CHAPTER 10: UPPER WILLAMETTE SUBBASIN TMDL

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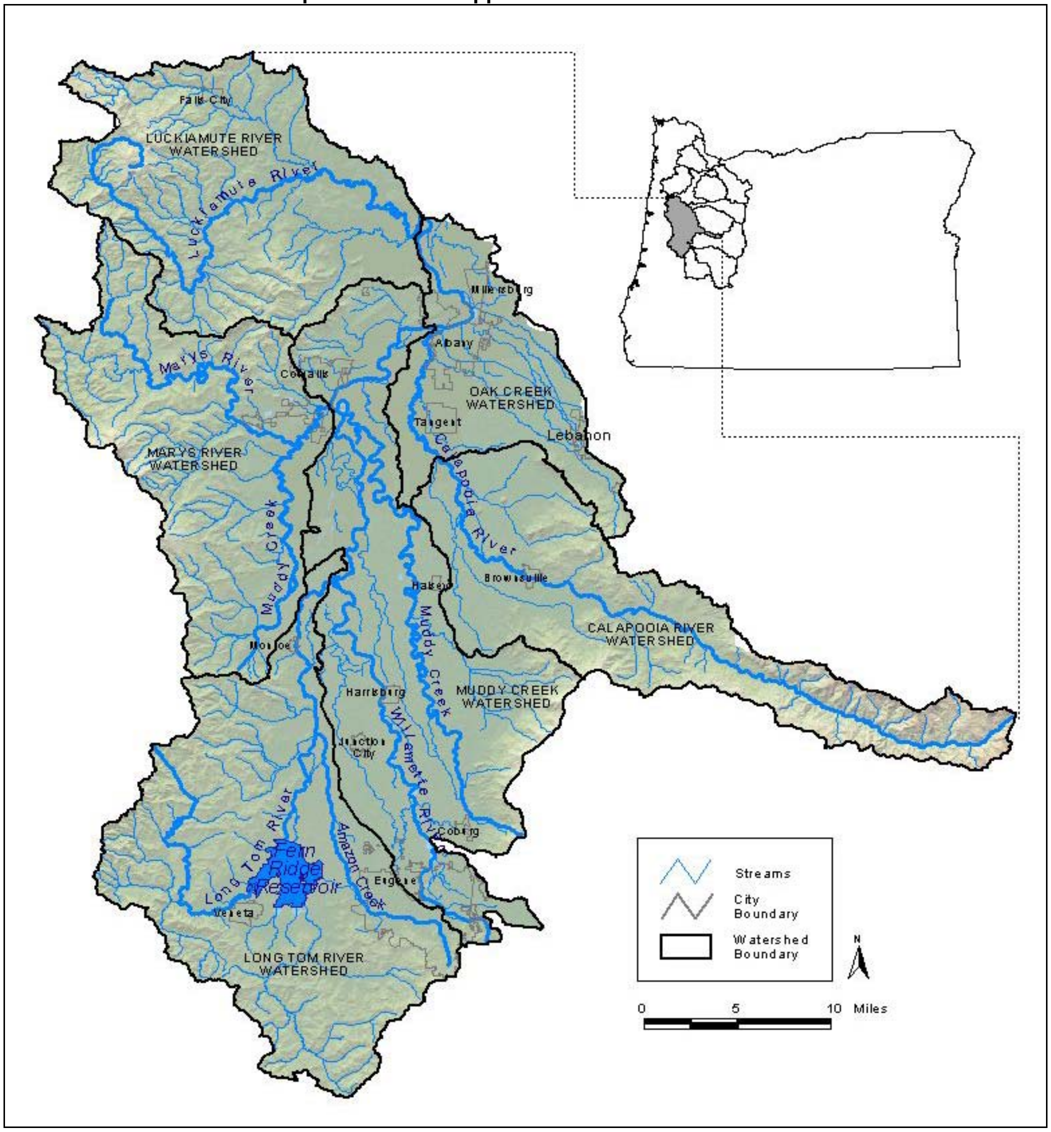
WATER QUALITY SUMMARY

Reason for action

The Upper Willamette Subbasin (Map 10.1) has stream segments listed under section 303(d)[1] of the federal Clean Water Act (CWA) that are exceeding water quality criteria for temperature, bacteria, dissolved oxygen, turbidity and toxics. Total Maximum Daily Loads (TMDLs) for temperature, bacteria, dissolved oxygen and turbidity are developed based on information for these parameters. Wasteload allocations are developed for individual facilities (point sources) that discharge during the critical period. In the case of temperature load allocations for nonpoint sources are developed for each geomorphic unit and apply to all sectors in the subbasin.

