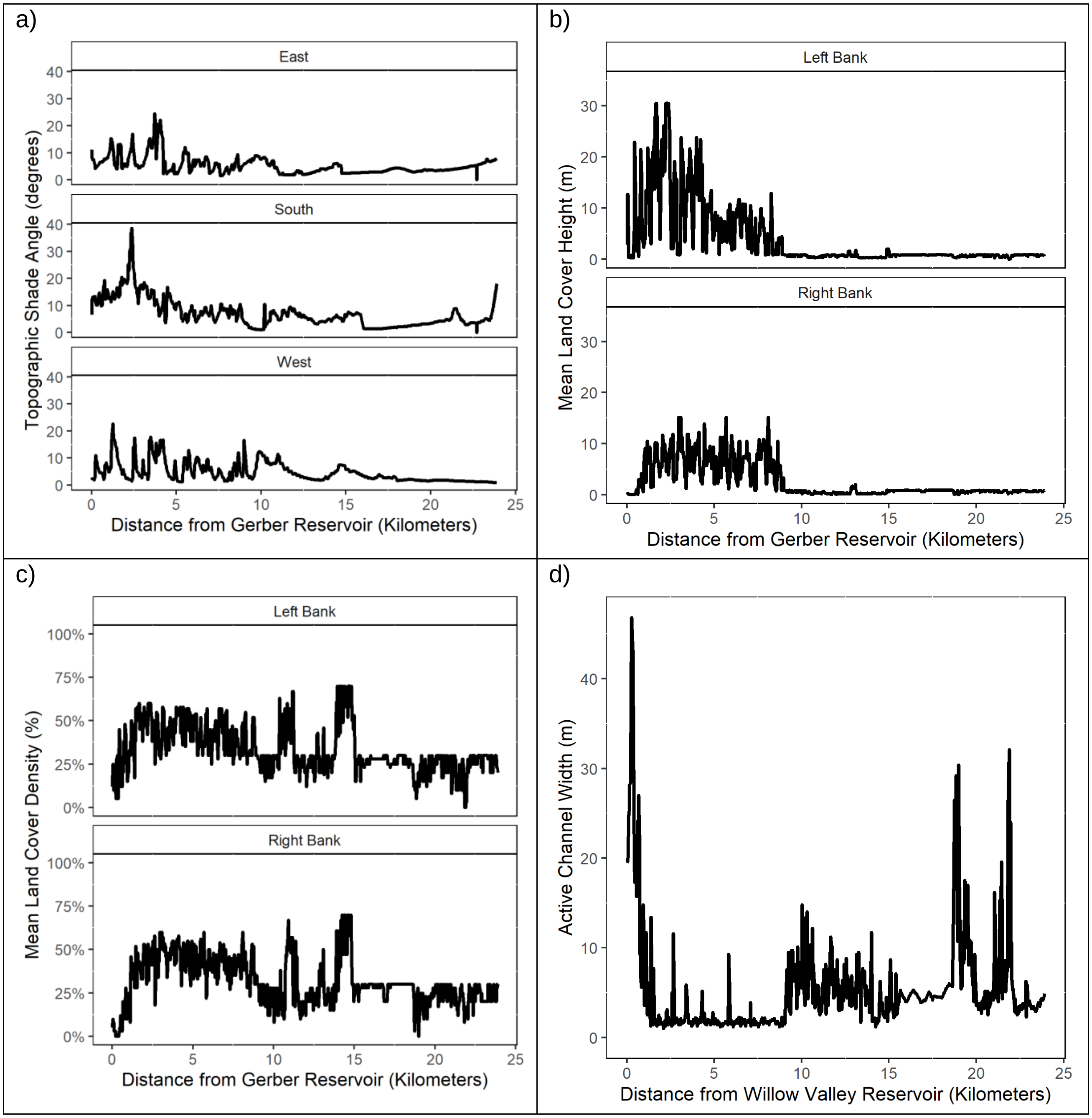


Figure A- 58. Barnes Valley Creek existing conditions as configured in the model (a – d).

Table A- 38. Barnes Valley Creek riparian area vegetation.

Land Cover Name	Height (m)	Density (%)	Overhang (m)	Prevalence in Scenario (%)	
				Current Condition	Restored Vegetation
Wetland grasses/shrubs mix	3.7	50%	0.3	4%	38%
Warm Willow	4.6	30%	0.9	5%	18%
Wetland grasses	0.9	30%	0.3	16%	16%
Western Juniper/Pine Mix	15.2	60%	0.9	8%	8%
Dry Meadow	0.3	30%	0.3	5%	5%
Meadow	0.3	70%	0.3	7%	4%
Wetland Grasses	0.9	30%	0.3	40%	4%
Large Conifer	30.5	60%	2.1	4%	4%
Large Deciduous	9.1	40%	1.8	1%	1%
Non-Riparian Ponderosa Pine	30.5	30%	1.2	0%	1%
Wetland Shrubs 2	2.0	50%	0.3	7%	0%
Wetland Shrubs	4.6	30%	0.3	1%	0%
Dryland Grasses	0.9	30%	0.3	1%	0%

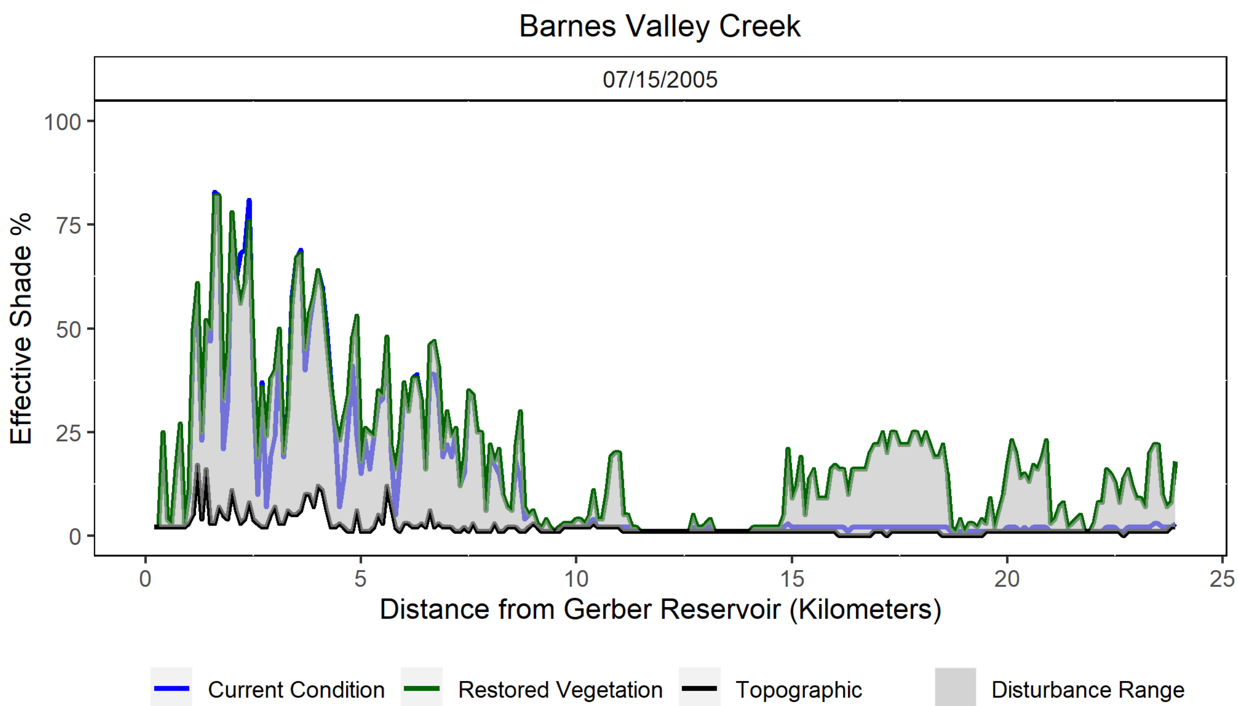


Figure A- 59. Barnes Valley Creek shade analysis results.

Table A- 39. Barnes Valley Creek mean effective shade results.

