Appendix G:

Analytical Methodology and Nonpoint Sources of Pollution - Sections 4.5.2 and 4.5.3 from 2001 Western Hood Subbasin TMDL

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This Appendix contains information from the 2001 WHS TMDL describing the data and analytical methodology used in the effective shade and temperature simulations. This Appendix repeats Section 4.5.2 and 4.5.3 from the 2001 WHS TMDL. We did not make any changes to these sections, but are including them here as an Appendix to make it easier for the reader to reference these pertinent sections of the 2001 WHS TMDL.

4.5.2 Analytical Methodology

The temperature model utilized by ODEQ to estimate stream network thermodynamics and hydrology is Heat Source (Boyd, 1996). It was developed in 1996 as a Masters Thesis at Oregon State University in the Departments of Bioresource Engineering and Civil Engineering. ODEQ currently supports the Heat Source methodology and computer programming (a more extensive discussion of the analytical framework for the model is provided in **Chapter 6**). The temperature model is designed to analyze and predict stream temperature for one day. This Western Hood Subbasin TMDL is primarily concerned with daily prediction of the diurnal energy flux and resulting temperatures on August 6, 1998.

Stream temperature was simulated for 23.6 miles of the mainstem Hood River and East Fork Hood River together – from the mouth of the Hood River to a point about 2 miles upstream of the East Fork Irrigation District Diversion from the East Fork Hood River. Stream temperature was also simulated for 7.8 miles of Neal Creek – from the mouth to the point where the East Fork Irrigation District ditch enters Neal Creek. Simulations were performed to assess the stream thermal response to: (1) current vs. system potential vegetation; and (2) different flow regimes. The results from the simulations are provided under **Sections 4.5.3.1.4, 4.5.3.2.3,** and **4.5.4.5.1** below**.**

Individual near stream vegetation and flow regime simulations were performed for each stream reach. Results from these single parameter simulations confirm the importance of both riparian vegetation and flow as stream parameters that influence stream heating processes. When both system potential riparian vegetation and flow regime were simulated together, the stream heating was affected to a greater extent.

4.5.3 Nonpoint Sources of Pollution

Elevated summertime stream temperatures attributed to nonpoint sources result from riparian vegetation disturbance (reduced stream-surface shade), reduced base flow, and channel widening (increased stream surface

Settlement of the Hood River watershed in the late-1800s brought about changes in the near stream vegetation and hydrologic characteristics of many of the rivers and streams in that watershed. Historical agricultural and logging practices altered the stream morphology and hydrology and decreased the amount of riparian vegetation. Beginning around 1880, orchards and strawberry fields began to progress up the valley as the natural landscape pattern of conifer forests and riparian habitat was transformed into pasture and fruit crops. Timber harvest cleared streams and riparian corridors of fallen trees and large woody debris, with riparian areas logged right down to the streambanks. Before 1900, streams began to be diverted into canals and ditches for irrigation. Diversions still occur in a number of streams in the watershed and can result in significant decreases in instream flows and the transferal of water from one watershed into another. Drainage and stream channelization has occurred in some small streams in agricultural areas.

More recently, increases in population have resulted in urbanization of parts of the watershed. Conversion of forest and pasture to residential development is occurring, even in riparian areas, which can result in reduced riparian vegetation. The flood plains of many rivers and streams have been affected by the development of transportation corridors. The East Fork Hood River and Neal Creek are among the streams that have been the most severely affected. The confinement of the East Fork Hood River due to construction, reconstruction and maintenance of State Highway 35 is reported as a significant and continuing impact to aquatic habitat. Neal Creek has also been heavily impacted by channelization, confinement and bank stabilization as a result of agricultural practices and road construction. These modifications have caused increased flood scour and channel incision that has separated the creek from its floodplain in many areas.

Riparian vegetation, stream morphology, hydrology, climate, and geographic location influence stream temperature. While climate and geographic location are outside of human control, riparian condition, channel morphology and hydrology are affected by land use activities.

Specifically, the elevated summertime stream temperatures attributed to anthropogenic nonpoint sources result from:

1. ***Near stream vegetation disturbance or removal*** *reduces stream surface shading via decreased riparian vegetation height, width and/or density, thus increasing the amount of solar radiation reaching the stream surface (shade is commonly measured as percent effective shade or open sky percentage). Riparian vegetation also plays an important role in shaping the channel morphology, resisting erosive high flows and maintaining floodplain roughness.*
2. ***Reduced summertime base flow*** *results from stream withdrawals*
3. ***Channel modifications and widening*** *(increased width to depth ratios) increases the stream surface area exposed to energy processes, namely solar radiation. Near-stream disturbance zone (NSDZ) widening decreases potential shading effectiveness of shade-producing near-stream vegetation.*

4.5.3.1 Riparian Vegetation

Riparian vegetation plays an important role in controlling stream temperature change. Near stream vegetation height, width and density combine to produce shadows that when, cast across the stream, reduce solar radiant loading. Bank stability is largely a function of riparian vegetation. Riparian corridors often produce a microclimate that surrounds the stream where cooler air temperatures, higher relative humidity and lower wind speeds are characteristic.

4.5.3.1.1 The Dynamics of Shade

Stream surface shade is a function of several landscape and stream geometric relationships. Some of the factors that influence shade are listed in **Table 6**. Geometric relationships important for understanding the mechanics of shade are displayed in **Figure 16**. In the Northern Hemisphere, the earth tilts on its axis toward the sun during summertime months allowing longer day length and higher solar altitude, both of which are functions of solar declination (i.e. a measure of the earth’s tilt toward the sun). Geographic position (i.e. latitude and longitude) fixes the stream to a position on the globe, while aspect provides the stream/riparian orientation. Riparian height, width and density describe the physical barriers between the stream and sun that can attenuate and scatter incoming solar radiation (i.e. produce shade). The solar position has a vertical component (i.e. altitude) and a horizontal component (i.e. azimuth) that are both functions of time/date (i.e. solar declination) and the earth’s rotation (i.e. hour angle). While the interaction of these shade variables may seem complex, the math that describes them is relatively straightforward geometry.

Percent effective shade is perhaps the most straightforward stream parameter to monitor and calculate and is easily translated into quantifiable water quality management and geometric relationships that affect stream surface shade recovery objectives. **Figure 17** demonstrates how effective shade is monitored and calculated. Using solar tables or mathematical simulations, the *potential daily solar load* can be quantified. The *measured solar load (current conditions)* at the stream surface can easily be measured with a Solar Pathfinder© or estimated using mathematical shade simulation computer programs (Boyd, 1996 and Park, 1993).

Table 6. Factors that Influence Stream Surface Shade

Description	*Measure*
Season/Time	Date/Time
Stream Characteristics	Aspect, Near-Stream Disturbance Zone Width
Geographic Position	Latitude, Longitude
Vegetative Characteristics	Buffer Height, Buffer Width, Buffer Density
Solar Position	Solar Altitude, Solar Azimuth

Figure 16. Geometric Relationships that Affect Stream Surface Shade

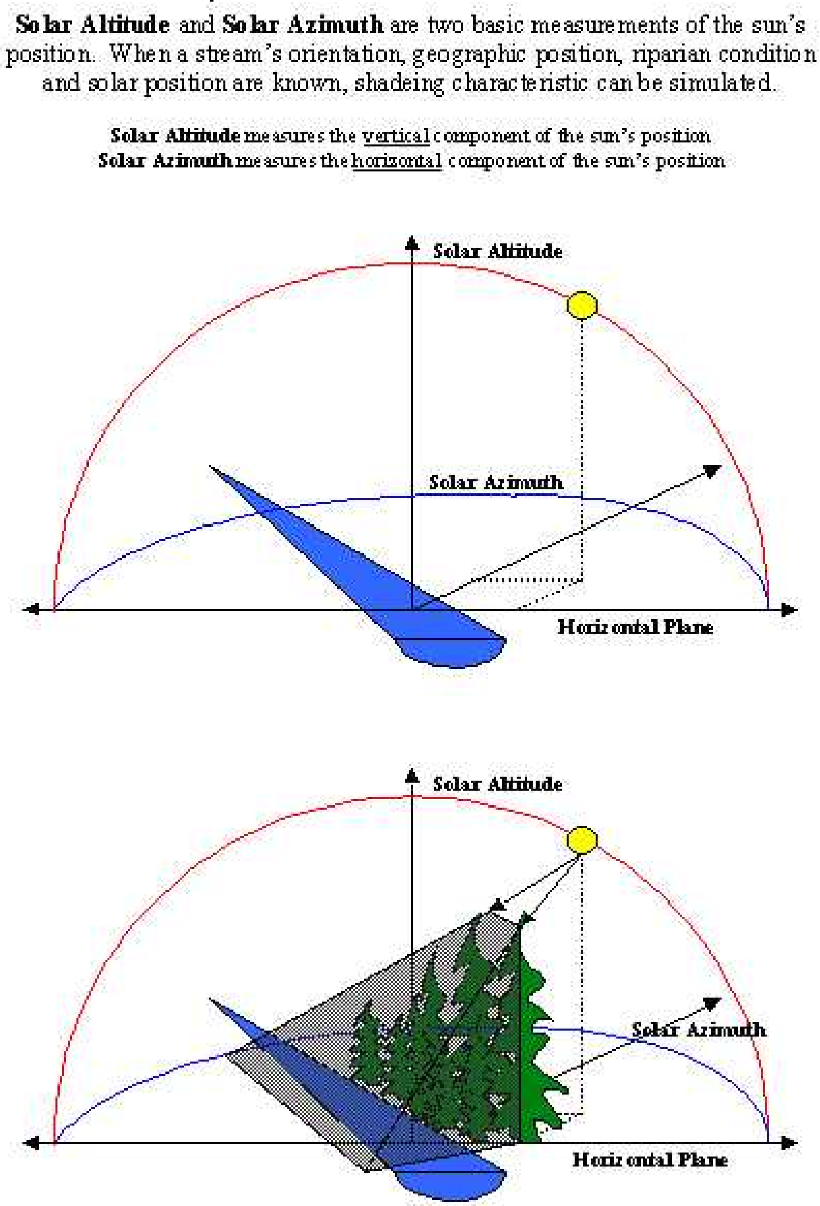
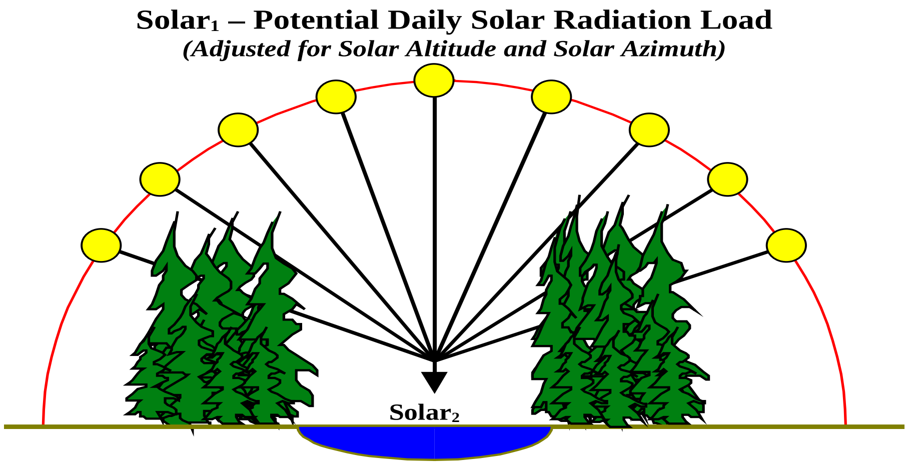


Figure 17. Effective Shade - Defined



Effective Shade Defined:

$$\text{Effective Shade} = \frac{(\text{Solar}_1 - \text{Solar}_2)}{\text{Solar}_1}$$

Where,

Solar_1: Potential Daily Solar Radiation Load
Solar_2: Measured Daily Solar Radiation Load at Stream Surface

4.5.3.1.2 Western Hood Subbasin Vegetation Conditions

In the source assessment for nonpoint sources in the Western Hood Subbasin, riparian vegetation and channel widths were characterized in all watersheds through analysis of a combination of digital orthophoto quads, color aerial photographs, and direct measures in the field. Current conditions were measured directly from one or more of these sources and system potential shade conditions were estimated (modeled) by altering vegetational characteristics and modifying Near-Stream Disturbance Zone widths.