Map 10.1 The Upper Willamette Subbasin



This chapter only includes TMDLs for rivers and streams in the Upper Willamette Subbasin. These subbasin rivers and streams are tributary to the Willamette River and the Long Tom River from its mouth to Fern Ridge Reservoir. For the Mainstem Willamette River and the Long Tom River, mouth to Fern Ridge Reservoir, the temperature analysis is included in the mainstem Willamette River TMDLs see Chapter 4. All other subbasin TMDLs are included in Chapters 5 – 13.

[1] The 303(d) list is a list of stream segments that do not meet water quality criteria.

Water Quality 303(d) Listed Waterbodies

OAR 340-042-0040(4)(a)

All current 303(d) listings for the subbasin are presented in Table 10.1.

Table 10. 1 Name and location of listed Upper Willamette Subbasin waterbodies.

Waterbody Name	Listed River Mile	Parameter	Season	Addressed in TMDL
A-3 Drain	mouth to headwaters	Dichloroethylenes	Year Around	No
A-3 Drain	mouth to headwaters	Tetrachloroethylene	Year Around	No
A-3 Drain	mouth to headwaters	Arsenic	Year Around	No
A-3 Drain	mouth to headwaters	Lead	Year Around	No
A-3 Drain	mouth to headwaters	Mercury	Year Around	No
A-3 Drain	mouth to headwaters	E Coli	June 1 - September 30	Yes
A-3 Drain	mouth to headwaters	E Coli	October 1 - May 31	Yes
Amazon Creek	0 to 22.6	Arsenic	Year Around	No
Amazon Creek	0 to 22.6	Lead	Year Around	No
Amazon Creek	0 to 22.6	E Coli	June 1 - September 30	Yes
Amazon Creek	0 to 22.6	E Coli	October 1 - May 31	Yes
Amazon Diversion Canal	0 to 1.8	Dissolved Oxygen	Spring/Summer/Fall	Yes
Amazon Diversion Canal	0 to 1.8	Fecal Coliform	Year Around	Yes
Calapooia River	0 to 42.8	Temperature	Summer	Yes
Calapooia River	0 to 42.8	Fecal Coliform	Winter/Spring/Fall	Yes
Coyote Creek	0 to 26.2	Dissolved Oxygen	Spring/Summer/Fall	Yes
Coyote Creek	0 to 26.2	Fecal Coliform	Year Around	Yes
Ferguson Creek	0 to 10	Temperature	Summer	Yes
Fern Ridge Reservoir/Long Tom River	24.2 to 31.8	Fecal Coliform	Winter/Spring/Fall	Yes
Fern Ridge Reservoir/Long Tom River	24.2 to 31.8	Turbidity	Year Around	Yes
Long Tom River	0 to 24.2	Fecal Coliform	Winter/Spring/Fall	Yes
Long Tom River	0 to 24.2	Temperature	Summer	Chapter 4
Luckiamute River	0 to 31.7	Fecal Coliform	Winter/Spring/Fall	Yes
Marys River	0 to 13.9	Temperature	Summer	Yes
Marys River	0 to 13.9	Fecal Coliform	Winter/Spring/Fall	Yes
Marys River	0 to 13.9	Dissolved Oxygen	October 1 - May 31	No
Muddy Creek	0 to 33	Temperature	Summer	Yes
Soap Creek	0 to 16.8	Dissolved Oxygen	October 1 - May 31	No
South Fork Berry Creek	0 to 2.1	Temperature	Summer	Yes
Willow Creek	0 to 2.8	Arsenic	Year Around	No

Water Quality Parameters Addressed

The following 303(d) parameters in the Upper Willamette Subbasin are addressed:

- Temperature
- Bacteria
- Dissolved Oxygen

  Dissolved oxygen standards violations in Amazon Diversion Channel and Coyote Creek are addressed by this TMDL. However, Marys River and Soap Creek were added to the 303(d) list in 2002 for violating dissolved oxygen standards and are not addressed in this TMDL due to the insufficient time to address these later listings.
- Turbidity
- Mercury

  Mercury is a parameter of concern throughout the Willamette Basin. A 27% reduction in mercury pollution is needed in the mainstem Willamette to remove fish consumption advisories. Pollutant load allocations are set for each sector but no effluent limits are specified at this time. Sources of mercury in the subbasin will be required to develop mercury reduction plans. Details of the mercury TMDL are included in Chapter 3, the Willamette Basin Mercury TMDL.