Analysis Date	Reach Length (km)	Mean Effective Shade Current Condition	Mean Effective Shade Restored Condition	Mean Effective Shade Deficit
07/15/2005	23.7	12%	18%	6%

A.4.7 Horse Canyon Creek

Stream Name: Horse Canyon Creek
Model: Heat Source version 7.0, solar only
Beginning date: 7/15/2005
Ending date: 7/15/2005
Time step: 10 minute
Distance step: 30.48 m
Extent: Dry Prairie Reservoir to the wetland prairie upstream of Horse Canyon Springs (river kilometer 3.81) (Figure A- 60).

The following figures and tables document the shade analysis for Horse Canyon Creek. The reach that was examined is within USFS and private lands (Figure A- 60). Vegetation was sampled along the stream in a radial pattern every 4 meters from the center of stream out to a distance of 16 meters. Shade due to restored vegetation is less than current shade for the middle portion of the reach (Figure A- 62). This effect is because the predicted restored vegetation for near conifers is less dense the current stands due to fire suppression and encroachment on meadows. Table A- 40 shows the relative prevalence of vegetation types used in the current condition and restored vegetation model scenarios.

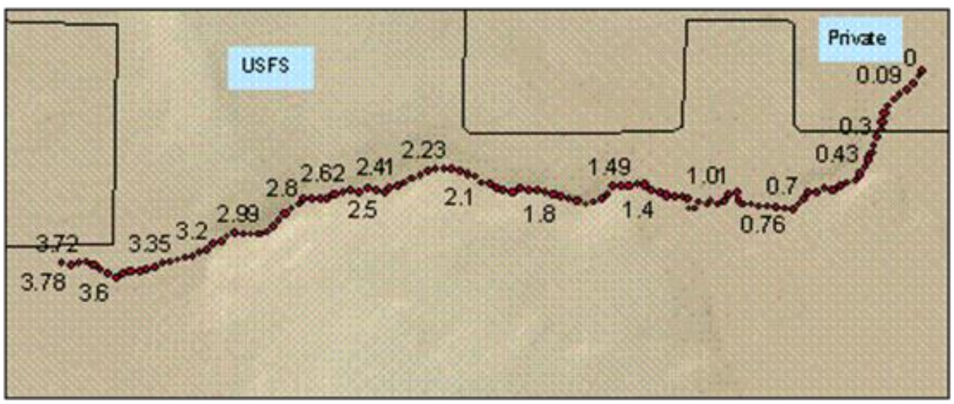


Figure A- 60. Horse Canyon analysis extent with ownership and distance upstream from mouth (km).

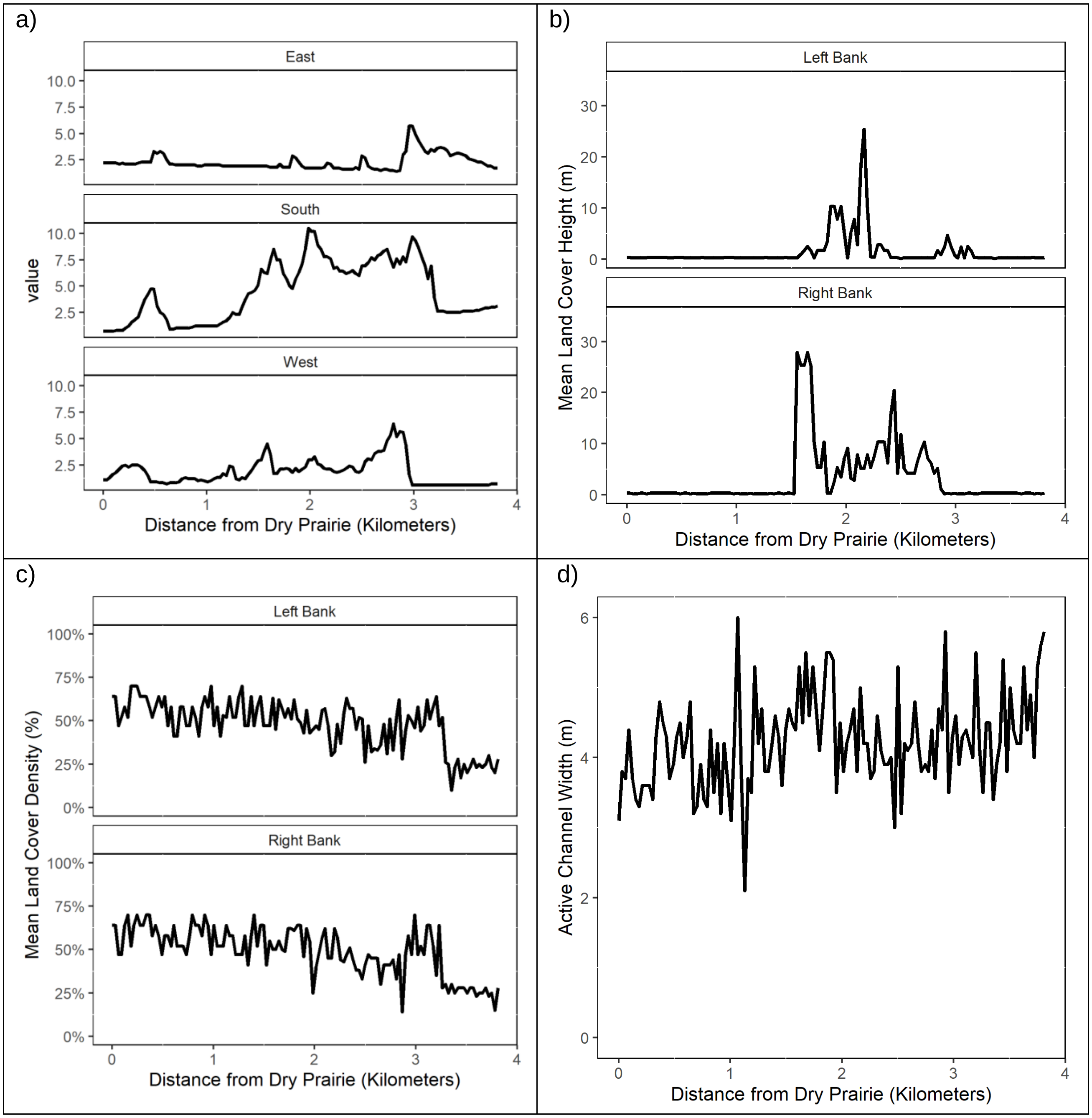


Figure A- 61. Horse Canyon existing conditions as configured in the model (a – d).

Table A- 40. Horse Canyon riparian area vegetation.

Land Cover Name	Height (m)	Density (%)	Overhang (m)	Prevalence in Scenario (%) Current Condition	Restored Vegetation
Dry Meadow	0.3	70%	0.3	39%	39%
Meadow	0.3	70%	0.3	32%	34%
Dry Meadow	0.3	30%	0.3	17%	15%
Large Conifer	30.5	30%	2.1	1%	5%

Silver Sagebrush/Wetland Grasses	0.9	30%	0.3	0%	3%
Non-Riparian Juniper	9.1	30%	0.5	0%	2%
Large Conifer	30.5	60%	2.1	5%	1%
Large Deciduous	9.1	40%	1.8	1%	1%
Barren- Forest Road	0.0	0%	0.0	0%	0%
Small Conifer	12.2	30%	1.1	3%	0%
Non-Riparian Juniper	9.1	60%	0.5	2%	0%