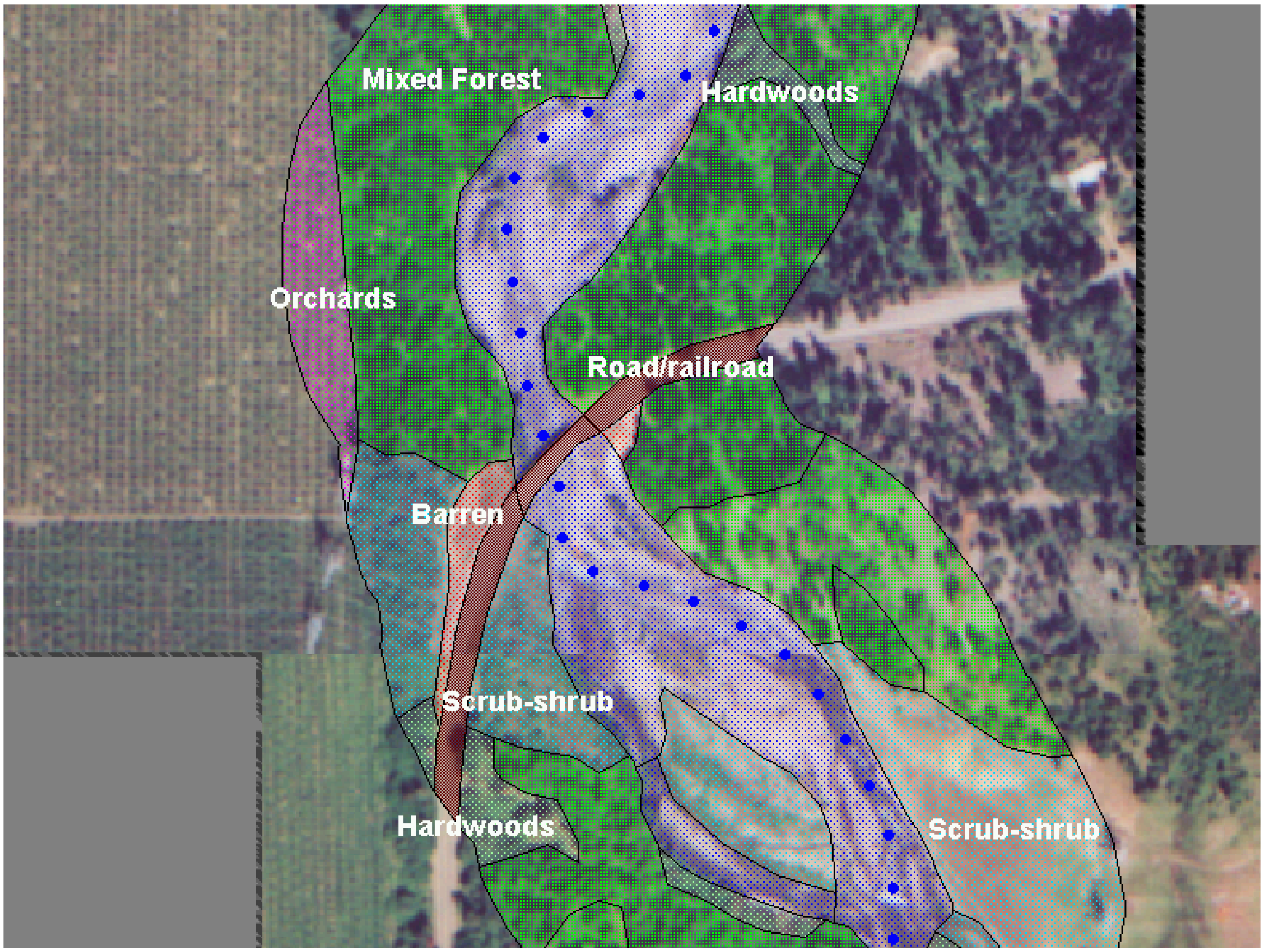
4.5.3.1.2.1 Current Condition

Sampling/Measuring Riparian Vegetation. Current condition riparian vegetation was characterized using digital orthophoto quads (DOQs) and color aerial photos. DOQs were available for the entire subbasin area from 1995. Color aerial photos, from a flight flown in 1999, were available for most of the non-Federal lands in the Hood River watershed. Vegetation polygons were digitized in the near stream area (300 feet on either side of the stream channel) and classified by vegetation type. All classifications included an average riparian vegetation height and canopy density. Polygons which appeared to have a limited system potential for natural reasons (such as a lava flow or a steep embankment) were classified as such so they could be analyzed differently under the "Potential Condition" Scenario described below.

Every near-stream vegetation code was quality checked against aerial photographs by ODEQ. Ground level measurements were collected by ODEQ and ODF in 1999 and 2000 throughout the Hood River watershed to assist in vegetation classifications. **Figure 18** displays an example of vegetation and land cover polygons derived from orthophotos and color aerial photographs at 1:3,000.

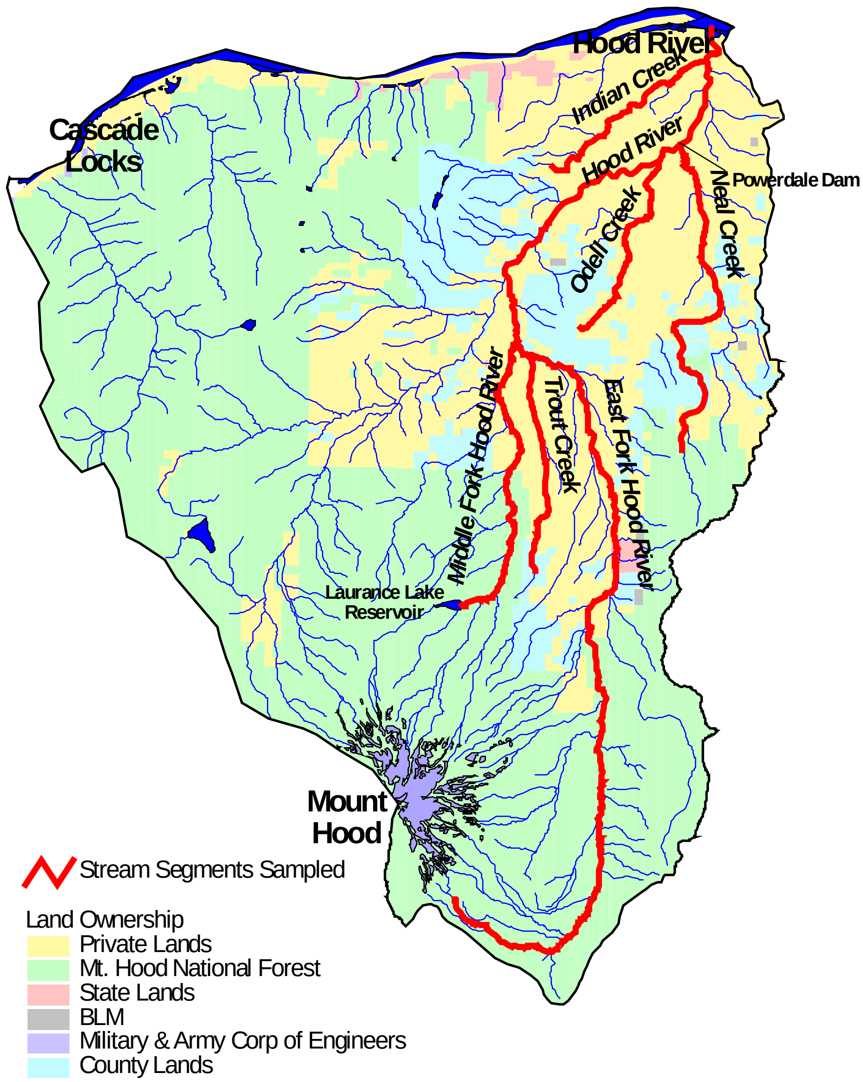
Stream reaches were also digitized from DOQs at less than 1:3,000. These stream data layers were then segmented into data points at a 100-foot interval. These data point layers form the basis for automated sampling performed using Ttools[1]. At every distance node (i.e. every 100 feet) along the stream, vegetation was sampled out to 120 feet from the channel edge at 15-foot intervals for both stream banks. A total of 18 vegetation samples are taken at each stream distance node. Automated near stream vegetation sampling was completed for 82.9 rivermiles in the Hood River (**Figure 19**) watershed including Hood River and East Fork Hood River (42.6 miles), Middle Fork Hood River (10.4 miles), Neal Creek (13.5 miles), Indian Creek (5.6 miles), Odell Creek (5.7 miles) and Trout Creek (5.1 miles).

Figure 18. Hood River Vegetation Mapping from Color Aerial Photograph



[1] Ttools is an automated sampling tool that was developed by ODEQ to sample the following spatial data: stream aspect, channel width, near stream vegetation and topographic shade angles. Sampling resolution is user defined and was set at 100 foot intervals longitudinally (i.e. along the stream) and 15 feet in the transverse direction (i.e. perpendicular to the stream).

Figure 19. Streams Analyzed for Riparian Vegetation and Shade



Riparian Vegetation Composition. Near stream vegetation was grouped as one of the following: water or floodplains, cultivated fields or grassed areas, orchards, conifer forests, deciduous forests, mixed (conifer and deciduous) forests, scrub/shrub (woody vegetation less than 15 feet high), timber harvest, roads, developed lands (both urban and rural residential and commercial), and barren lands. Within these general vegetation types, near stream vegetation was further classified by observed differences in average tree height (taller vs. shorter forests) and in density (**Table 7**). Existing tree heights were determined by ODEQ using ground level data and the professional expertise of foresters with the Oregon Department of Forestry (Larry Hoffman, Unit Forester and Doug Thiesies, Forest Practices Act Forester) and the Mt. Hood National Forest (Bruce Holmson, Silviculturist). Canopy density is presented as the percentage of ground that is covered by one-story vegetation when viewed from directly above. Mixed forest was the most prevalent land cover type found in the near stream area analyzed and comprised 38.6% of the sampled near stream areas (**Figure 20**).

Current riparian vegetation distribution and height and potential riparian vegetation height are displayed in **Figures 21** through **26** for the six streams analyzed. The vegetation distribution is shown for both the right and left stream banks. Vegetation information presented in these figures was sampled from a GIS vegetation data layer. Note that the river miles presented in these figures were derived from a 1:5000 stream coverage used for ODEQ simulation purposes and may differ slightly from other sources (such as OWRD ro USGS river miles).

Table 7. Mean Vegetation Height and Density for Trees in the Hood River Watershed

Near-stream Vegetation Class		Height (ft)	Density (%)
Water & Floodplain	Water & Floodplain	0.0	0%
Cultivated Fields & Grassed Areas	Cultivated Lawns & Fields	0.0	0%
	Grasslands	3.3	75%
Orchards	Young Orchard	6.6	75%
	Mature Orchard	20.0	75%
Mixed Forest	Taller Forest	85.0	25% or 75%
	Shorter Forest	40.0	25% or 75%
Deciduous Forest	Taller Forest	75.1	25% or 75%
	Shorter Forest	34.8	25% or 75%
Conifer Forest	Taller Forest	89.9	25% or 75%
	Shorter Forest	40.0	25% or 75%
Scrub/Shrubs	Scrub/Shrubs	15.1	25% or 75%
Timber Harvest	Recent Clearcut	3.3	75%
	Clearcut - regrowth	15.1	25% or 75%
Developed	Residential	20.0	100% (buildings)
	Industrial or Commercial	29.9	100% (buildings)
	Roads & Railroads	0.0	0%
	Canals or Pipelines	0.0	0%
Barren	Lava flow - barren	0.0	0%
	Lava flow - some tree growth	85.0	25% or 50%
	Barren Lands	0.0	0%

Figure 20. Near Stream Vegetation Distribution Throughout the Hood River Watershed
(82.9 River Miles Analyzed)