Water Quality Parameters Not Addressed

The Willamette Basin TMDL project began in early 2000 and was designed to address the 1998 303(d) listed waterbodies for parameters that exceeded water quality criteria. In 2002 the 303(d) list was updated. Where data were readily available, new parameter listings were addressed in this TMDL. However, there was not sufficient time to collect the additional data and complete the analysis for some of the newly listed parameters for this TMDL study. These parameters will be addressed in subsequent TMDL efforts. Parameters that are specifically excluded from this TMDL are:

- Arsenic and Lead

The 1998 arsenic listing and the 2002 lead listing for the A-3 Drain will not be covered in this TMDL. The 2002 arsenic and lead listings for Amazon Creek will also not be covered in this TMDL. This determination was made based on the small size of the initially listed waterbody (A-3 Drain) and the recent listing of additional adjacent waterbodies (e.g. Amazon and Willow Creeks) in 2002. ODEQ recommends further monitoring of arsenic and lead in the water column and sediment, along with stream flow measurements over a period of at least one-year. These data will provide the basis for a source assessment and load allocation development. In the interim, ODEQ recommends the control of upland soil erosion, increase in stream bank stability, and the protection and restoration of riparian buffers to minimize upland loading to the stream.

- Toxics

Dichloroethylenes, tetrachloroethylene, and mercury listings in the A-3 Drain will not be addressed in this TMDL document. The mercury listing was based on exceedance of aquatic criteria. ODEQ only addressed mercury in terms of fish tissue problems. Sufficient data have not been collected to assess sources and distribution of these pollutants. ODEQ recommends further monitoring of the organic pollutants in the water column and sediment, and determination of potential sources, along with stream flow measurements over a period of at least one-year. This data will provide the basis for a source assessment and load allocation development.

Who helped us

Many organizations assisted ODEQ in the development of this TMDL and data from many different sources were considered. ODEQ would like to acknowledge the assistance of the following organizations and agencies.

- Long Tom Watershed Council
- Marys River Watershed Council
- Pedee Creek Watershed Council
- Calapooia River Watershed Council
- Lane Council of Governments
- City of Eugene
- Eugene Water and Electric Board
- Springfield Utility Board
- U.S. Bureau of Land Management (BLM)
- U.S. Forest Service (USFS)
- U.S. Geological Survey, Oregon District (USGS)
- Oregon Water Resources Department (WRD)
- Oregon Department of Fish and Wildlife (ODFW)
- U.A. Army Corps of Engineers (USACE)