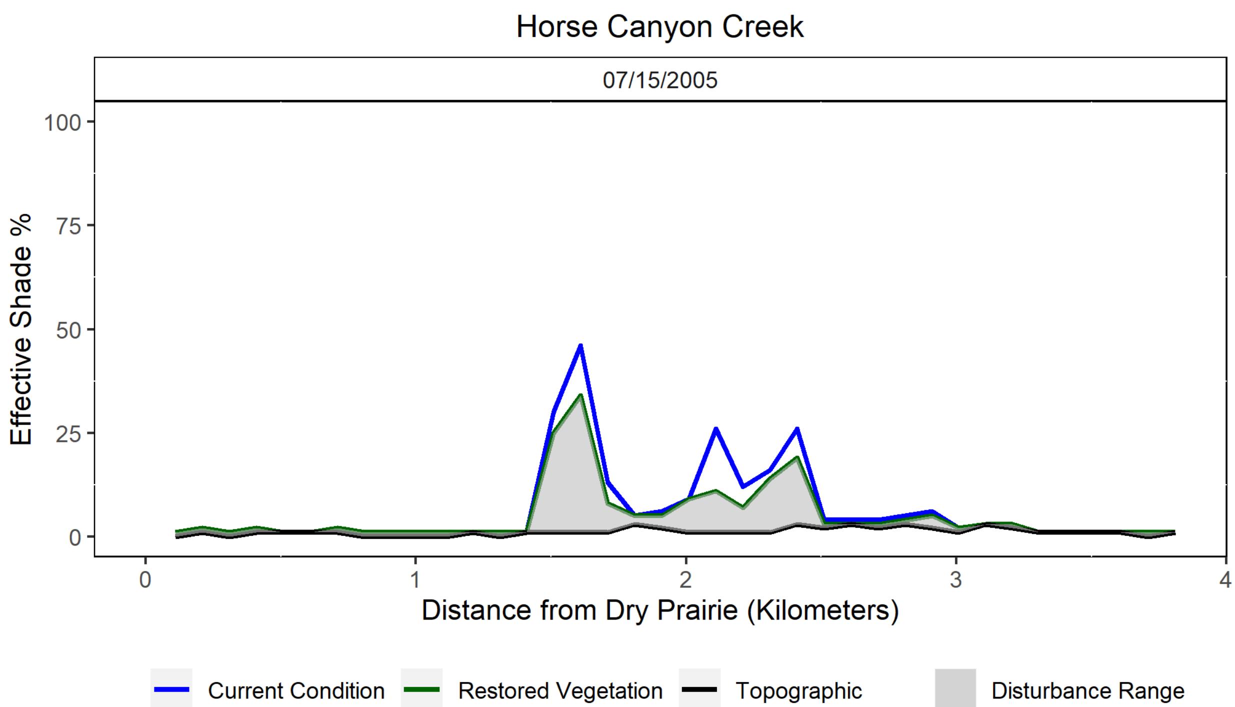


Figure A- 62. Horse Canyon shade analysis results.

Table A- 41. Horse Canyon mean effective shade results.

Analysis Date	Reach Length (km)	Mean Effective Shade Current Condition	Mean Effective Shade Restored Condition	Mean Effective Shade Deficit
07/15/2005	3.7	6%	5%	-1%

A.4.8 Lapham Creek

Stream Name: Lapham Creek
Model: Heat Source version 7.0, solar only
Beginning date: 7/15/2005
Ending date: 7/15/2005
Time step: 10 minute
Distance step: 30.48 m
Extent: Mouth to headwaters in Holmes Meadow (river kilometer 7.44) (Figure A- 60).

The following figures and tables document the shade analysis on Lapham Creek. The reach that was examined flows through private and USFS (Figure A-57). Vegetation was sampled along the stream in a radial pattern every 3 meters from the center of stream out to a distance of 12 meters. Most of the increases in shade are predicted to occur on private land in the lower portion due to the predicted increase in wetland shrubs (Figure A- 65). Table A- 42 shows the relative prevalence of vegetation types used in the current condition and restored vegetation model scenarios.

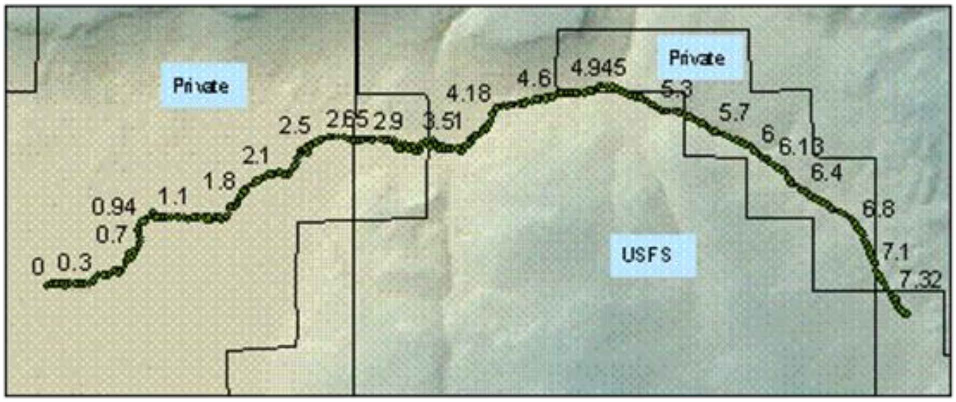


Figure A- 63. Lapham Creek analysis extent with ownership and distance upstream from mouth (km).

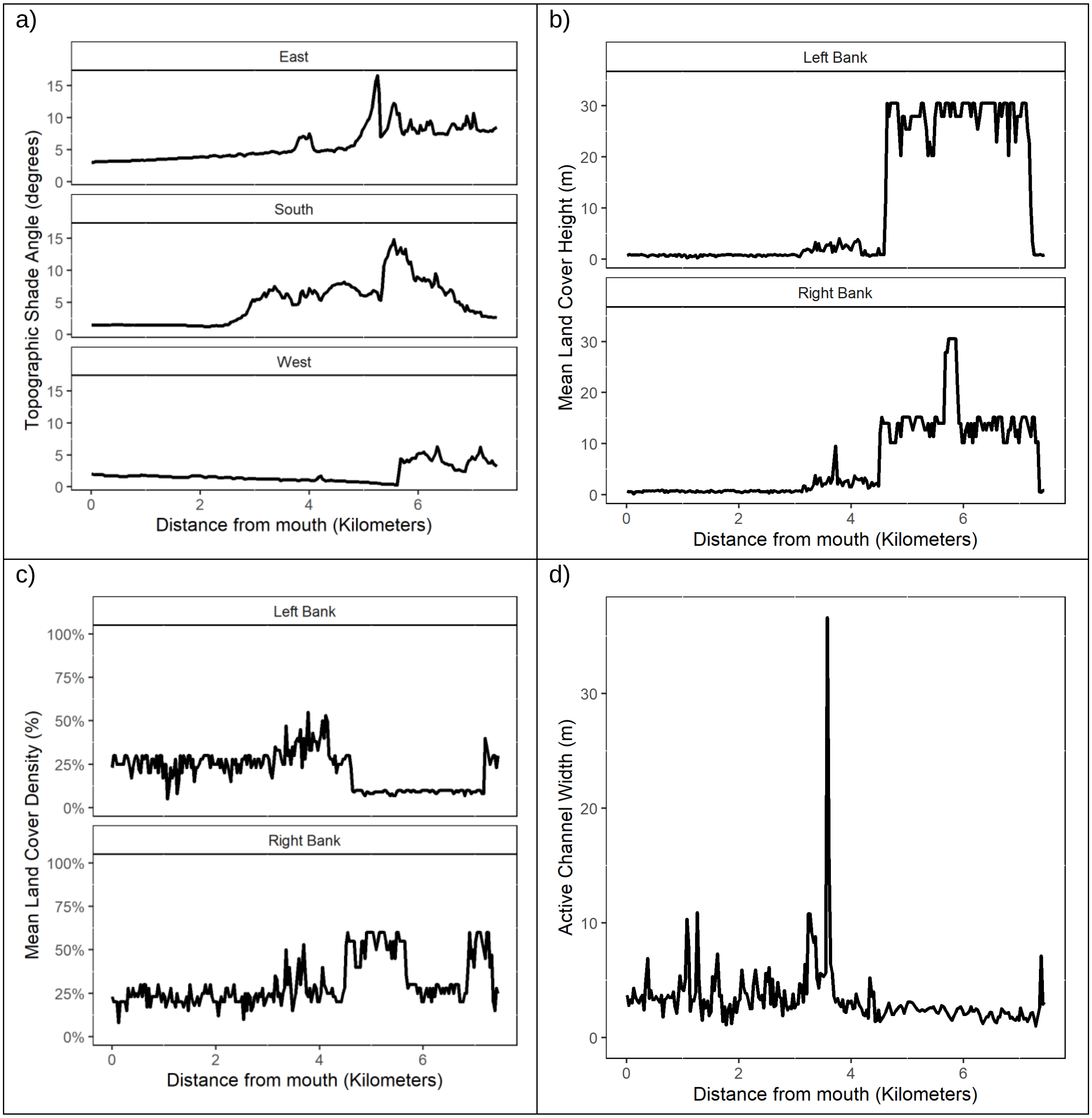


Figure A- 64. Lapham Creek existing conditions as configured in the model (a – d).