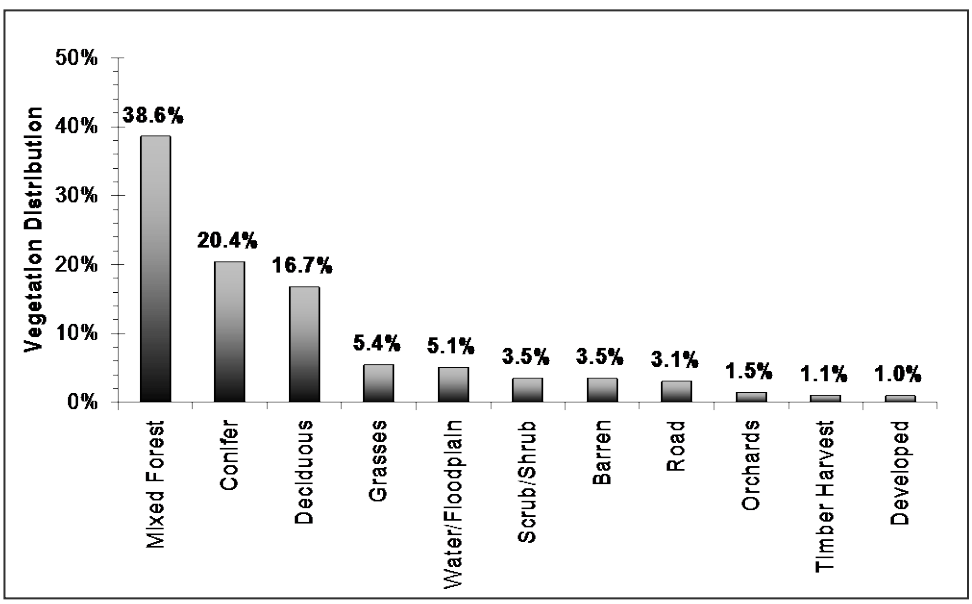


Figure 21. Hood River/East Fork Hood River Near Stream Vegetation Distribution

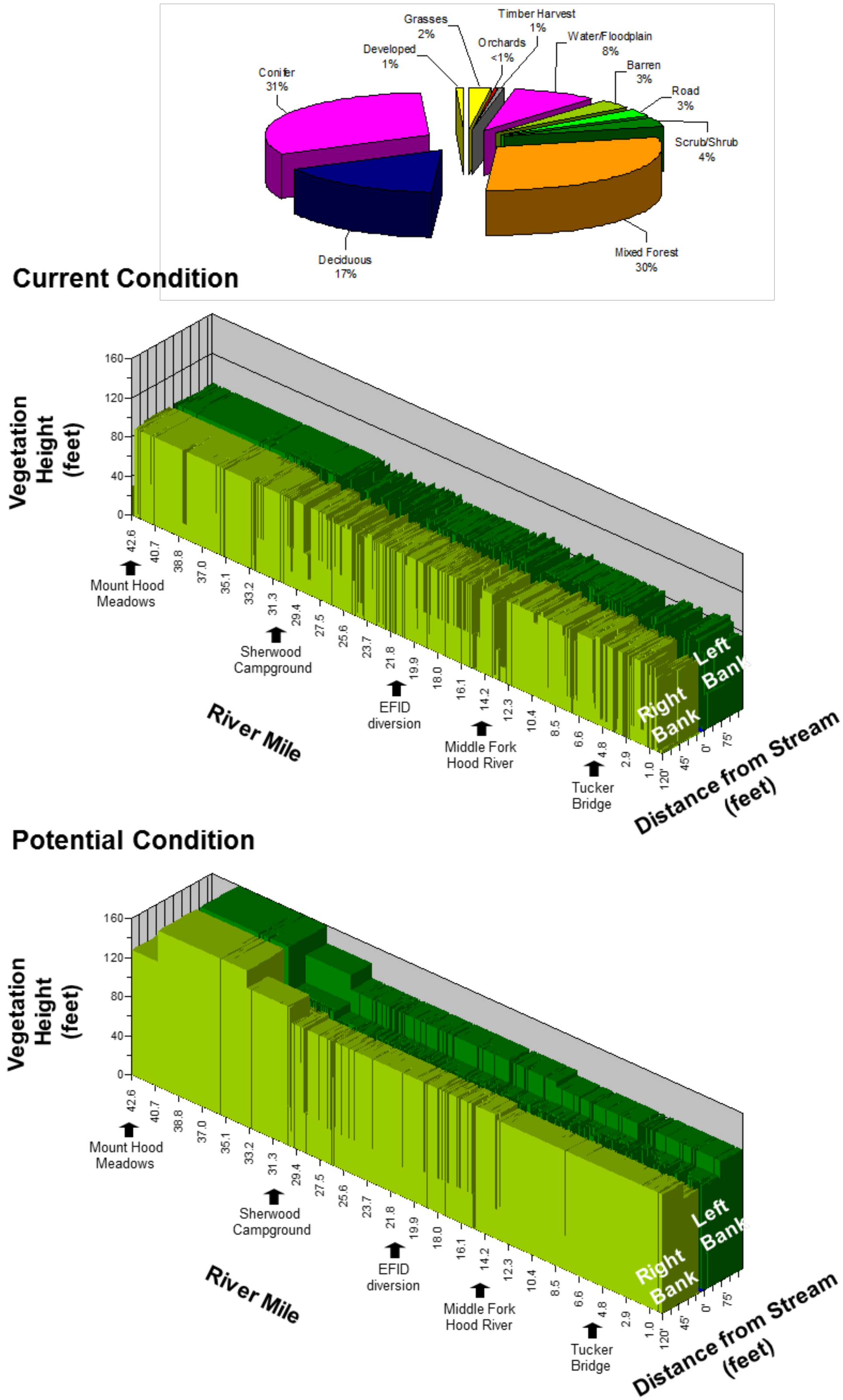
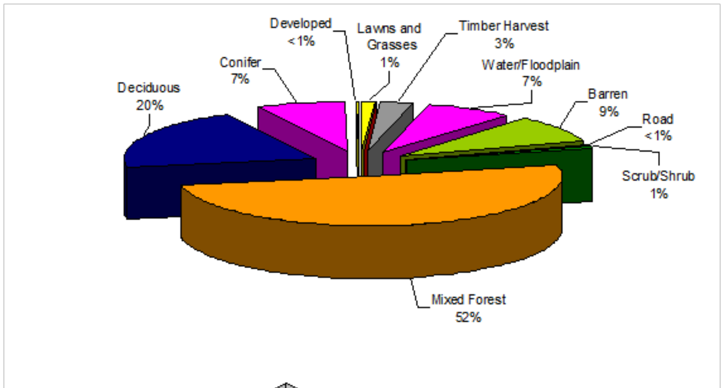
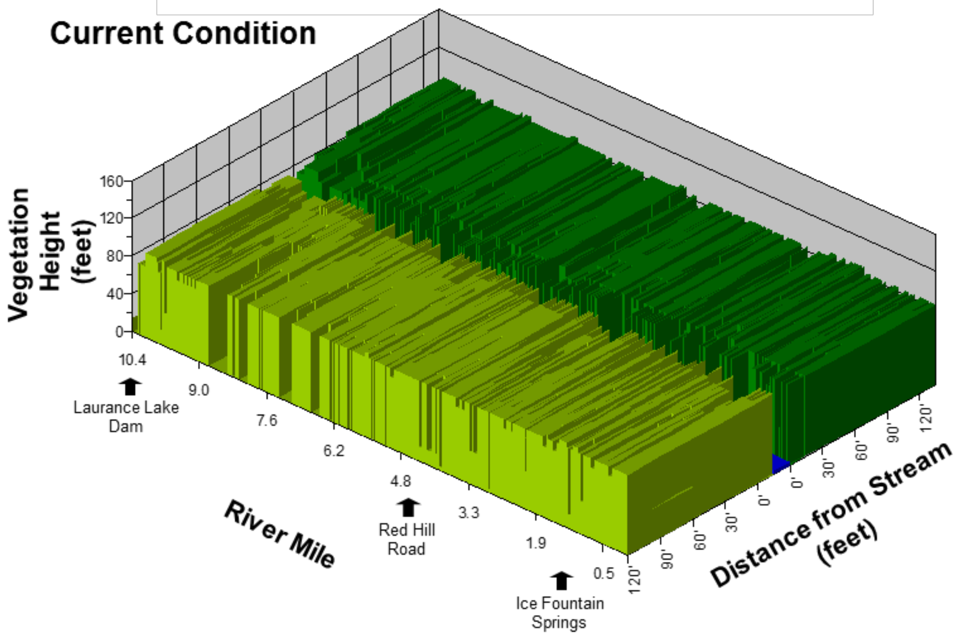


Figure 22. Middle Fork Hood River Near Stream Vegetation Distribution





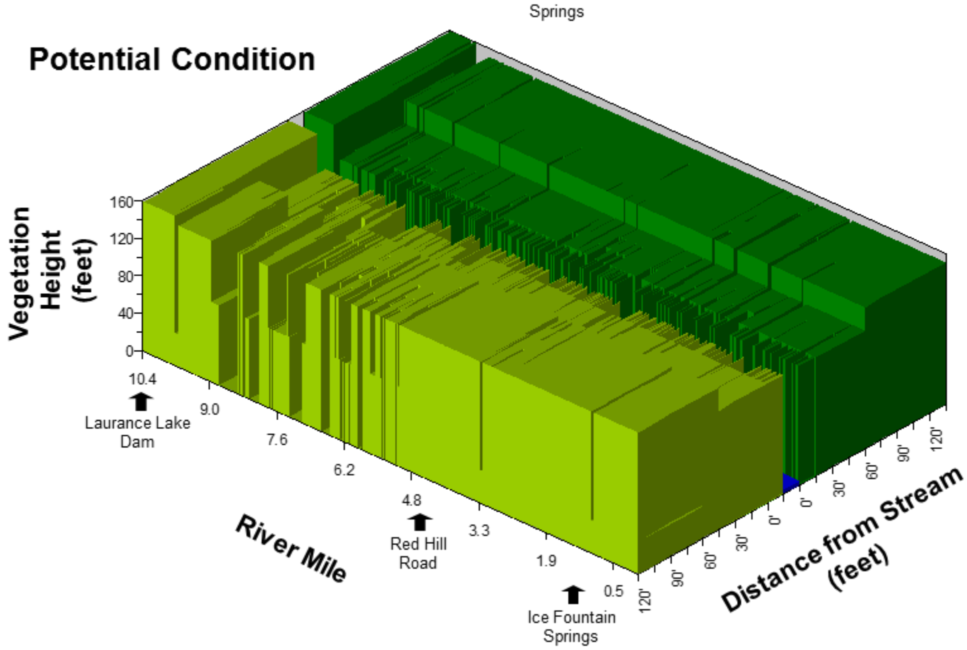
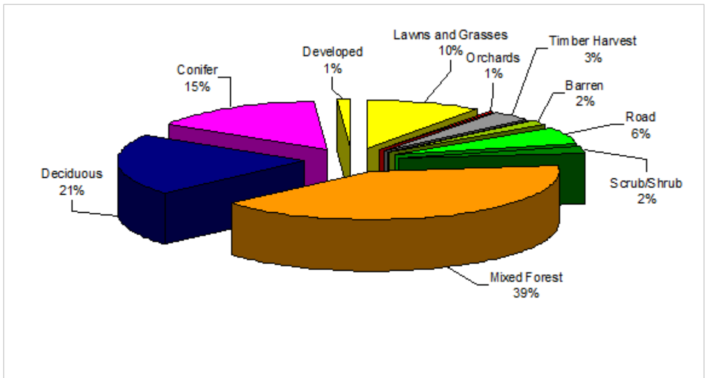
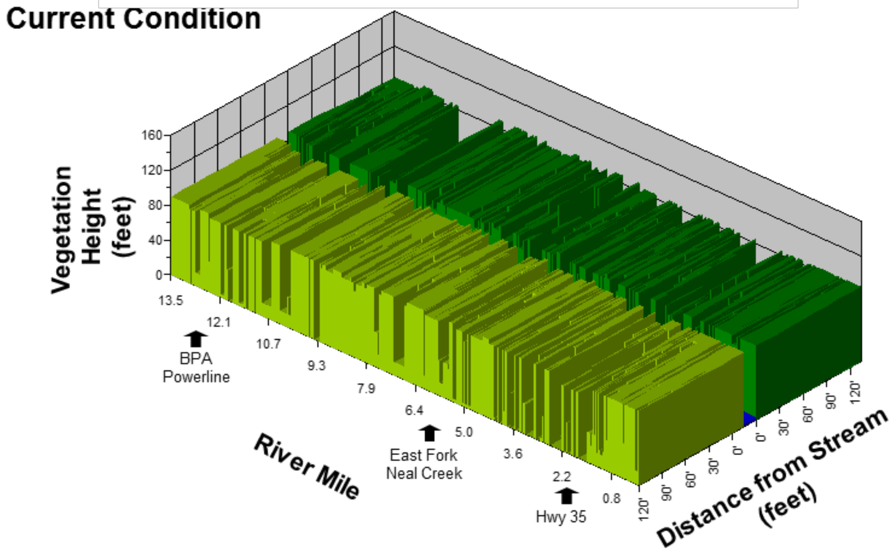