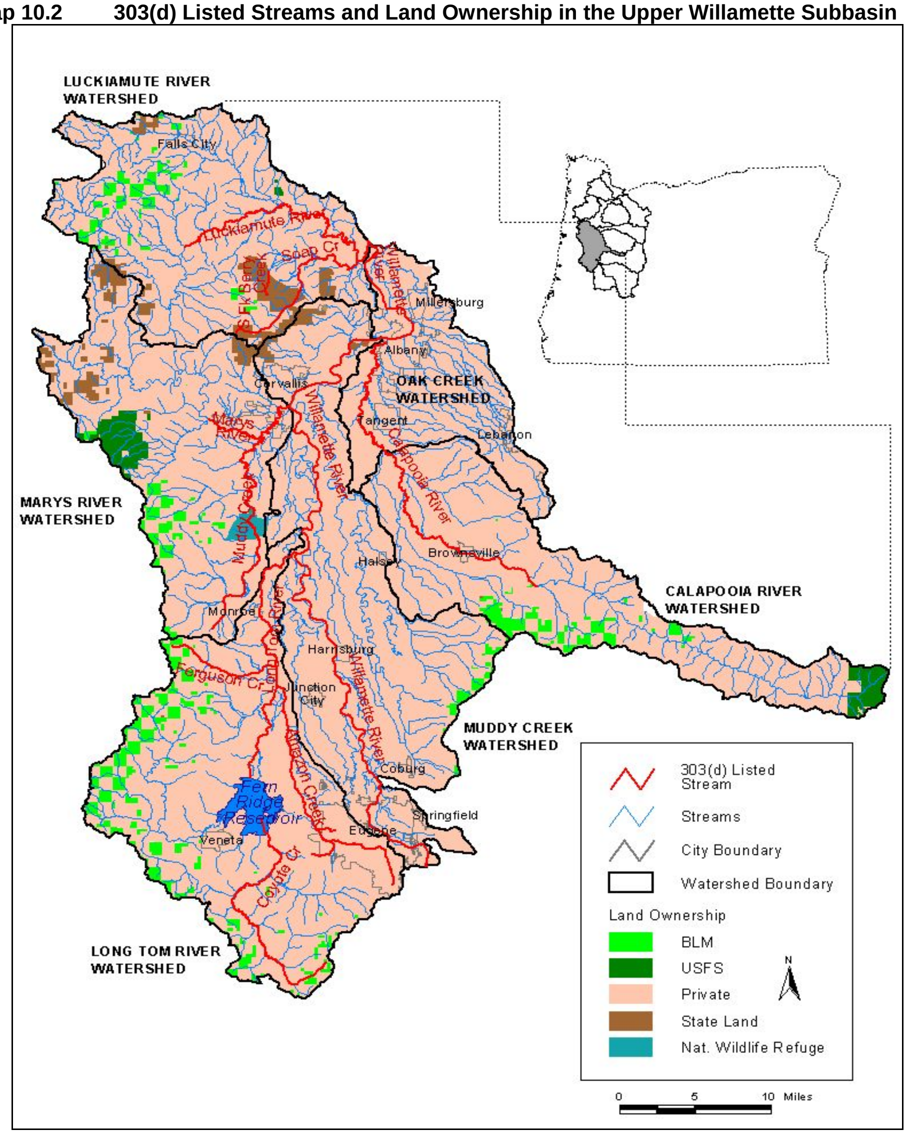
SUBBASIN OVERVIEW

The Upper Willamette Subbasin (Hydrologic Unit Code 17090003) is located in the southwest portion of the Willamette Basin with tributaries that flow to the Willamette River. The subbasin's 1,861 square miles (1,190,770 acres) extend from the foothills of the Cascade Mountains on the east to the Coast Range foothills on the west. The subbasin includes the following six watersheds:

- Calapooia River Watershed
- Long Tom River Watershed
- Luckiamute River Watershed
- Marys River Watershed
- Muddy Creek Watershed
- Oak Creek Watershed

The subbasin's political jurisdiction includes portions of Lane, Linn, Benton, and Polk Counties. The following cities are within the Upper Willamette Subbasin: Adair Village, Albany, Brownsville, Coburg, Corvallis, Eugene, Falls City, Halsey, Harrisburg, Junction City, Lebanon, Millersburg, Monroe, Philomath, Sodaville, Springfield, Tangent, and Veneta. The subbasin is owned almost entirely by private land owners. However, the Bureau of Land Management (BLM), United States Forest Service (USFS) and the State of Oregon own a small portion of the subbasin, Map 10.2. The land use is primarily agriculture in the low-land valley, scattered urban developments in the valley, and forestry in the upper subbasin.

Map 10.2 303(d) Listed Streams and Land Ownership in the Upper Willamette Subbasin



Key Watershed Descriptions

Luckiamute Watershed

The Luckiamute Watershed drains 314 square miles (201,059 acres) on the east slope of the coast range and includes mostly rural areas in Polk and Benton Counties. Falls City is the only incorporated municipality within the watershed. Forested areas within the uplands of the watershed are owned primarily by industrial timber companies. Agricultural areas consisting of grass fields, row crops, vineyards, and livestock operations dominate the lower watershed.

The BLM's Rowell Creek/Mill Creek/Rickreall Creek/Luckiamute River Watershed Analysis (BLM,1998) indicated that a large percentage of the forested portions of the upper Luckiamute and the Little Luckiamute contain trees 80 years or younger, indicating that nearly the entire area has been disturbed at least once (and in many cases twice or more) this century.

Long Tom Watershed

The Long Tom Watershed accounts for 410 square miles (262,000 acres) originating on the eastern side of the Coast Range at the southwestern end of the Willamette Valley (Thieman, 2000). Land use in the watershed includes a mixture of forest land, small farms and small incorporated communities. The upper and lower Long Tom watersheds are divided by Fern Ridge Reservoir. Coyote and Amazon Creek drain the southern and eastern portions of the upper basin, and also flow into Fern Ridge Reservoir. The lower Long Tom River is approximately 25 miles long with flows regulated by Fern Ridge Reservoir. It joins the Willamette River at two locations, the original northern confluence and the channelized southern confluence at Norwood Island. Upper Amazon Creek is diverted to Fern Ridge Reservoir via Amazon Creek Diversion channel. The Lower Amazon Creek does not enter the lake.