Table A- 42. Lapham Creek riparian area vegetation.

Land Cover Name	Height (m)	Density (%)	Overhang (m)	Prevalence in Model (%)	
				Current Condition	Restored Vegetation
Wetland grasses/shrubs mix	3.7	50%	0.3	0%	68%
Western Juniper/Pine Mix	15.2	30%	0.9	6%	17%
Wetland Shrubs 1	4.6	60%	0.3	6%	6%

Silver Sagebrush/Wetland Grasses	0.9	30%	0.3	9%	4%
Wetland Shrubs	4.6	30%	0.3	3%	3%
Large Conifer	30.5	30%	2.1	2%	2%
Wetland grasses	0.9	30%	0.3	41%	0%
Shrubs with Ponderosa Pine mix	30.5	10%	0.9	21%	0%
Western Juniper/Pine Mix	15.2	60%	0.9	11%	0%
Dryland Grasses	0.9	30%	0.3	1%	0%

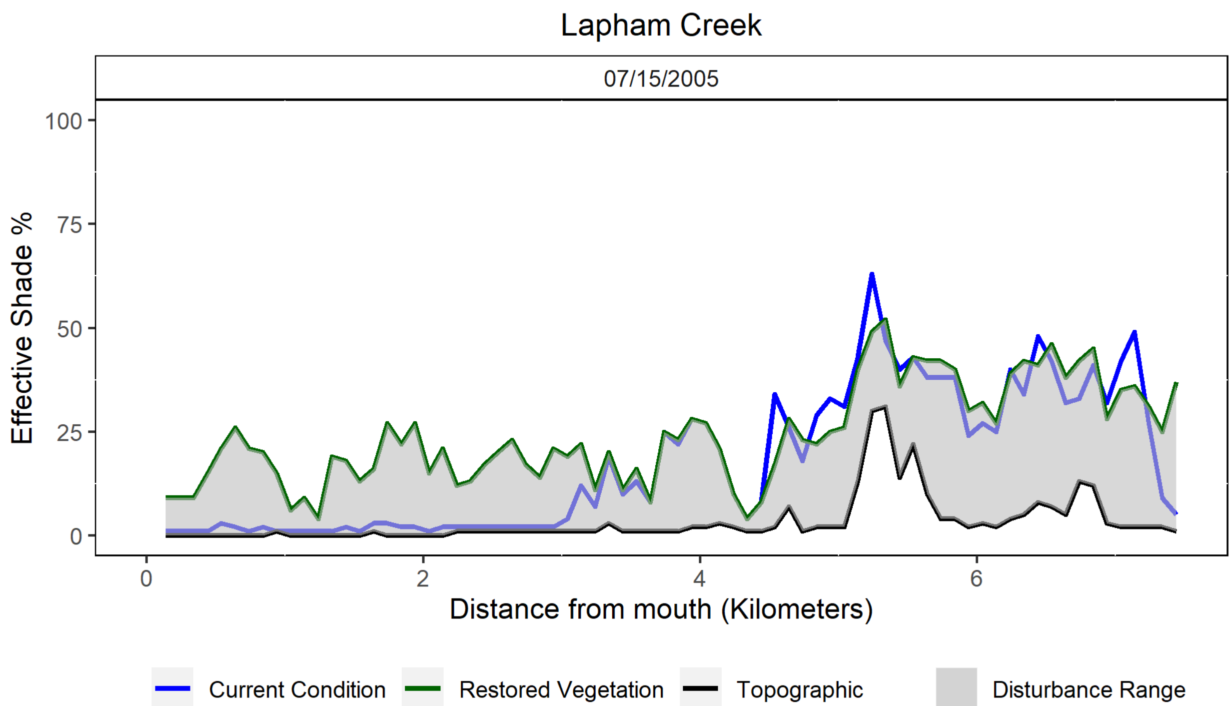


Figure A- 65. Lapham Creek shade analysis results.

Table A- 43. Lapham Creek mean effective shade results.

Analysis Date	Reach Length (km)	Mean Effective Shade Current Condition	Mean Effective Shade Restored Condition	Mean Effective Shade Deficit
07/15/2005	7.3	17%	24%	7%

A.4.9 Long Branch Creek

Stream Name: Long Branch Creek
Model: Heat Source version 7.0, solar only
Beginning date: 7/15/2005
Ending date: 7/15/2005
Time step: 10 minute
Distance step: 30.48 m
Extent: Mouth to headwaters at a Spring Seep (river kilometer 8.11) (Figure A-59Figure A- 60).

The following figures and tables document the shade analysis on Long Branch Creek. The reach that was examined flows through private, USFS and BLM lands (Figure A-59). Most of the increases in shade are predicted to occur on private land due to the predicted increase in wetland shrubs (Figure A- 68). Table A- 44 shows the relative prevalence of vegetation types used in the current condition and restored vegetation model scenarios.

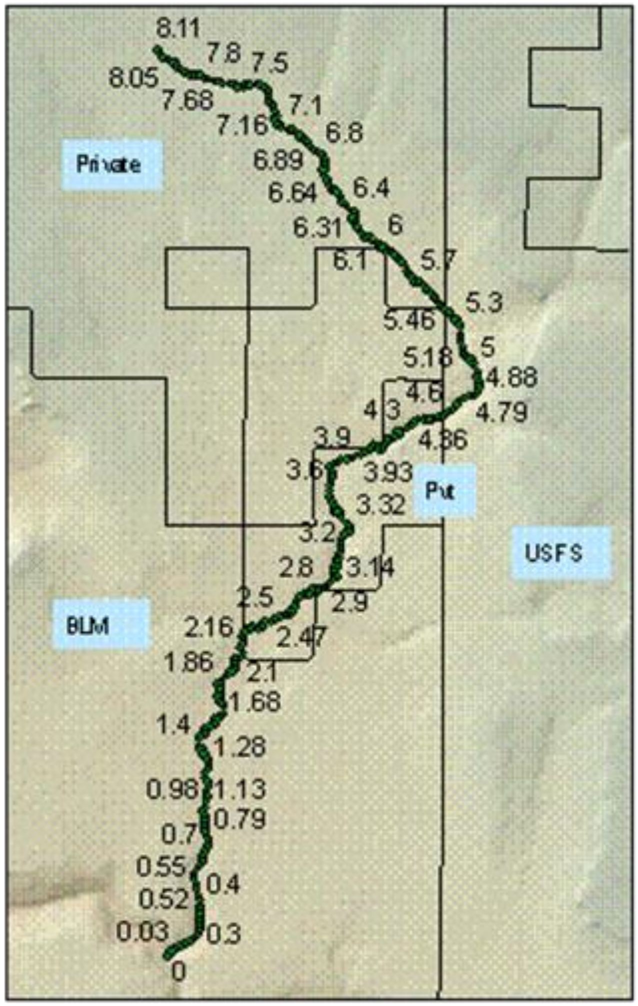


Figure A- 66. Long Branch Creek analysis extent with ownership and distance upstream from mouth (km).