Figure 23. Neal Creek Near Stream Vegetation Distribution





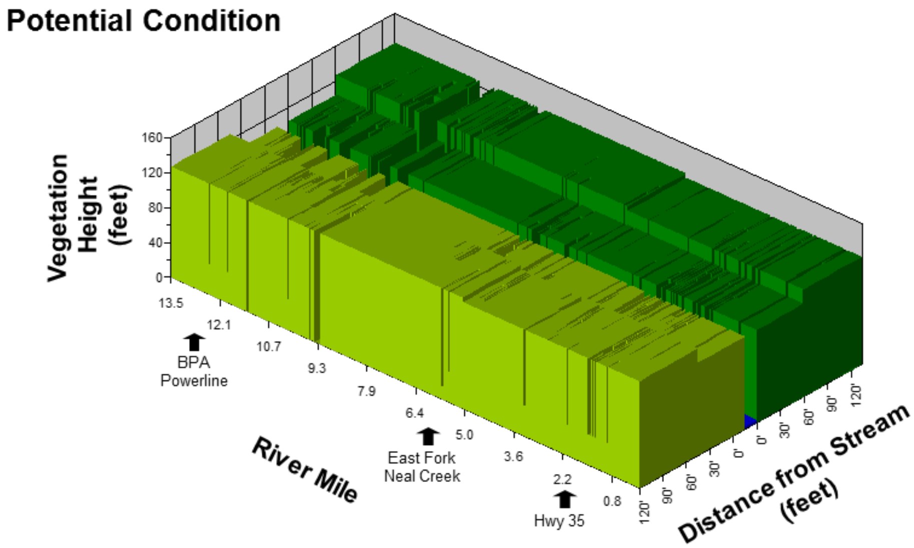
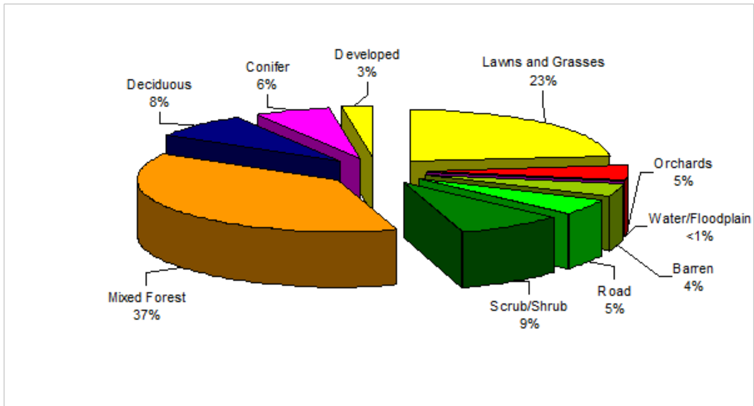
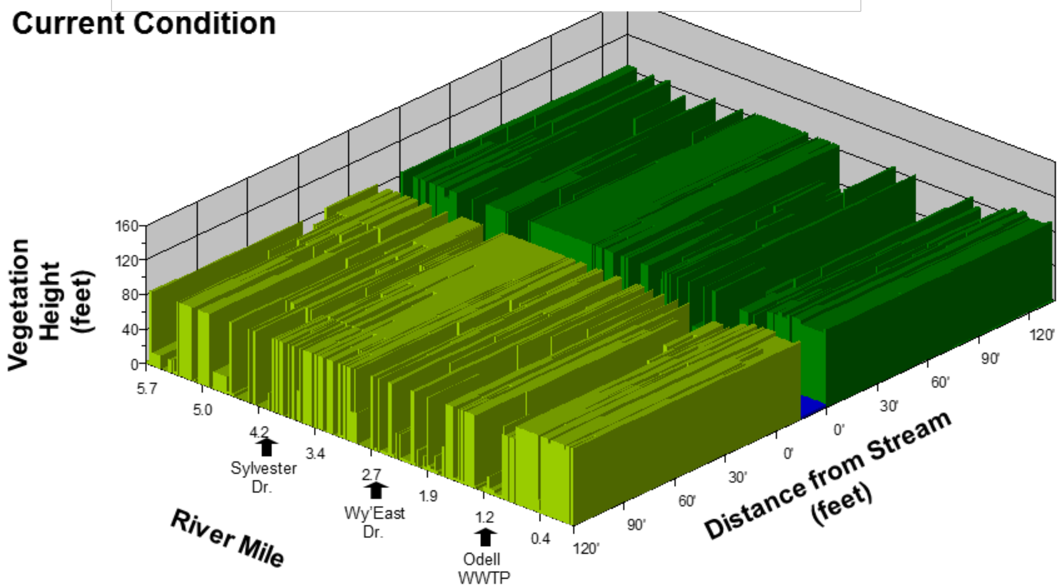


Figure 24. Odell Creek Near Stream Vegetation Distribution





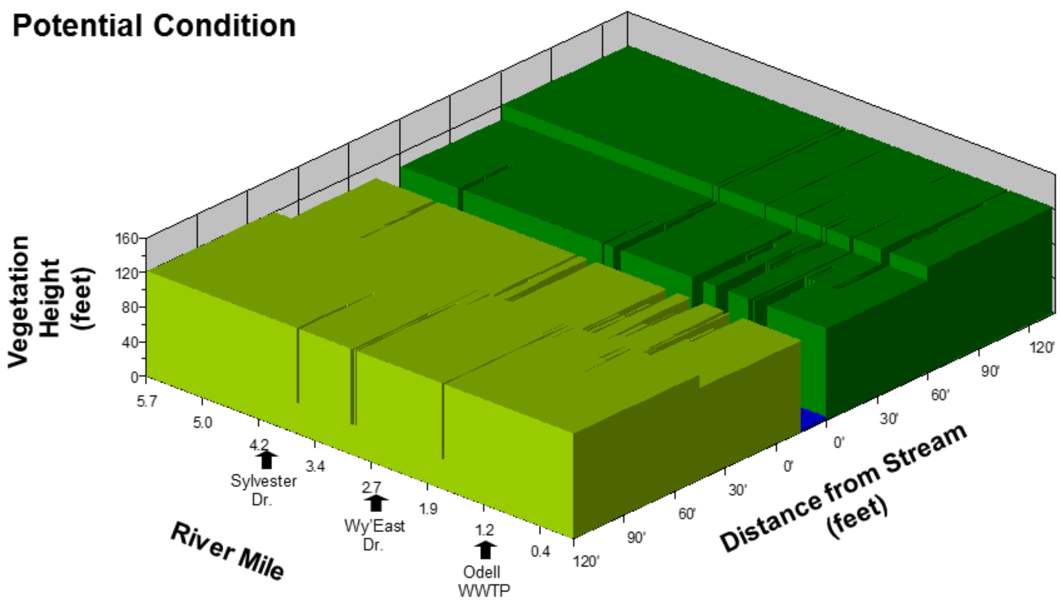


Figure 25. Trout Creek Near Stream Vegetation Distribution

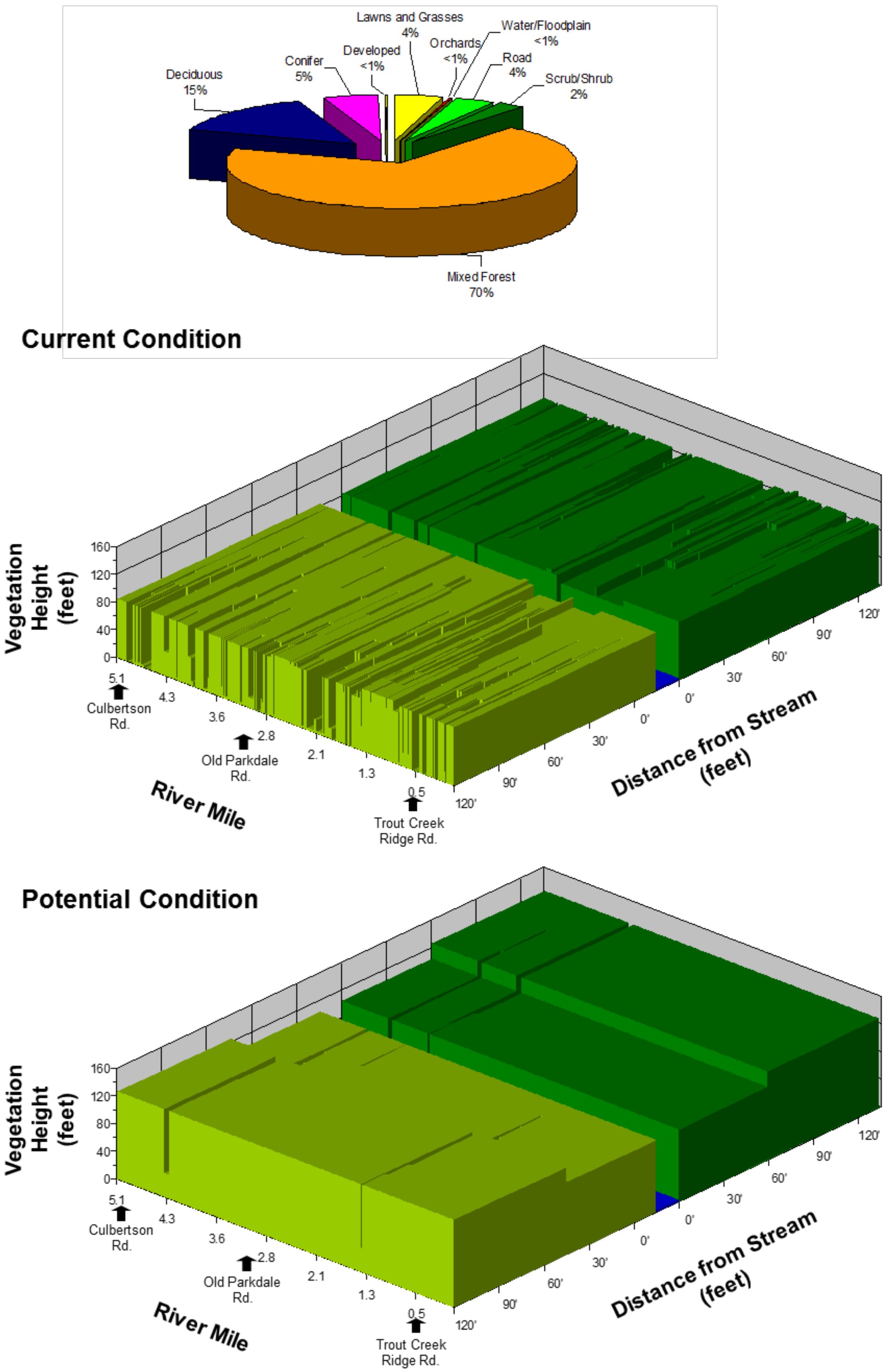
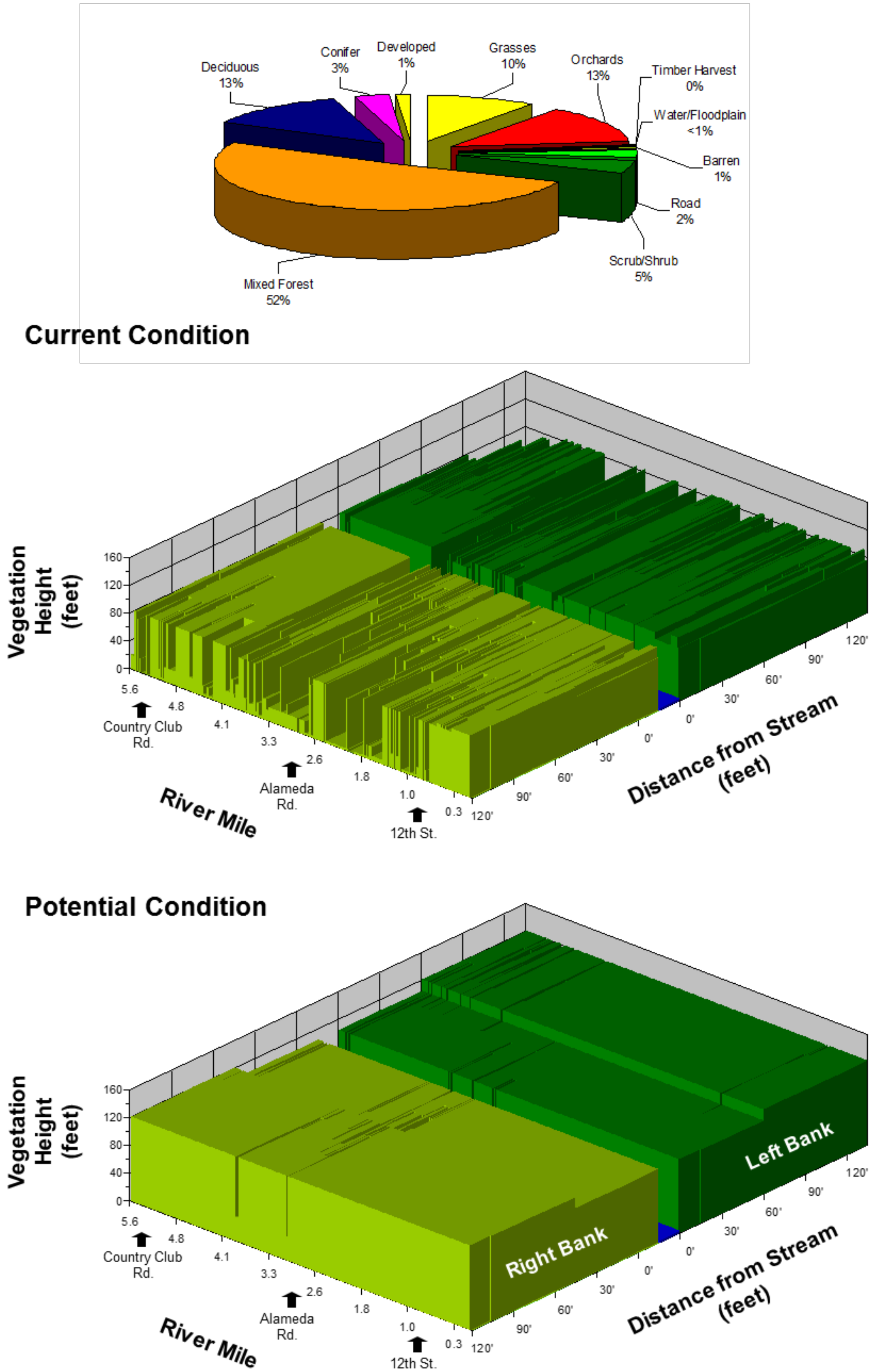


Figure 26. Indian Creek Near Stream Vegetation Distribution



4.5.3.1.2.2 Potential Condition

System potential effective shade occurs when near stream vegetaion is at a climax life stage. A climax life stage is represented by the following conditions:

- Vegetation is mature and undisturbed;
- Vegetation height and density is at or near the potential expected for the given plant community;
- Vegetation is sufficiently wide to maximize solar attenuation; and
- Vegetation width accommodates channel migrations.

System potential vegetation in the Western Hood Subbasin was developed by the Mt. Hood National Forest (Bruce Holmson, Sliviculturist), the Oregon Department of Forestry (Larry Hoffman, Unit Forester and Doug Thiesies, Forest Practices Act Forester) and ODEQ staff (**Table 8**). Potential vegetation zones were developed based on the Mt. Hood National Forest Plant Associations for Ponderosa Pine (Topik et al., 1988), Douglas Fir (Topik et al.,1988), Western Hemlock (Halverson et al.,1986), Grand Fir (Topik et al., 1988), Pacific Silver Fir (Hemstrom et al., 1982), and Mountain Hemlock Zones (Diaz et al., 1997). The geographic distribution of these zones were obtained from the Mt. Hood National Forest GIS data layer and modified using best professional judgement to include lands off-forest (**Figure 27**).