Coyote Creek Watershed

Coyote Creek Watershed drains 104 square miles (66,600 acres) of land. Land use in this area is a mixture of forestry, agriculture, and rural residential land, although land zoned for forestry still covers the majority of the drainage (Thieman, 2000). The watershed also has many impoundments, which aside from Fern Ridge Reservoir, appear to be small agricultural impoundments used for livestock watering, fishponds or unspecified domestic use. Coyote Creek Watershed has been degraded primarily due to a removal of trees in riparian areas that once were densely forested. This activity has resulted in reduced shade and large woody debris (LWD) available in this watershed compared to historic times. Remnants of forests still exist along the streams in the Coyote Creek Watershed, but they have been greatly reduced.

Calapooia Watershed

The Calapooia Watershed encompasses 365 square miles (233,599 acres) with 94% in private ownership (OWEB, 2004). The Calapooia River travels 72 miles and changes elevation from 350 feet above sea level at its mouth in Albany, to 3,400 ft at its headwaters on Tidbits Mountain. River flow ranges from 50 cfs in the summer to over 2,000 cfs during the winter months in the Calapooia River.

Marys River Watershed

The Marys River Watershed is located along the east side of the Coast Range in western Oregon. The watershed encompasses 310 square miles (198,000 acres) with land uses consisting of upland forest area, a valley agriculture area, and a downstream urban area. The headwaters of the watershed drain the highest point in the Coast Range, Marys Peak at 4,200 feet elevation, and flows into the Willamette River in the city of Corvallis at 250 feet elevation.

UPPER WILLAMETTE TEMPERATURE TMDL

The temperature TMDL for the Upper Willamette Subbasin includes tributaries to the Willamette River and Long Tom River, mouth to Fern Ridge Reservoir, within HUC 17090003. As per Oregon Administrative Rule (OAR) 340-042-0040 required components of a TMDL are listed in Table 10.2.

Table 10. 2 Upper Willamette Subbasin Temperature TMDL Components.