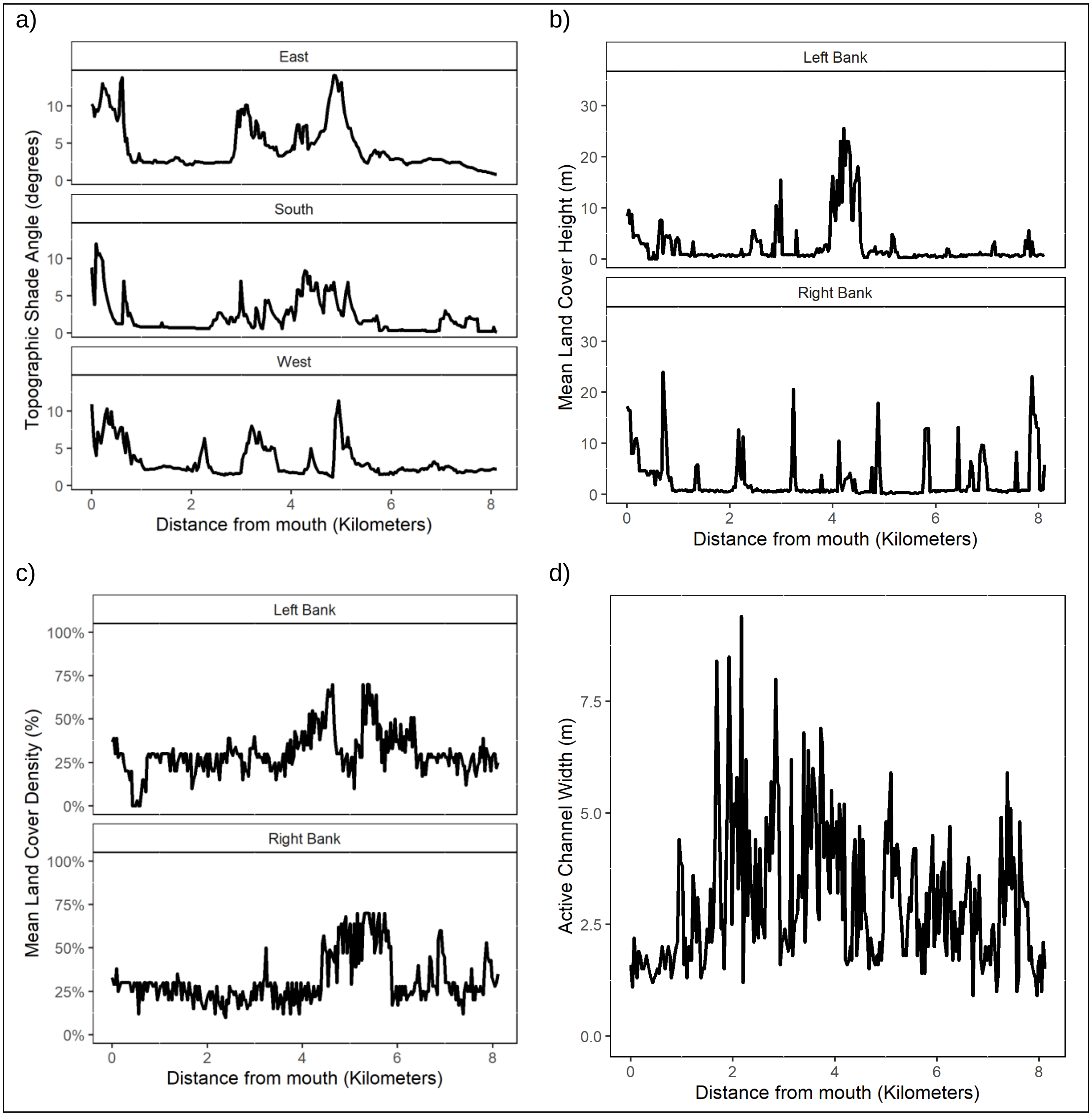


Figure A- 67. Long Branch Creek existing conditions as configured in the model (a – d).

Table A- 44. Long Branch Creek riparian area vegetation.

Land Cover Name	Height (m)	Density (%)	Overhang (m)	Prevalence in Model (%) Current Condition	Restored Vegetation
Wetland grasses/shrubs mix	3.7	50%	0.3	2%	36%
Silver Sagebrush/Wetland Grasses	0.9	30%	0.3	22%	19%
Wetland grasses	0.9	30%	0.3	35%	10%
Warm Willow	4.6	30%	0.9	0%	9%
Meadow	0.3	70%	0.3	12%	8%
Wetland Shrubs	4.6	30%	0.3	10%	4%
Large Conifer	30.5	60%	2.1	4%	4%
Upland Shrubs/sagebrush	0.9	30%	0.3	3%	3%
barren-rubbleland	0.0	0%	0.0	2%	2%
Large Conifer	30.5	30%	2.1	1%	2%
Large Deciduous	9.1	40%	1.8	1%	1%
Small Conifer	12.2	60%	1.1	1%	1%
Upland shrub/tree mix	9.1	50%	0.0	1%	1%
Warm Willow	1.5	30%	0.9	3%	0%

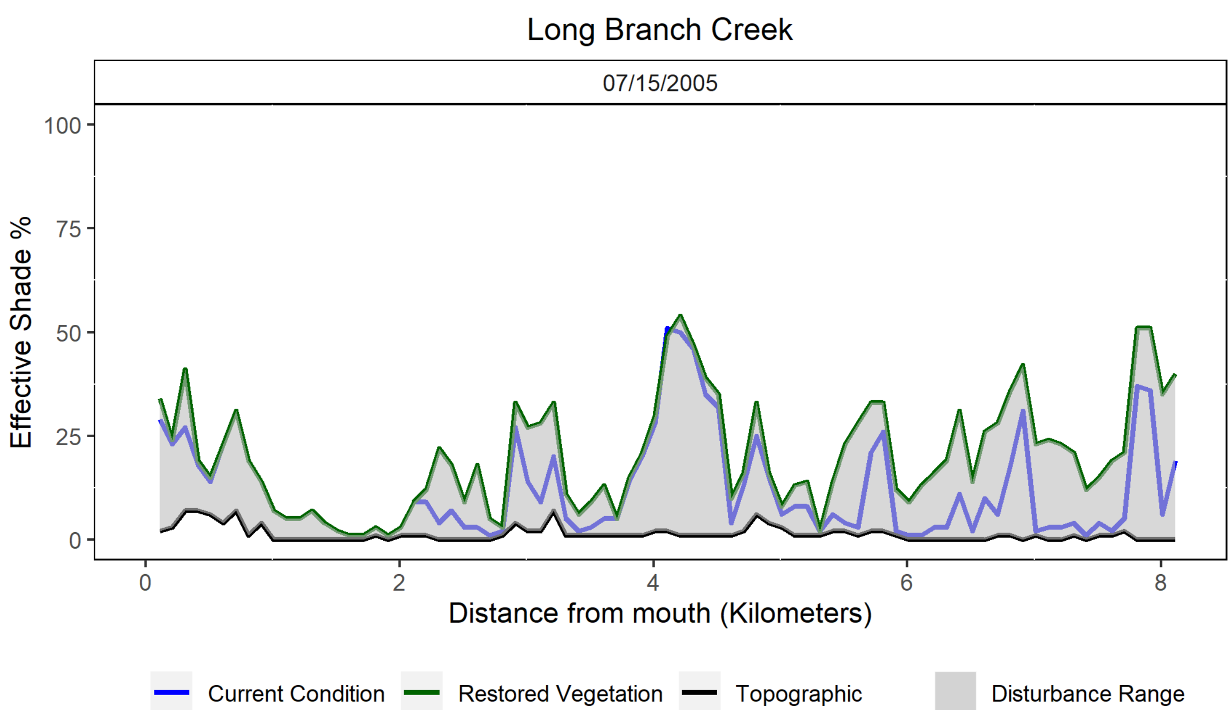


Figure A- 68. Long Branch Creek shade analysis results.

Table A- 45. Long Branch Creek mean effective shade results.

Analysis Date	Reach Length (km)	Mean Effective Shade Current Condition	Mean Effective Shade Restored Condition	Mean Effective Shade Deficit
07/15/2005	8.00	12%	20%	8%

A.4.10 Lost River

Stream Name: Lost River
Model: Heat Source version 9.0, solar only
Beginning date: 7/15/1999
Ending date: 7/15/1999
Time step: 1 minute
Distance step: 50 m
Extent: Oregon/California border to Malone Diversion Dam (river kilometer 98.0) (Figure A- 60).

The following figures and tables document the shade analysis on the Lost River. Temperature was also modeled on the Lost River using CE-QUAL-W2. The temperature results are discussed in Appendix D. The Lost River primarily flows through private lands and lands owned by the Bureau of Reclamation. Current condition vegetation was characterized using available LiDAR data (WS 2011).

Table A- 46 shows the vegetation types used in the restored vegetation model scenario and the prevalence. Only the composite averages were used in the model scenario.

The restored vegetation types include a mix of Cottonwood, Aspen, native shrubs (e.g., Willow), native grasses/sagebrush, and occasional Ponderosa Pine at drier upland site near the Lost River. These vegetation types were selected based on personal communications of Klamath County community members discussing their observations on Lost River conditions from before many of the major landuse changes, channel modifications, and diversion projects occurred. DEQ also reviewed the publication called “Common Plants of the Upper Klamath Basin” (Native Plant Society of Oregon, 2007) to review the habitat types where these species typically occur and confirm they are found in riparian areas in this area. This publication was also used to identify mature vegetation heights.