Automated near stream vegetation sampling was repeated to determine the potential condition for each stream reach, replacing the heights and densities in **Table 7** with those in **Table 8** by potential vegetation zone. All current conditions near stream vegetation classes were replaced with the potential heights with the exception of polygons which had been designated as having limited system potential for natural reasons (such as a lava flow or a steep embankment) or that had been coded as "shorter deciduous forest". The "shorter deciduous forest" primarily reflected streambank areas dominated by alders. Based on best professional judgement, ODF, ODEQ, and Mount Hood National Forest staff decided that this shorter deciduous component should be included in the potential condition scenario to reflect the continued natural disturbance expected from flooding and fires in the watershed.

Table 8. Potential Vegetation Zones in the Western Hood Subbasin

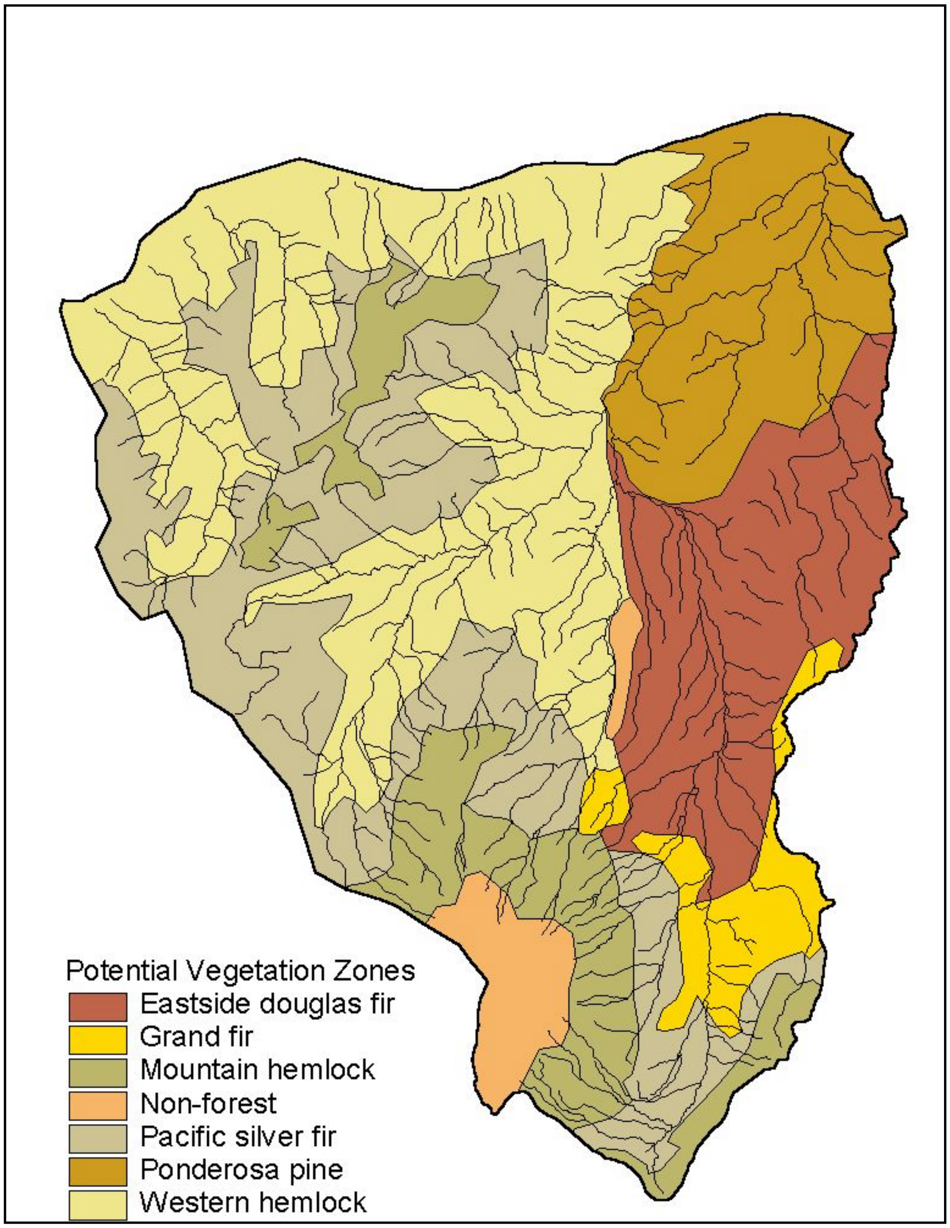
(Data gathered from Mt. Hood National Forest Plant Association Guides, personal communications with Larry Hoffman & Doug Thiesies [ODF] and Bruce Holmson [Mt. Hood National Forest], and the Hood River Watershed Assessment [1999])

Vegetation Zone	Historic Condition Notes	Potential Overstory Near Stream Vegetation Characteristics		
		Vegetation	Height (feet)	Assumed Canopy Density
Ponderosa Pine		**50 feet closest to stream**		
		Red Alder	55	
		Cottonwood	100	
		Oregon White Oak	70	
		Bigleaf Maple	65	
		Ponderosa Pine	130	
		Douglas Fir	150	
		Grand Fir	140	
		Western Red Cedar	140	
		Composite Dimension *(50% hardwoods/50% conifers)*	**106 feet**	**85%**
	Pine-oak forests probably dominated. Today rural residential development, orchards, pastureland, and some urbanization are common.	**Greater than 50 feet from stream**		
		Oregon White Oak	70	
		Bigleaf Maple	65	
		Ponderosa Pine	130	
		Douglas Fir	150	
	Lower elevation, dryer sites	***Composite Dimension*** *(75% conifer/25% hardwoods)*	**122 feet**	**70%**
Eastside Douglas Fir		**50 feet closest to stream**		
		Red Alder	55	
		Cottonwood	100	
		Oregon White Oak	70	
		Bigleaf Maple	65	
		Ponderosa Pine	130	
		Douglas Fir	150	
		Grand Fir	140	
		Western Red Cedar	130	
		Composite Dimension *(50% hardwoods/50% conifers)*	**105 feet**	**85%**
		Greater than 50 feet from stream		
		Oregon White Oak	70	
		Bigleaf Maple	65	
		Ponderosa Pine (10%)	130	
		Douglas Fir (75%)	150	
		Grand Fir (15%)	140	
	Lower elevation, dryer sites	***Composite Dimension*** *(75% conifer/25% hardwoods)*	**127 feet**	**80%**

Table 8. Potential Vegetation Zones in the Western Hood Subbasin (continued)

	Potential Overstory Near Stream Vegetation Characteristics			
	Historic Condition	**Vegetation**	**Height**	**Assumed Canopy Density**
Western Hemlock	In the lower valley the landscape was a mixture of vegetation types. Oak patches would have been common along with conifers, maples, alder and wetland meadows. Today rural residential development, orchards, pastureland, and some urbanization are common. Lower elevation, wetter sites.	**50 feet closest to stream** Red Alder Cottonwood Bigleaf Maple Western Hemlock Douglas Fir Western Red Cedar Noble Fir Grand Fir ***Composite Dimension*** *(50% hardwoods/50% conifers)*	 80 100 70 190 190 150 170 140 **126 feet**	**85%**
		Greater than 50 feet from stream Bigleaf Maple Western Hemlock Douglas Fir Grand Fir Western Red Cedar Noble Fir ***Composite Dimension*** *(90% conifer/10% hardwoods)*	 70 150 190 140 150 170 **151 feet**	**80%**
Grand Fir	Higher elevation, dryer sites	**30 feet closest to stream** Cottonwood Bigleaf maple Grand Fir Douglas Fir Ponderosa Pine Western Red Cedar ***Composite Dimension*** *(50% hardwoods/50% conifers)*	 100 70 140 170 130 130 **114 feet**	**85%**
		Greater than 30 feet from stream Bigleaf Maple Grand Fir Douglas Fir Ponderosa Pine ***Composite Dimension*** *(90% conifer/10% hardwoods)*	 70 150 170 130 **142 feet**	**80%**
Pacific Silver Fir	3000-5000 feet in elevation, varied precipitation	Pacific Silver Fir Western Hemlock Douglas Fir Western Red Cedar Noble Fir Western White Pine Englemann Spruce ***Composite Dimension***	170 170 180 160 180 150 110 **160 feet**	**80%**
Mountain Hemlock	Cold, upper-elevation sites with deep snowpacks and short growing season. Susceptible to large, high intensity fires (lightning).	Pacific Silver Fir Mountain Hemlock Subalpine Fir Lodgepole Pine Western White Pine ***Composite Dimension***	130 140 120 110 140 **128 feet**	**80%**

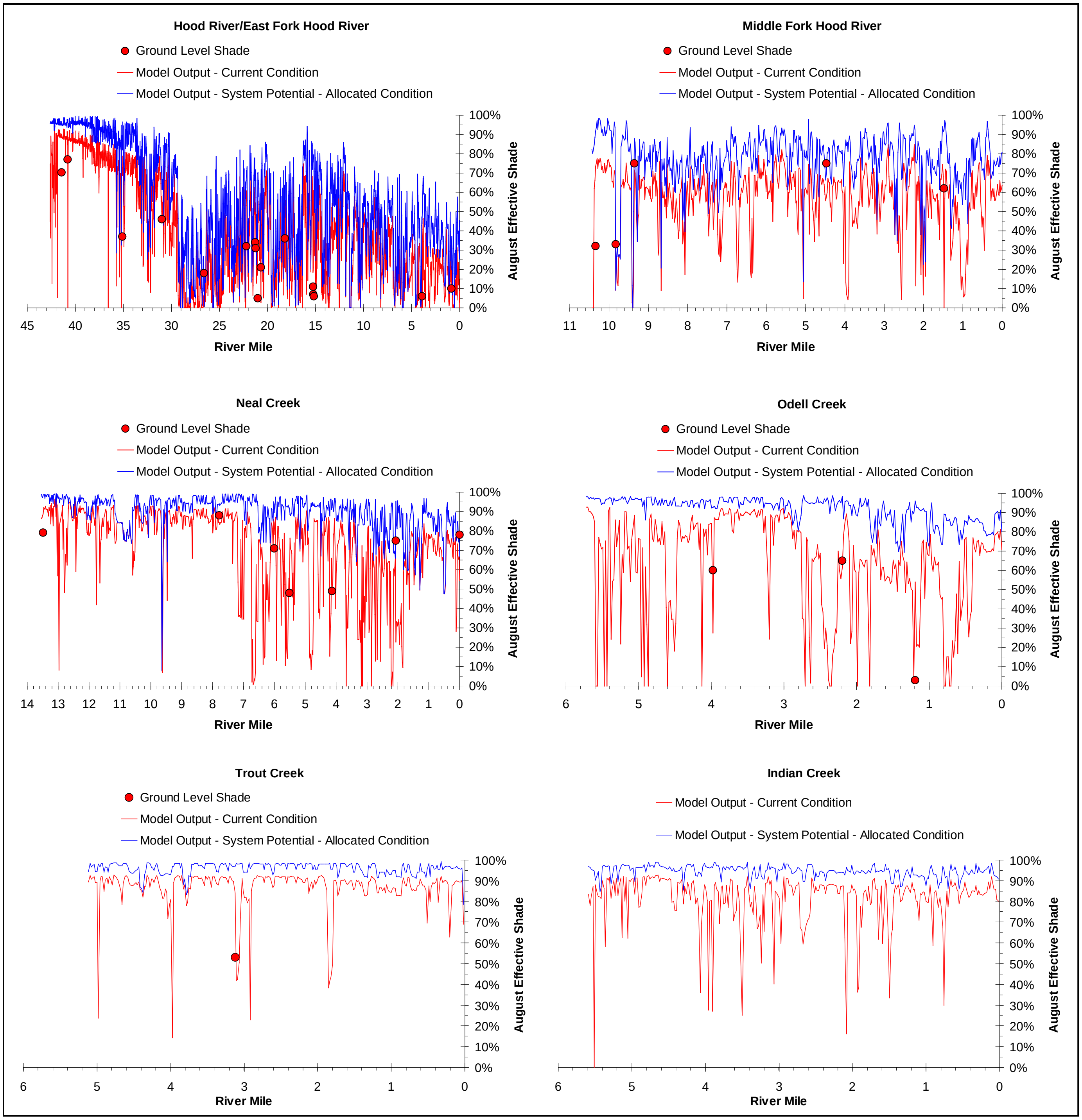
Figure 27. Potential Vegetation Zones, Western Hood Subbasin



4.5.3.1.3 Western Hood Subbasin Shade Conditions

A comparison of effective shade profiles under current conditions and system potential is shown in **Figure 28**. In addition to the simulated conditions, this figure also displays data points where ground level shade measurements (measurements taken to ground-truth model predictions) were taken during the summer of 1998.

Figure 28. Effective Shade Profiles – Current Condition and System Potential



4.5.3.1.4 Western Hood Subbasin Thermal Response Simulations

To assess the thermal response of stream temperature to changes in vegetation, simulations were performed with the Heat Source model using current vegetation conditions and system potential vegetation conditions. August 6, 1998 was selected as the date representing critical summer conditions to use in running model simulations. Simulations were done for stream reaches where sufficient data had been collected during the first week of August, 1998. These reaches included 23.6 miles of the main stem Hood River and the East Fork Hood River (from the mouth of the Hood River to a point about 2 miles upstream of the East Fork Irrigation District Diversion) and 7.8 miles of Neal Creek (from the mouth to the point where the East Fork Irrigation District (EFID) Ditch enters Neal Creek) (**Figure 29**). Simulations at system potential were performed by increasing stream vegetation to potential height, width and density as described in **Section 4.5.3.1.2.2 Potential Condition**. The results of the simulations are presented in **Figures 30** and **31**. Significant reductions in daily maximum stream temperature resulted from system potential conditions. Diurnal temperature fluctuations were also moderated. Daily minimum stream temperatures were reduced slightly.

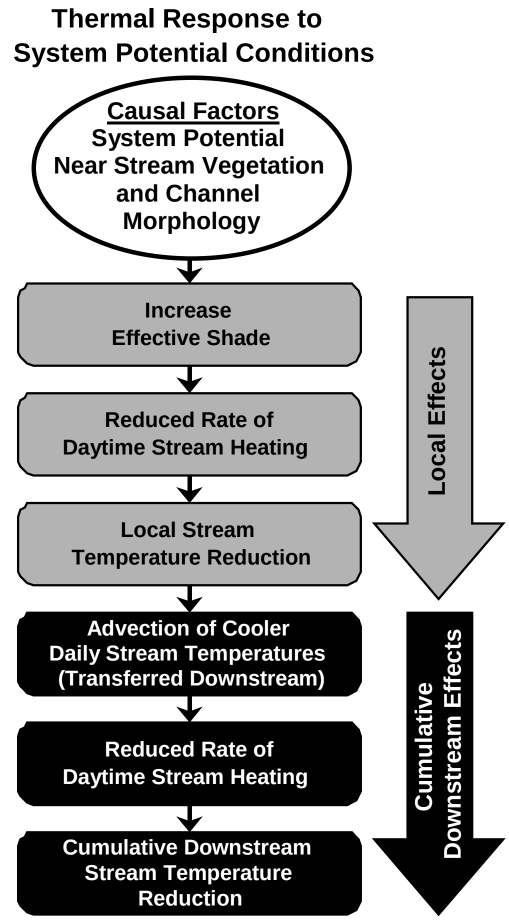


Figure 29. Stream Segments Modeled to Assess Thermal Responses to Changes in Riparian Vegetation and Flow

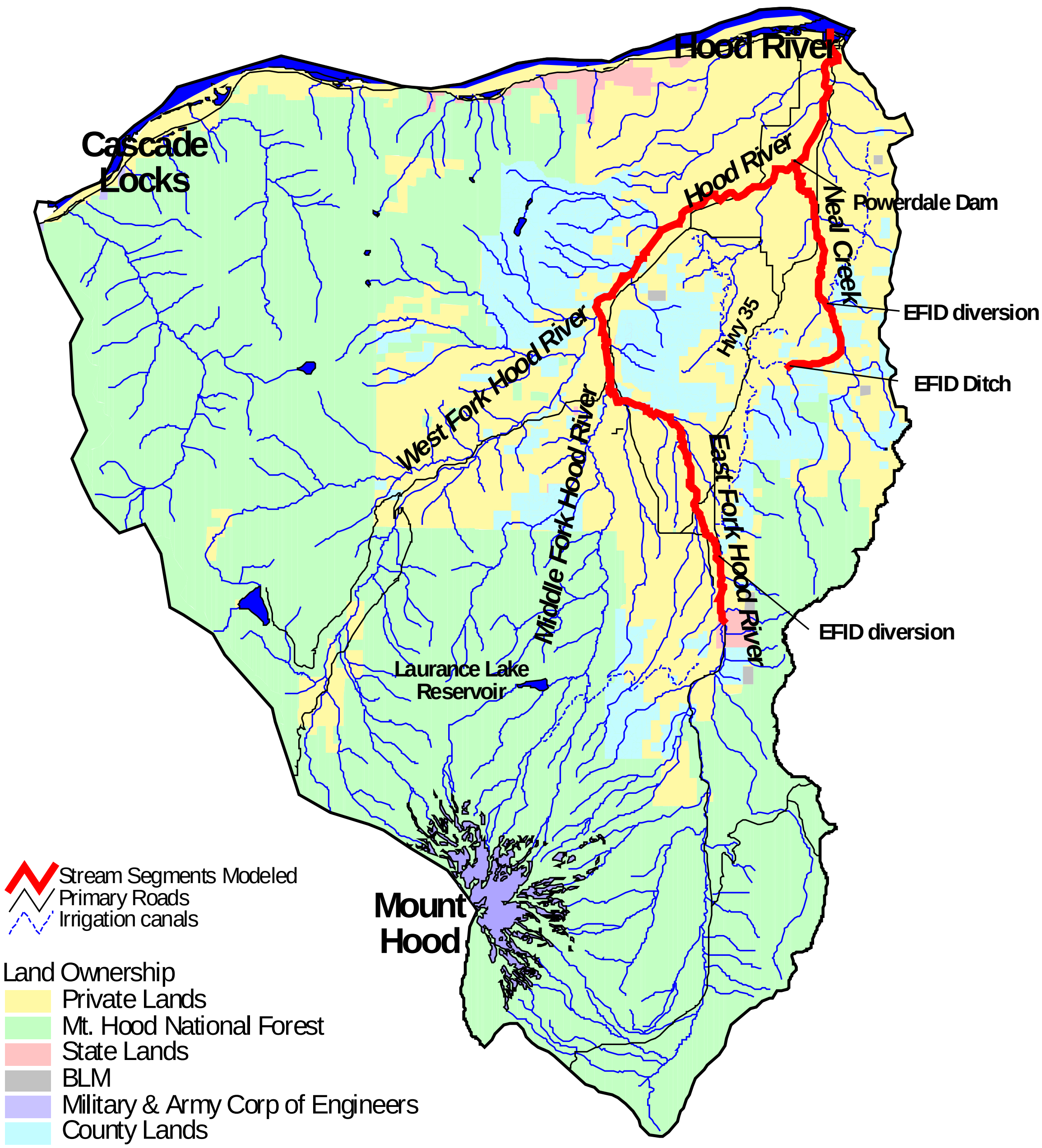


Figure 30. Hood River/East Fork Hood River Diurnal Temperatures: Current Condition Shade and Potential Shade (August 6, 1998)

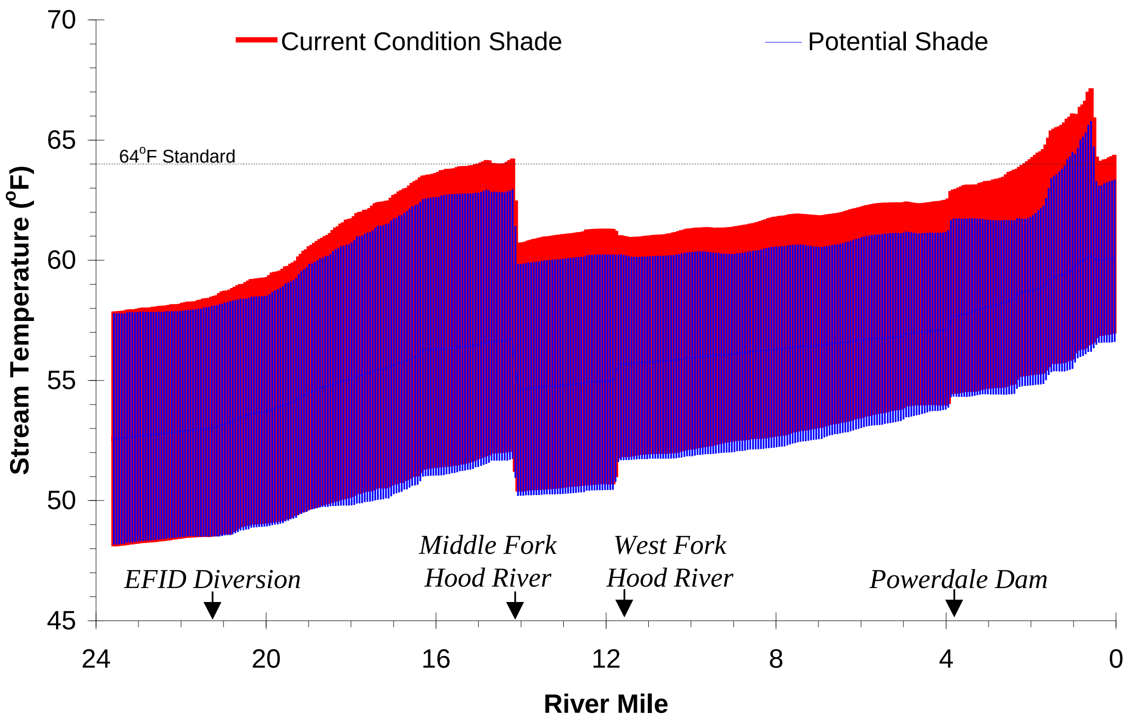
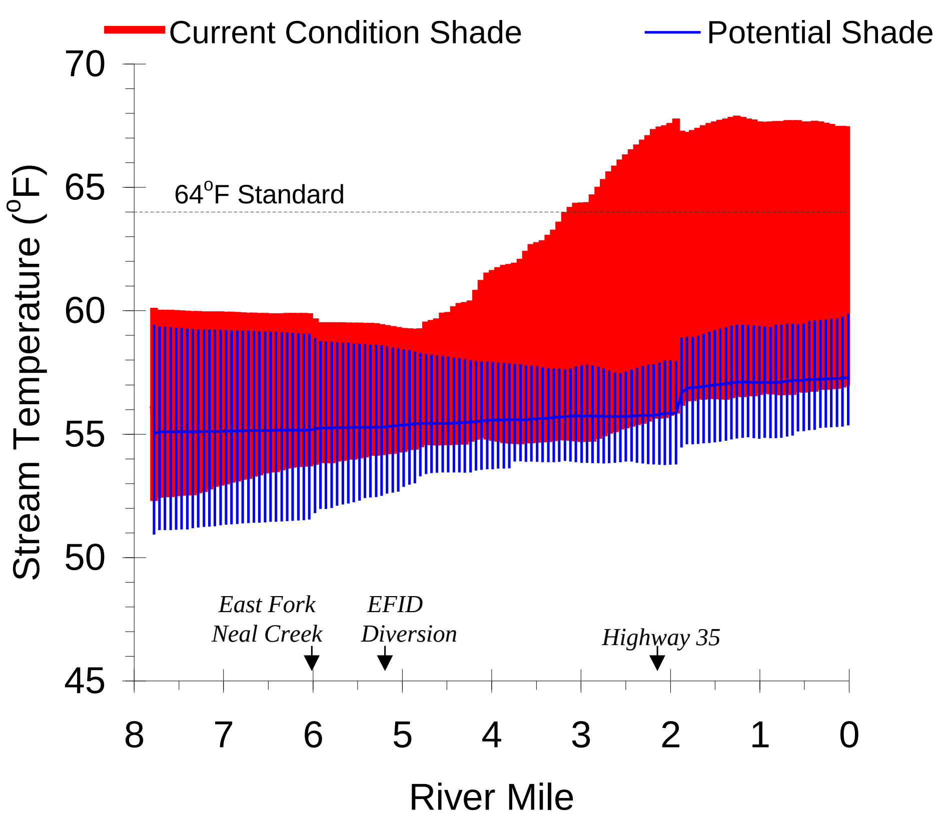


Figure 31. Neal Creek Diurnal Temperatures: Current Condition Shade and Potential Shade (August 6, 1998)