The restored vegetation model scenario incorporates these vegetation types as a single composite mix broken down into two zones: 0-10 meters from the stream bank, and > 10 meters from the stream bank. The closer zone is to recognize that this is likely where more Cottonwoods are to be growing and the farther zone where more Aspens and native grasses will occur. Ten meters was chosen as the inner zone distance based on a visual review of the existing LiDAR data (WS 2011). This is the distance where most of the taller denser vegetation exists, at least within the more sinuous sections that still have any vegetation remaining.

The proportion of each vegetation type is based on DEQ’s professional judgment. Restored vegetation types on the Lost River are difficult to estimate given there are no known reference sites along the river.

Table A- 46. Lost River restored vegetation types.

Location	Vegetation Type	Proportion in model	Height (m)	Density	Overhang (m)
Within 10-meters from stream channel	Cottonwood	0.60	36.5	70%	3.0
	Aspen	0.10	12	70%	3.0
	Willow	0.30	4.5	90%	3.0
	Composite Average	**1.00**	**24.5**	**76%**	**3.0**
Beyond 10-meters from stream channel	Cottonwood	0.25	36.5	70%	0.0
	Aspen	0.20	12	70%	0.0
	Willow	0.30	4.5	90%	0.0
	Sagebrush and/or Native Grasses	0.20	0.9	100%	0.0
	Ponderosa Pine	0.05	30.5	10%	0.0
	Composite Average	**1.00**	**14.6**	**79%**	**0.0**

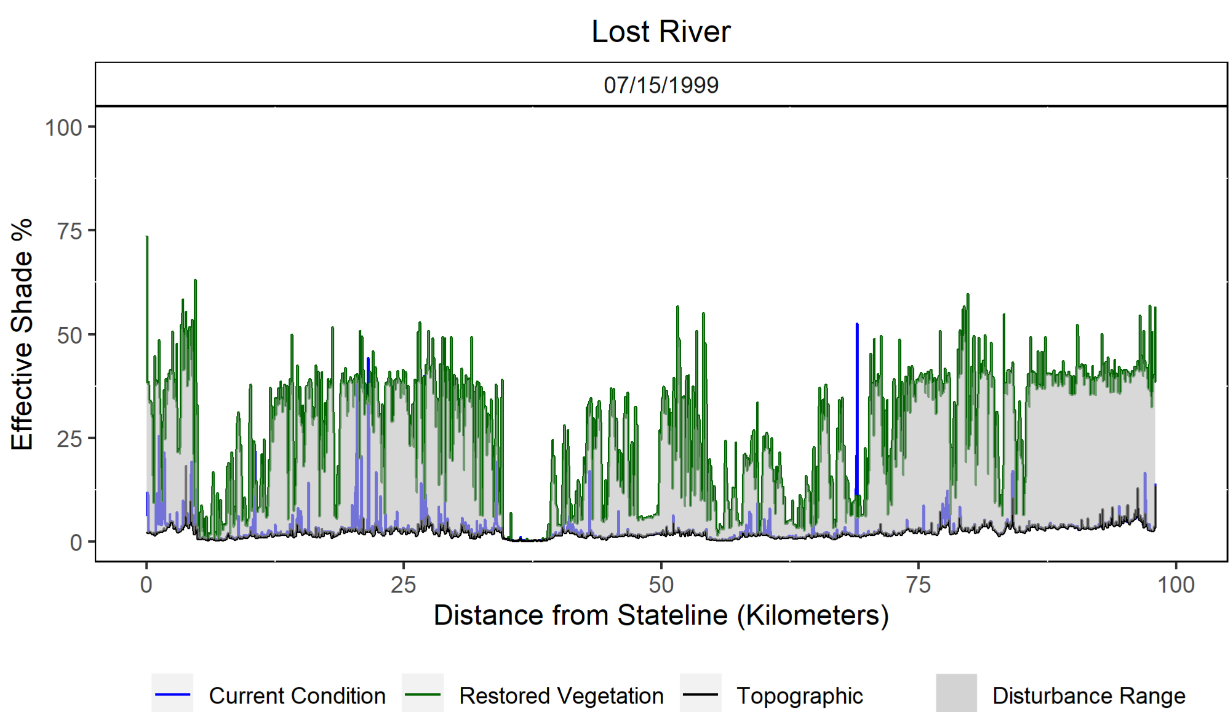


Figure A- 69. Lost River shade analysis results.

Table A- 47. Lost River mean effective shade results.

Analysis Date	Reach Length (km)	Mean Effective Shade Current Condition	Mean Effective Shade Restored Condition	Mean Effective Shade Deficit
07/15/1999	98.0	3%	26%	23%

Table A- 48. Lost River mean effective shade results by reach.

Reach	Reach Length (km)	Mean Effective Shade Current Condition	Mean Effective Shade Restored Condition	Mean Effective Shade Deficit
Malone Dam to Harpold Dam	38.6	3%	30%	27%
Harpold Dam to Poe Valley Bridge (RM 27)	5.0	1%	12%	11%
Poe Valley Bridge (RM 27)-Wilson Reservoir	15.05	2%	20%	18%
Wilson Reservoir	4.6	0%	0%	0%
Wilson Dam to Anderson Rose Dam	29.6	3%	27%	24%
Anderson Rose Dam to Stateline	4.9	6%	37%	31%

A.4.11 North Fork Willow Creek

Stream Name: North Fork Willow Creek
Model: Heat Source version 7.0, solar only
Beginning date: 7/15/2005
Ending date: 7/15/2005
Time step: 10 minute
Distance step: 30.48 m
Extent: Oregon/California border to the Yocum Valley wetland complex (river kilometer 5.43) (Figure A- 70Figure A- 60).

The following figures and tables document the shade analysis on North Fork Willow Creek. The reach that was examined flows through private and USFS lands (Figure A- 70). Vegetation was sampled along the stream in a radial pattern every 2 meters from the center of stream out to a distance of 8 meters. Most of the increases in shade are predicted to occur on private land due to the predicted increase in wetland shrubs (Figure A- 72 and Table A-25). Shade due to restored vegetation is less than current shade around river km 1. This effect is because the predicted restored vegetation for conifers is less dense than current stands due to fire suppression. Table A- 49 shows the relative prevalence of vegetation types used in the current condition and restored vegetation model scenarios.