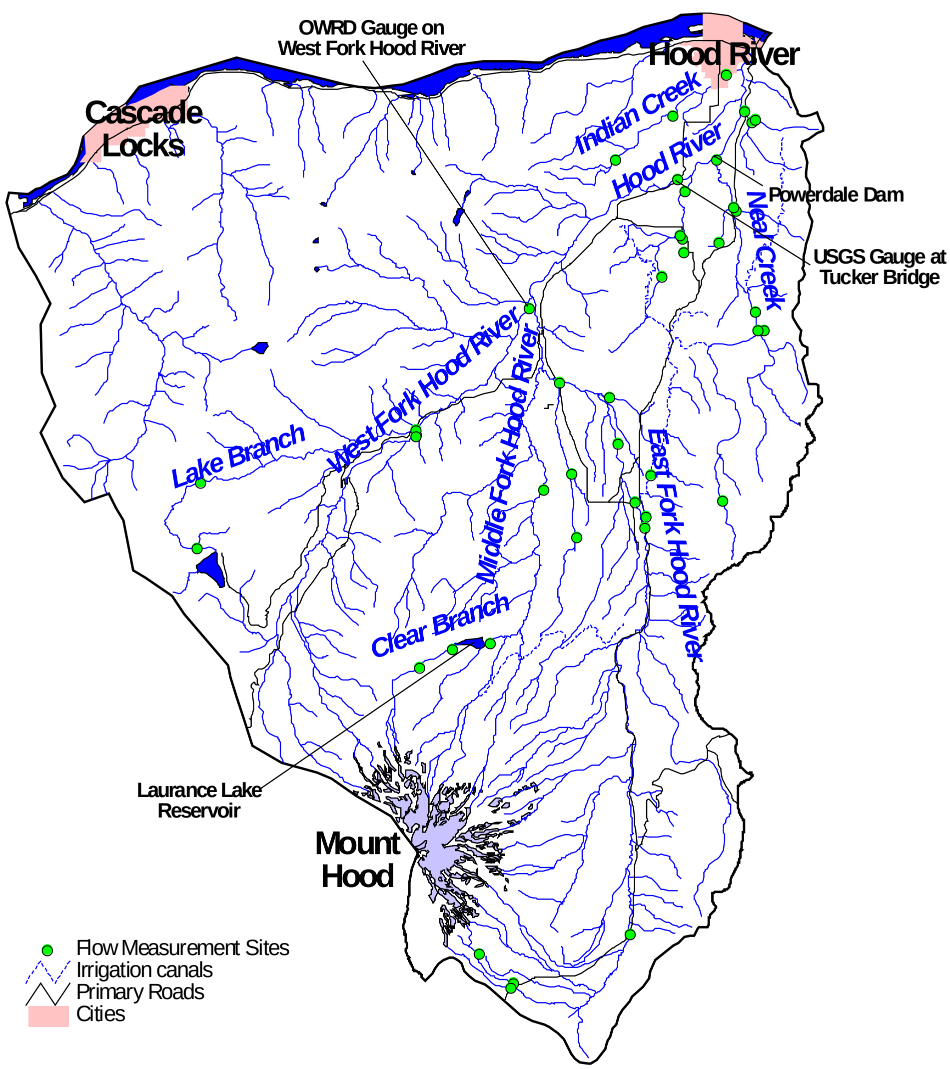
4.5.3.2 Flow

4.5.3.2.1 Western Hood Subbasin Flow Conditions

Stream temperature change is generally inversely related to flow volume. As flows decrease, stream temperature tends to increase if energy processes remain unchanged (Boyd, 1996). Runoff in the Western Hood Subbasin is primarily derived from rainfall precipitation and snow melt, with peak runoff typically occurring in the winter. Late summer low flows are common for many streams in the watershed due to low summer precipitation and water withdrawals. 7Q10[2] low flows were calculated for the two currently gauged rivers: Hood River at Tucker Bridge - 201 cfs and West Fork Hood River near Dee - 102 cfs.

In addition to the two active gauging stations, stream flow was sampled throughout the Hood River watershed in August, 1998 by ODEQ staff (**Figure 32**).

Figure 32. ODEQ Flow Measurement Sites, August 3-7, 1998



[2] 7Q10 low flow is the average seven day interval with a return period of 10 years. This condition has a 10% probability of occurring during any one year.

Stream flow is used extensively for calculating Manning's equation for stream velocity and average wetted depth.

Manning's Equation,

$$Q = A \cdot V = 1.49 \cdot A \cdot \frac{1}{n} \cdot R_h^{\frac{2}{3}} \cdot S^{\frac{1}{2}}$$

which can be rearranged to calculate velocity,

$$V = 1.49 \cdot \frac{1}{n} \cdot R_h^{\frac{2}{3}} \cdot S^{\frac{1}{2}}$$

where,

- Q: Stream flow volume (ft^3/s)
- V: Stream velocity (ft/s)
- A: Wetted cross-sectional area (ft^2)
- R_h: Hydraulic radius (ft)
- S: Stream gradient
- n: Mannings's n

In addition to affecting wetted channel dimensions, stream velocity is used in the hydraulic routing of water downstream. Advection, the movement of water, is the primary means of mass transfer of water in the downstream direction. Travel times are largely a function of stream velocity. Therefore, the effect of stream velocity is considerable in the temperature response of a stream system. Not only does stream velocity help shape the wetted channel (and the surface areas exposed to thermodynamic processes), but exposure times are also largely controlled by the rate of advective transfer of water downstream.

4.5.3.2.2 Groundwater Mixing

Groundwater inflow has a cooling effect on summertime stream temperatures. Subsurface water is insulated from surface heating processes. Groundwater temperatures fluctuate little and are typically cool (45°F to 55°F). Many land use activities that disturb riparian vegetation and associated flood plain areas may affect the surface water connectivity to groundwater sources. Groundwater inflow not only cools summertime stream temperatures, but also augments summertime flows. Reductions or elimination of groundwater inflow will have a compounding warming effect on surface water. The ability of riparian soils to capture, store and slowly release groundwater is largely a function of floodplain/riparian area health.

The effects of groundwater were not analyzed in the Western Hood Subbasin TMDL effort, although it is anticipated that groundwater probably does affect stream thermal conditions in some locations, such as the Middle Fork Hood River. The data required to completely assess the thermal effects of groundwater, such as forward-looking infrared radiometry (FLIR) have not been collected in the Western Hood Subbasin. FLIR, collected via remote sensing, provides the best tool to identify and analyze groundwater and surface stream temperature interactions. ODEQ recommends such data collection for future groundwater/stream analysis.

4.5.3.2.3 Western Hood Subbasin Thermal Response Simulations

To assess the thermal response of stream temperature to changes in flow, simulations were performed using current flow conditions, "natural" flow conditions (no diversions), and several scenarios in between those conditions removing each of the major diversions in the Hood River system. The analysis used estimated average water use in August, 1998. August 6, 1998 was selected as the date representing critical summer conditions to use in running model simulations. Simulations were done for stream reaches where sufficient data had been collected during the first week of August, 1998 and where there was sufficient information to project "natural" flow conditions. These reaches included 23.6 miles of the main stem Hood River and the East Fork Hood River – from the mouth of the Hood River to a point about two miles upstream of the East Fork Irrigation District Diversion. To arrive at the natural flow conditions simulation, all known anthropogenic diversions from the Hood River watershed were removed (**Table 9**).

All simulations are presented in **Figure 33**. Significant reductions in daily maximum and minimum stream temperature resulted from natural flow conditions, as well as from the removal of the East Fork Irrigation District diversion from the East Fork Hood River. Removal of Powerdale Dam also showed a significant reduction in daily maximum temperatures in the reach of the Hood River below Powerdale Dam.

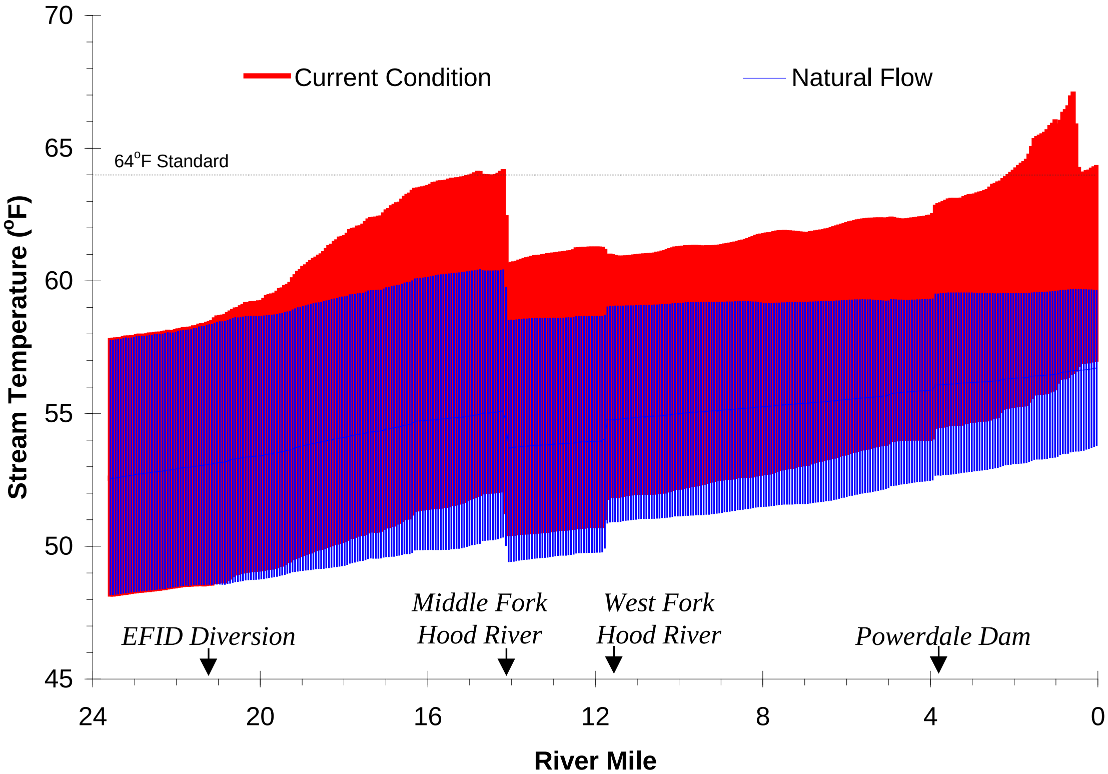
It should be noted that this analysis of stream flow relative to temperature has been done to demonstrate that improved stream flow can improve stream temperatures. It will not be used, however, as a basis for a requirement in this TMDL that out-of-stream flow diversions be reduced or eliminated. Control or limitations on flow or water rights are outside the authority of a TMDL, with the exception of flows required in the 401 Certification for the Powerdale Hydroelectric Project. These flow simulations do provide, however, a good reason for water users to efficiently use their allocated water so that the amount of diverted water is minimized.

Table 9. Estimated Anthropogenic Diversions in the Hood River Watershed for August, 1998

(Data gathered from the Hood River Watershed Assessment (1999), the Tucker bridge gauge station, personal communication with Tod Hilstad (Farmers Irrigation District), Brian Connors (Middle Fork Irrigation District), John Buckley (East Fork Irrigation District) and Dave Anderson (The Dalles Public Works Department), and from field measurements by ODEQ staff)

Source of Diversion	Organization	Estimated Average Use (cfs)
East Fork Hood River Watershed		
Dog River	City of The Dalles	3
Crystal Springs	Crystal Springs Water District	4
East Fork Hood River	East Fork Irrigation District	141
Evans Creek	Middle Fork Irrigation District	1
Emil Creek	Middle Fork Irrigation District	1
Trout Creek	Middle Fork Irrigation District	2.1
Middle Fork Hood River Watershed		
Laurence Lake	Middle Fork Irrigation District	49
Coe Branch	Middle Fork Irrigation District	19
Eliot Branch	Middle Fork Irrigation District	20
Rogers Creek	Middle Fork Irrigation District	5
Tony Creek	Aldridge Irrigation Company	1
Ice Fountain Springs	Ice Fountain Water District	1
West Fork Hood River Watershed		
Various tributaries, including Green Point Creek	Farmers Irrigation District	25
West Fork Hood River & various tributaries (Camp, Alder, No Name, Deer Creeks)	Dee Irrigation District	13
Cold Springs	City of Hood River	2
Stone Springs	City of Hood River	4
Mainstem Hood River Watershed		
Hood River	Farmers Irrigation District	70
Hood River	PacifiCorp (Powerdale Dam)	405

Figure 33. Hood River/East Fork Hood River Diurnal Temperatures: Current Condition Flow and Projected Conditions with Removal of Diversions (August, 1998)



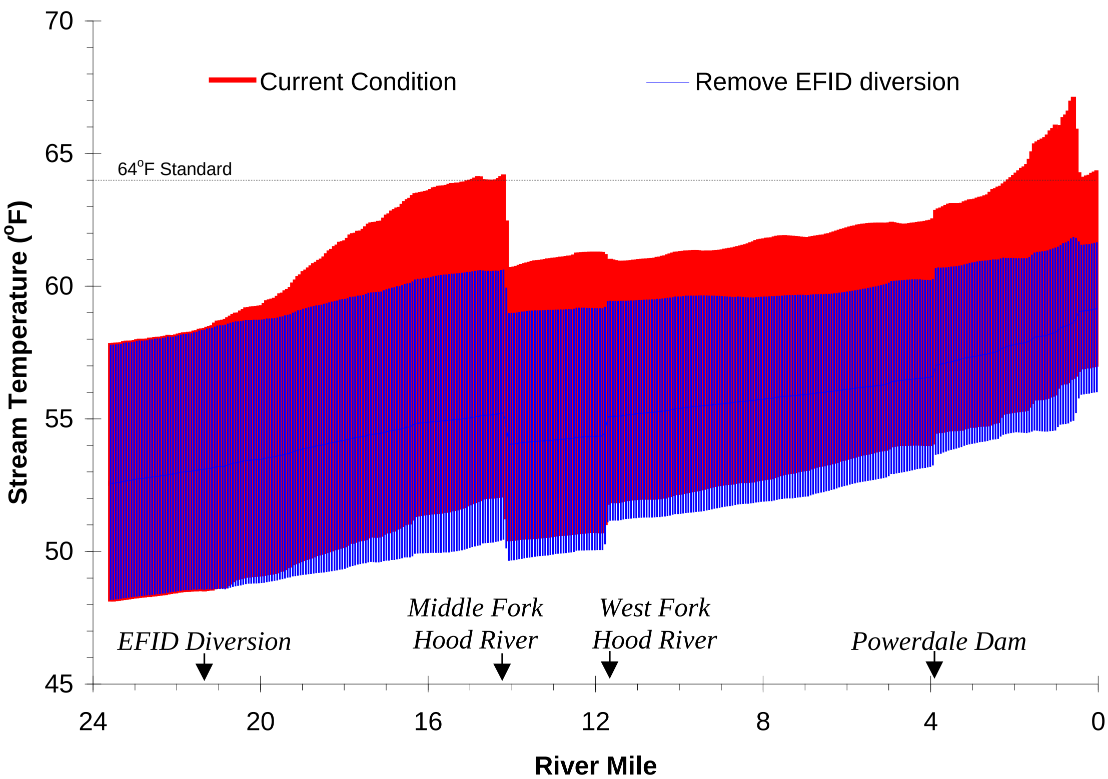
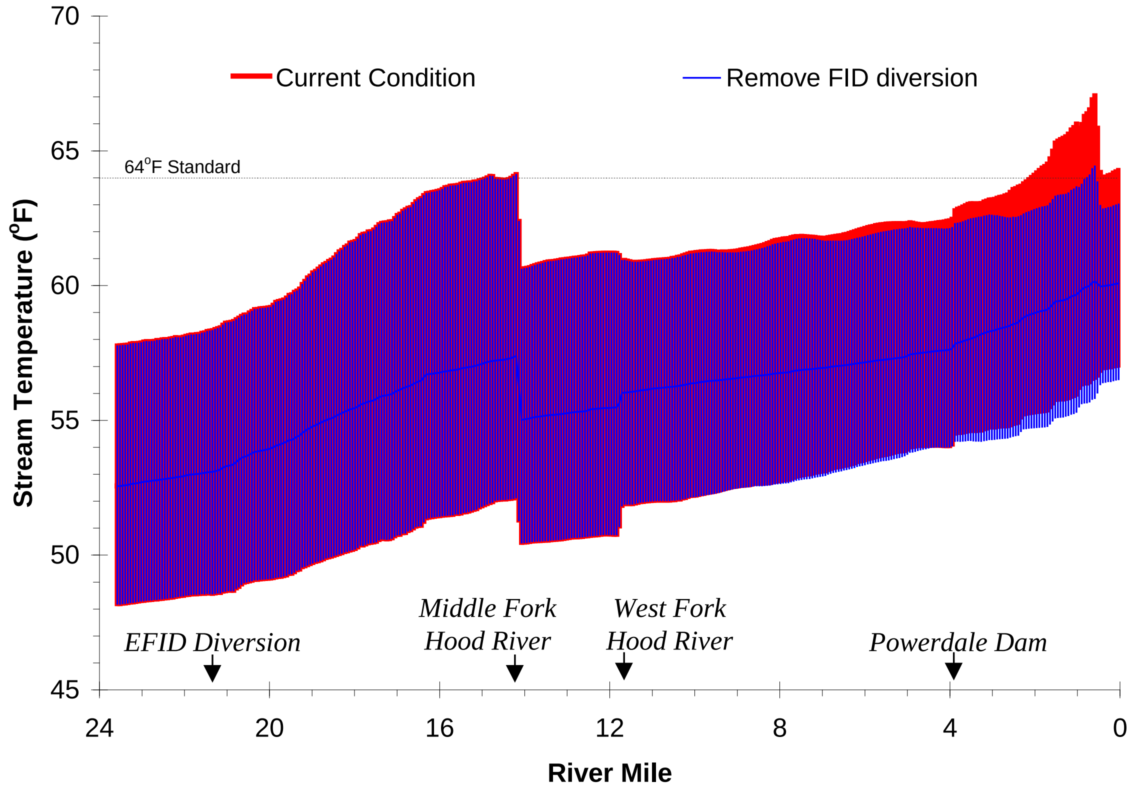
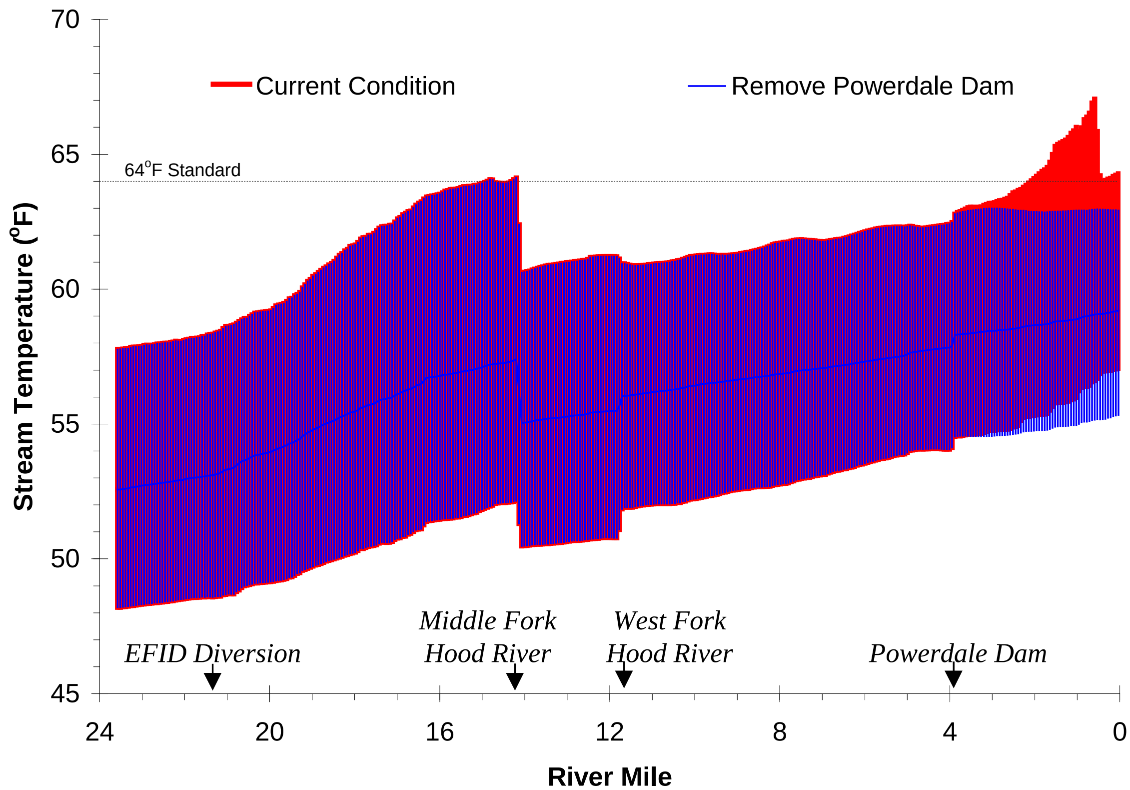


Figure 33. Hood River/East Fork Hood River Diurnal Temperatures: Current Condition Flow and Projected Conditions with Removal of Diversions (continued)





4.5.3.3 Channel Morphology

Changes in channel morphology, namely channel widening, impact stream temperatures. As a stream widens, the surface area exposed to radiant sources and ambient air temperature increases, resulting in increased energy exchange between the stream and its environment (Boyd, 1996). Further, wide channels are likely to have decreased levels of shade due to simple geometric relationships between riparian height and channel width. Conversely, narrow channels are more likely to experience higher levels of shade. An additional benefit inherent to narrower/deeper channel morphology is a higher frequency of pools that contribute to aquatic habitat or cold water refugia.

Channel morphology was not targeted directly in this TMDL. Because of glacial influences on the East Fork Hood River and Hood River, the local stakeholder committee advised ODEQ that changes in channel morphology were not likely to have a significant impact on temperature in the East Fork Hood River or the mainstem Hood River. The committee and ODEQ did feel that it was important to acknowledge the important role that channel morphology can play in regulating stream temperatures, particularly in smaller tributaries, such as Indian Creek, Odell Creek and Neal Creek. A brief discussion of channel morphology is presented here.

4.5.3.3.1 Channel Width

The width to depth ratio is a fundamental measure of channel morphology. High width to depth ratios (greater than 10.0) imply wide shallow channels, while low width to depth ratios (less than 10.0) suggest that the channel is narrow and deep. In terms of reducing stream surface exposure to radiant energy sources, it is generally favorable for stream channels to be narrow and deep (low width to depth ratios).

Channel widening is often related to degraded riparian conditions that allow increased stream bank erosion and sedimentation of the streambed. Both active stream bank erosion and sedimentation correlate strongly to riparian vegetation type and age. Riparian vegetation contributes to rooting strength and flood plain/stream bank roughness that dissipates erosive energies associated with flowing water. Established mature woody riparian vegetation adds the highest rooting strengths and flood plain/stream bank roughness. Annual (grassy) riparian vegetation communities offer less rooting strength and flood plain/stream bank roughness. It is expected that width to depth ratios would be lower (narrower and deeper channels) when established mature woody vegetation is present. Annual (grassy) riparian communities may allow channels to widen and become shallower.

Further, channel morphology, namely wetted width to depth values, are not solely dependent on riparian conditions. Sedimentation can deposit material in the channel and agrade the streambed, reducing channel depth and increasing channel width. Flow events play a major role in shaping the stream channel. Channel modification usually occurs during high flow events. Naturally, land uses that affect the magnitude and timing of high flow events may negatively impact channel width and depth.

Riparian vegetation conditions will affect the resilience of the stream banks/flood plain during periods of sediment introduction and high flow. Linking width to depth ratios to riparian vegetation is fundamental. Disturbance processes may have drastically differing results depending on the ability of riparian vegetation to shape and protect channels. Low width to depth ratios are thus related to riparian vegetation community composition and condition by:

- ✓ ***Building stream banks:*** *Trap suspended sediments, encourage deposition of sediment in the flood plain and reduce incoming sources of sediment.*
- ✓ ***Maintaining stable stream banks:*** *High rooting strength and high stream bank and flood plain roughness prevent stream bank erosion.*

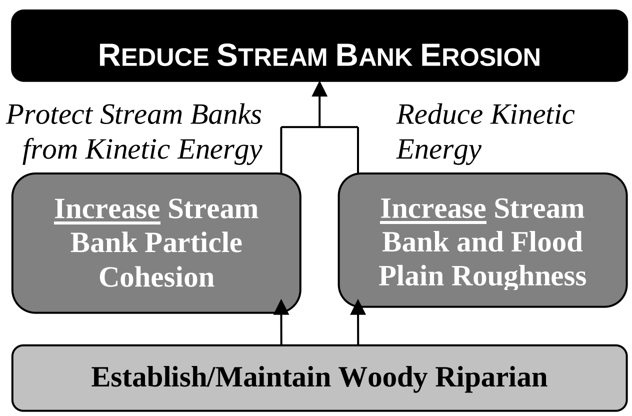
- ✓ ***Reducing flow velocity (erosive kinetic energy):*** *Supplying large woody debris to the active channel, high pool to riffle ratios and adding channel complexity that reduces shear stress exposure to stream bank soil particles.*

4.5.3.3.2 Stream Bank Erosion

Stream bank erosion results from detachment, entrainment and removal of bank material as individual grains or aggregates via fluvial processes. *Stream bank failure* indicates a gravity-related collapse of the stream bank by mass movement. Both *stream bank erosion* and *stream bank failure* result in *stream bank retreat*, which is a net loss of stream bank material and a corresponding widening of the stream channel.

Stream bank stability reflects the condition of riparian vegetation contributing to rooting strength in stream bank soils and flood plain roughness. Riparian vegetation rooting structure serves to strengthen the stream bank and resist the erosive energy exerted on the stream bank during high flow conditions. Flood plain roughness reflects the ability of the flood plain to dissipate erosive flow energy during high flow events that over-top stream banks and inundate the flood plain. Riparian vegetation disturbance often has a compounding effect of increased stream bank erosion, increased kinetic energy exposure, decreased bank rooting strength, loss of soil cohesion and loss of flood plain roughness.

4.5.3.3.3 Stream Bank Protection and Riparian Vegetation



A stream bank erosion recovery process requires the concurrent occurrence of two elements that induce stream bank building: protect stream banks from kinetic energy (bank particle cohesion) and reduce kinetic energy (stream bank/flood plain roughness). High levels of stream bank cohesion tend to protect the stream bank from erosive kinetic energy associated with flowing water. Stream bank erosion reflects looseness of bank soil, rock and organic particles. The opposite condition is cohesion of stream bank soil, rock and organic particles. Vegetation strengthens particle cohesion by increasing rooting strength that helps bind soil and add structure to the stream bank. Different riparian vegetation communities (annual, perennial, deciduous, mixed and conifer dominated) offer a variety of rooting strengths to stream banks. It is a general observation that healthy and intact indigenous riparian vegetation communities will add preferable stream bank cohesion over bare soil and ground conditions.

Physical relationships that relate to decreasing/preventing stream bank erosion can be summarized as:

- ✓ *Rough surfaces decrease local flow velocity,*
- ✓ *Reduced local velocity lowers shear stress acting on the stream bank,*
- ✓ *Lower shear stress acting on the stream bank will be less likely to detach and entrain stream bank particles.*

In an effort to control stream bank erosion processes, the focus is to retain high stream bank and flood plain roughness via riparian vegetation. The species composition and condition of the riparian vegetation determines natural stream bank roughness.