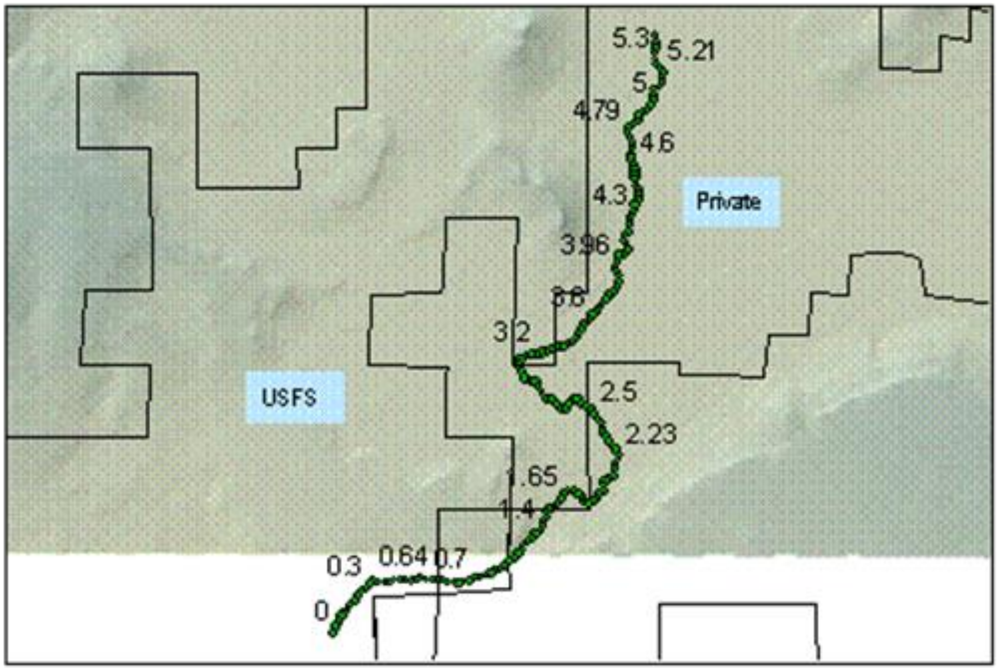
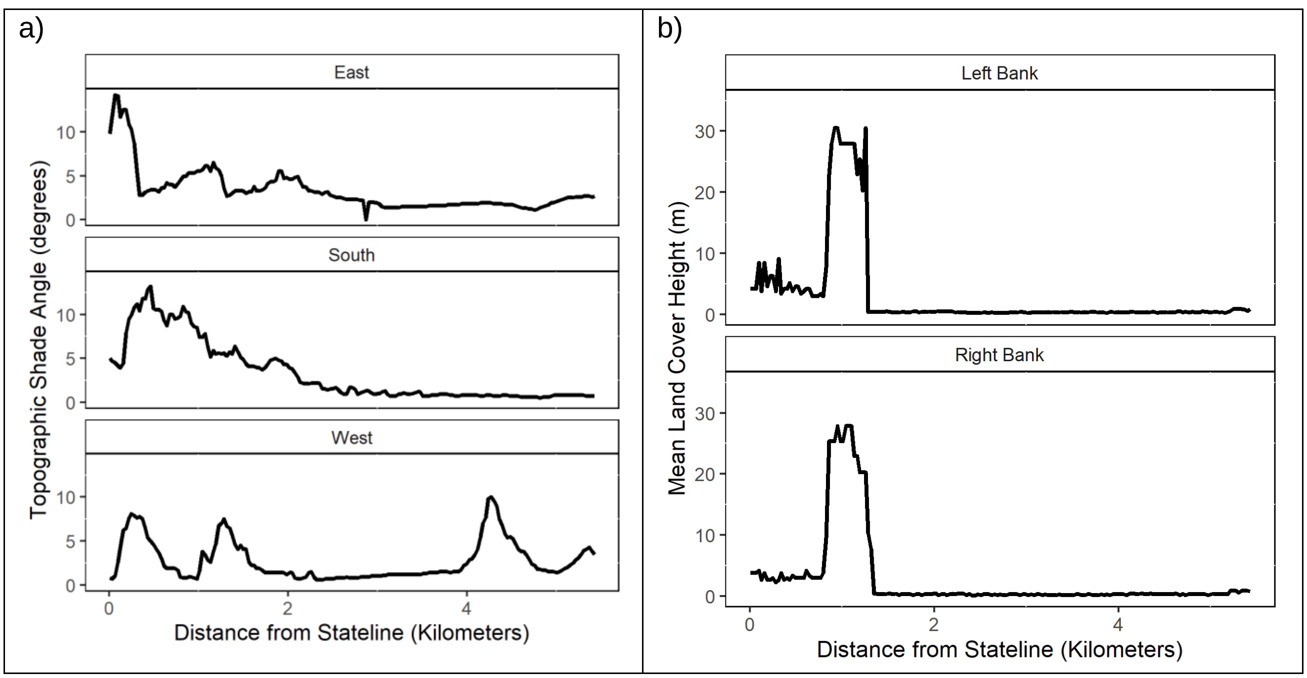


Figure A- 70. North Fork Willow Creek analysis extent with ownership and distance upstream from mouth (km).



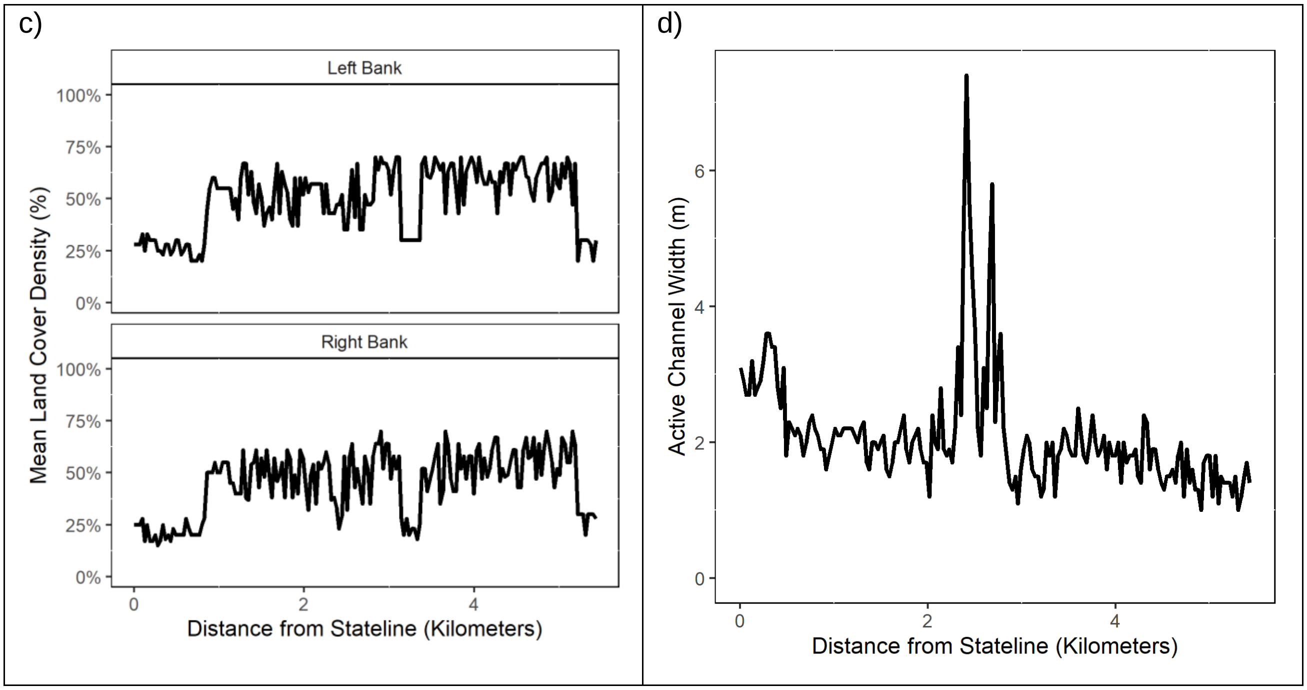


Figure A- 71. North Fork Willow Creek existing conditions as configured in the model (a – d).

Table A- 49. North Fork Willow Creek riparian area vegetation.

Land Cover Name	Height (m)	Density (%)	Overhang (m)	Prevalence in Model (%) Current Condition	Prevalence in Model (%) Restored Vegetation
Warm Willow	4.6	30%	0.9	14%	66%
Meadow	0.3	70%	0.3	61%	18%
Large Conifer	30.5	30%	2.1	0%	9%
Upland Shrubs/sagebrush	0.9	30%	0.3	12%	7%
Dry Meadow	0.3	30%	0.3	5%	0%
Large Conifer	30.5	60%	2.1	9%	0%

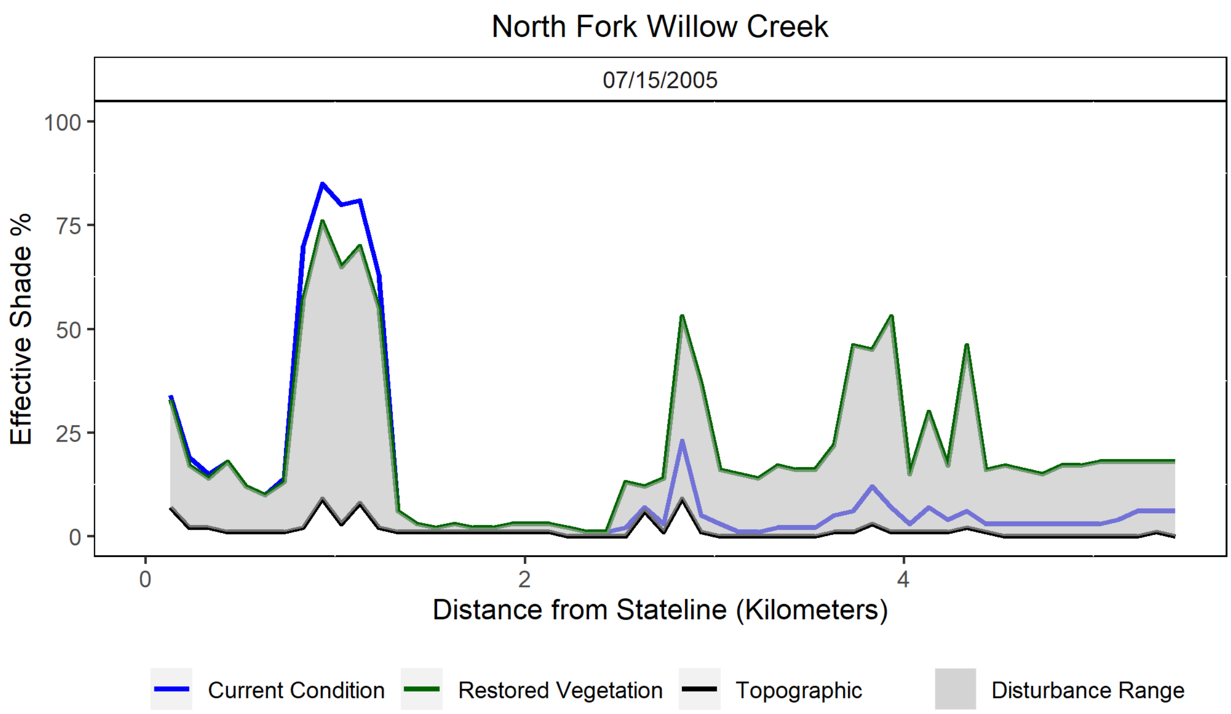


Figure A- 72. North Fork Willow Creek shade analysis results.

Table A- 50. North Fork Willow Creek mean effective shade results.

Analysis Date	Reach Length (km)	Mean Effective Shade Current Condition	Mean Effective Shade Restored Condition	Mean Effective Shade Deficit
07/15/2005	5.3	12%	21%	9%

A.5 Limitations

It should be acknowledged that there are limitations to this modeling effort:

- The scale of this effort is large with obvious challenges in capturing spatial variability in stream and landscape data. Available spatial data sets for vegetation and channel morphology are coarse, while derived data sets are limited to aerial photo resolution and human error.
- The hydraulics of the model is one dimensional which necessitates lateral and depth averaging. Although appropriate for many of the reaches modeled, portions of the streams and river with impoundments, side channels, deep pools or a high degree of lateral variability may not be represented accurately.
- Data are insufficient to describe high-resolution instream flow conditions making validation of derived mass balances difficult.
- The water quality issues are complex and interrelated. The state of the science is still evolving in the context of comprehensive landscape scaled water quality analysis. For example, quantification techniques for microclimates that occur in near-stream areas are not developed and available to this effort. Regardless, recent studies indicate that forested microclimates play an important, yet variable, role in moderating air temperature, humidity fluctuations and wind speeds.
- Quantification techniques for estimating potential subsurface inflows/returns and behavior within substrate are not employed in this analysis. While analytical techniques exist for describing subsurface/stream interactions, it is beyond the scope of this effort with regard to data availability, technical rigor and resource allocations.
- Land use patterns vary through the drainage from heavily impacted areas to areas with little human impacts. However, it is extremely difficult to find large areas without some level of either current or past human impacts.
- The development of restored natural stream temperatures is based on stated assumptions within this document. Limitations to stated assumptions are presented where appropriate. It should be acknowledged that as better information is developed these assumptions will be refined.
- Current analytical methods fail to capture some upland, atmospheric and hydrologic processes. At a landscape scale these exclusions can lead to errors in analytical outputs. For example, methods do not currently exist to simulate riparian microclimates at a landscape scale. In some cases, there is not scientific consensus related to riparian, channel morphology and hydrologic potential conditions. This is especially true when confronted with highly disturbed sites, meadows and marshes, potential hyporheic/subsurface flows, and sites that have been altered to a state where potential conditions produce an environment that is not beneficial to stream thermal conditions (such as a dike).

The following items affect model uncertainty:

- Riparian vegetation was mapped from aerial photographs and placed within general height categories. For example, trees identified as “Large Conifers” were assigned a single height of 125 feet throughout a single watershed, when in reality, “Large Conifer” heights may range between 110 and 140 feet. It is not possible to assign actual heights to each tree mapped using aerial photographs. These general height categories became Heat Source inputs and are one source of modeling imprecision.

- Riparian vegetation densities were estimated base on aerial photograph analysis. General categories of “dense”, “moderately dense”, and “sparse” were used to delineate vegetation stands. Restored vegetation used single density values for each ecoregion and vegetation type. In the real world, vegetation densities are variable and this variability is not accounted for in the simulations.

- The actual position of the sun within the sky can only be calculated with an uncertainty of 10-15%. The sun’s position is important when determining a stream’s effective shade. Solar position is another source of modeling imprecision.

- Heat Source always assumes that the wetted stream is flowing directly down the center of the active channel, and effective shade calculations are based upon that assumption. In reality, a stream migrates all over the active channel. This is another source of modeling imprecision.

- Microclimates often develop around streams. Humidity, air temperature, and wind depend on factors such as elevation, vegetation, terrain, etc. Stream temperatures are affected by microclimates which are another source of modeling imprecision.

- Groundwater exchanges and hyporheic flows are difficult to measure and may not always be accounted for within stream temperature modeling. In addition, natural stream conditions may have had more groundwater connection, wetland areas, and hyporheic interactions prior to anthropogenic disturbances. These conditions are not included in the restored conditions (RC) model scenarios. Stream restoration may increase groundwater connectivity which could reduce the restored conditions temperatures.

- Increased channel complexity and more coarse woody debris are not accounted for in the restored conditions scenarios. Including these factors may result in cooler temperatures.

- Heat Source breaks the stream into 50-meter segments. Inputs (vegetation, channel morphology, etc.) are averaged for each 50-meter segment, which means that the simulation may not account for some of the real world variability. For example, isolated pools or riffles within a 50 meter reach will not be included as unique features.

- For the tributaries to the Klamath and Lost Rivers, Heat Source simulations were performed for at most for a two to three week period during the months of July or August. during a single summer, which was intended to represent a critical condition for aquatic life. Stream temperatures will react differently to effective shade under other flow regimes and climactic conditions.

- “Natural” flows were included in the restored condition scenarios. Estimates were used to create the existing flow mass balances, and withdrawals were estimated for the current condition, based on thermal infrared aerial data, the OWRD points of diversion database, and instream flow measurements. “Natural” or restored flows are estimates based on removing the assumed anthropogenic impacts on the current flow regimes.

- To estimate restored conditions, some headwater and boundary condition stream temperature had to be estimated using professional judgment or the biologically based criterion as a guide.

- Stream velocities and depths were calculated by Heat Source for the “natural” flow conditions based on measured channel dimensions and substrate composition. These estimated velocities and depths for the “natural” flows may have some error associated with them since they have not been verified through field measurements.

- Some stream elevations and gradients were sampled and calculated from 10-meter digital elevation models (DEMs). DEMs have a certain level of imprecision associated with them and may be a source of uncertainty in the simulation results.

- Existing air temperature and relative humidity were assigned to each simulation from various weather stations in the basin. Natural variations in air temperature and relative humidity along the stream may not be accounted for in the simulations. For example, temperatures may change as the landscape changes over short distances along the stream. These are similar to the microclimates created by vegetation cover.

In this TMDL process there are a number of necessary decisions which are based on information with a certain amount of uncertainty: determination of impairment, model calibration acceptance, model scenario acceptance and allocations. For each of these four decision points, the uncertainty is handled differently.

The determination of impairment is based on a comparison of data with the water quality standard. The comparison of data with a numeric standard is relatively straight forward, however comparison of data to a ‘natural conditions’ based standard has more uncertainty because ‘natural condition’ cannot be observed and is based on estimates. DEQ accounts for this uncertainty by trying to minimize the likelihood of a Type II error (where the actual condition is impaired but analysis shows the system is not impaired).

The determination that a model is representing system (i.e., acceptance of a calibrated model) is based on comparison of model results with observed data. Statistics and graphical comparison are utilized. While the uncertainty related to model scenarios is evaluated using a sensitivity analysis. Lastly, the uncertainty related to allocations is accounted for in the Margin of Safety.

While these assumptions outline potential areas of weakness in the methodology used in the stream temperature analysis, the Oregon Department of Environmental Quality has undertaken a comprehensive approach. All important stream parameters that can be accurately quantified are included in the analysis. In the context of understanding of stream temperature dynamics, these areas of limitations should be the focus for future studies.

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