Waterbodies **OAR 340-042-0040(4)(a)**	Perennial and/or fish bearing, as identified in OAR 340-041- 0340; Figures 340A & 340B, streams in the Upper Willamette Subbasin, HUCs 170900301, 170900302, 170900303, 170900304, 170900305, and 170900306.
Pollutant Identification **OAR 340-042-0040(4)(b)**	*Pollutants:* Human caused temperature increases from (1) solar radiation loading and (2) warm water discharge to surface waters
Beneficial Uses **OAR 340-042-0040(4)(c)**	Salmonid fish spawning and rearing, anadromous fish passage, resident fish and aquatic life are the most sensitive beneficial uses in the Upper Willamette Subbasin.
Target Criteria Identification **OAR 340-042-0040(4)(c)** **CWA §303(d)(1)** **OAR 340-041-0028(4)(f)** **OAR 340-041-0028(4)(a)** **OAR 340-041-0028(4)(b)** **OAR 340-041-0028(4)(c)** **OAR 340-041-0028(8)** **OAR 340-041 0028(12)(b)(B)**	OAR 340-041-0028 provides numeric and narrative temperature criteria. Maps and tables provided in OAR 340-041-0101 to 0340 specify where and when the criteria apply. 12.0°C during times and at locations of bull trout spawning and juvenile rearing use. 13.0°C during times and at locations of salmon and steelhead spawning. 16.0°C during times and at locations of core cold water habitat identification. 18.0°C during times and at locations of salmon and trout rearing and migration. *Natural Conditions Criteria:* Where the department determines that the natural thermal potential temperature of all or a portion of a water body exceeds the biologically-based criteria in section 4 the natural thermal potential temperatures supersede the biologically-based criteria and are deemed the applicable criteria for that water body. Maps and tables provided in OAR 340-041-0101 to 0340 specify where and when the criteria apply. Following a temperature TMDL or other cumulative effects analysis, waste load and load allocations will restrict all NPDES point sources and nonpoint sources to a cumulative increase of no greater than 0.3 degrees Celsius (0.5 Fahrenheit) above the applicable criteria after complete mixing in the water body, and at the point of maximum impact.
Existing Sources **OAR 340-042-0040(4)(f)** ***CWA §303(d)(1)***	Nonpoint source solar loading due to a lack of riparian vegetation from forestry, agriculture, rural residential, and urban activities. Point source discharge of warm water to surface water.
Seasonal Variation **OAR 340-042-0040(4)(j)** ***CWA §303(d)(1)***	Peak temperatures typically occur in mid-July through mid-August and often exceed the salmon and trout rearing and migration criterion. Temperatures are much cooler late summer through late spring but occasionally exceed the spawning criterion.
TMDL **Loading Capacity and Allocations** **OAR 340-042-0040(4)(d)** **OAR 340-042-0040(4)(e)** **OAR 340-042-0040(4)(g)** **OAR 340-042-0040(4)(h)** ***40 CFR 130.2(f)*** ***40 CFR 130.2(g)*** ***40 CFR 130.2(h)***	*Loading Capacity:* OAR 340-041-0028 (12)(b)(B) states that no more than a 0.3°C increase in stream temperature above the applicable biological criteria or the natural condition criteria as a result of human activities is allowable. This condition is achieved when the cumulative effect of all point and nonpoint sources results in no greater than a 0.3°C (0.5°F) increase at the point of maximum impact. Loading capacity is the heat load that corresponds to the applicable numeric criteria plus the small increase in temperature of 0.3°C provided with the human use allowance. *Excess Load*: The difference between the actual pollutant load and the loading capacity of the waterbody. In these temperature TMDLs excess load is the difference between heat loads that meet applicable temperature criteria plus the human use allowance and current heat loads from background, nonpoint source and point source loads. *Wasteload Allocations (NPDES Point Sources):* Allowable heat load based on achieving no greater than a 0.3°C temperature increase at the point of maximum impact. This is achieved by limiting stream temperature increases from individual point sources to 0.075ºC. This may also be expressed as a limitation of 0.3ºC increase in 25% of the 7Q10 stream flow. Where multiple point sources discharge to a single receiving stream the accumulated heat increase for point sources is limited to 0.2˚C. *Load Allocations (Nonpoint Sources)*: Background solar radiation loading based on system potential vegetation near the stream. An additional heat load equal to 0.05°C temperature increase at the point of maximum impact is available but is not explicitly allocated to individual sources. • Coyote Creek background solar radiation loading based on system potential vegetation is 1.87×10^8 kcal/day. • Luckiamute River background solar radiation loading based on system potential vegetation is 11.17×10^8 kcal/day. • Calapooia River background solar radiation loading based on system potential vegetation is 19.40×10^8 kcal/day.

Surrogate Measures **OAR 340-042-0040(5)(b)** ***40 CFR 130.2(i)***	*Translates Nonpoint Source Load Allocations* Effective shade targets translate riparian vegetation objectives into the nonpoint source solar radiation loading capacity. These targets are based on vegetation communities appropriate for each geomorphic unit in the subbasin.
Margins of Safety **OAR 340-042-0040(4)(i)** ***CWA §303(d)(1)***	*Margins of Safety* are demonstrated in critical condition assumptions for point source load calculations and are inherent in the methodology for determining nonpoint source loads**.**
Reserve Capacity **OAR 340-042-0040(4)(k)**	*Allocation for increases in pollutant loads for future growth from new or expanded sources.* Reserve capacity will be a percentage of the 0.3˚C human use allowance (HUA). The HUA will be divided among various sources. When point sources are present reserve capacity will be 0.05˚C, 17% of the HUA. Where there are no point sources in a subbasin, or less than the allowed 0.2˚C is used by point source discharges, the remainder is allocated to reserve capacity.
Water Quality Management Plan **OAR 340-042-0040(4)(l)**	*The Water Quality Management Plan (WQMP)* provides the framework of management strategies to attain and maintain water quality criteria. The WQMP is designed to complement the detailed plans and analyses provided in specific implementation plans. See Chapter 14.
Criteria Attainment & Reasonable Assurance **OAR 340-042-0040(4)(l)(e) & (j)**	Implementation of pollutant load reductions and limitations in the point source and nonpoint source sectors will result in water quality standards attainment. Standards Attainment and Reasonable Assurance are addressed in the WQMP, Chapter 14.

Waterbodies Listed for Temperature
OAR 340-042-0040(4)(a)

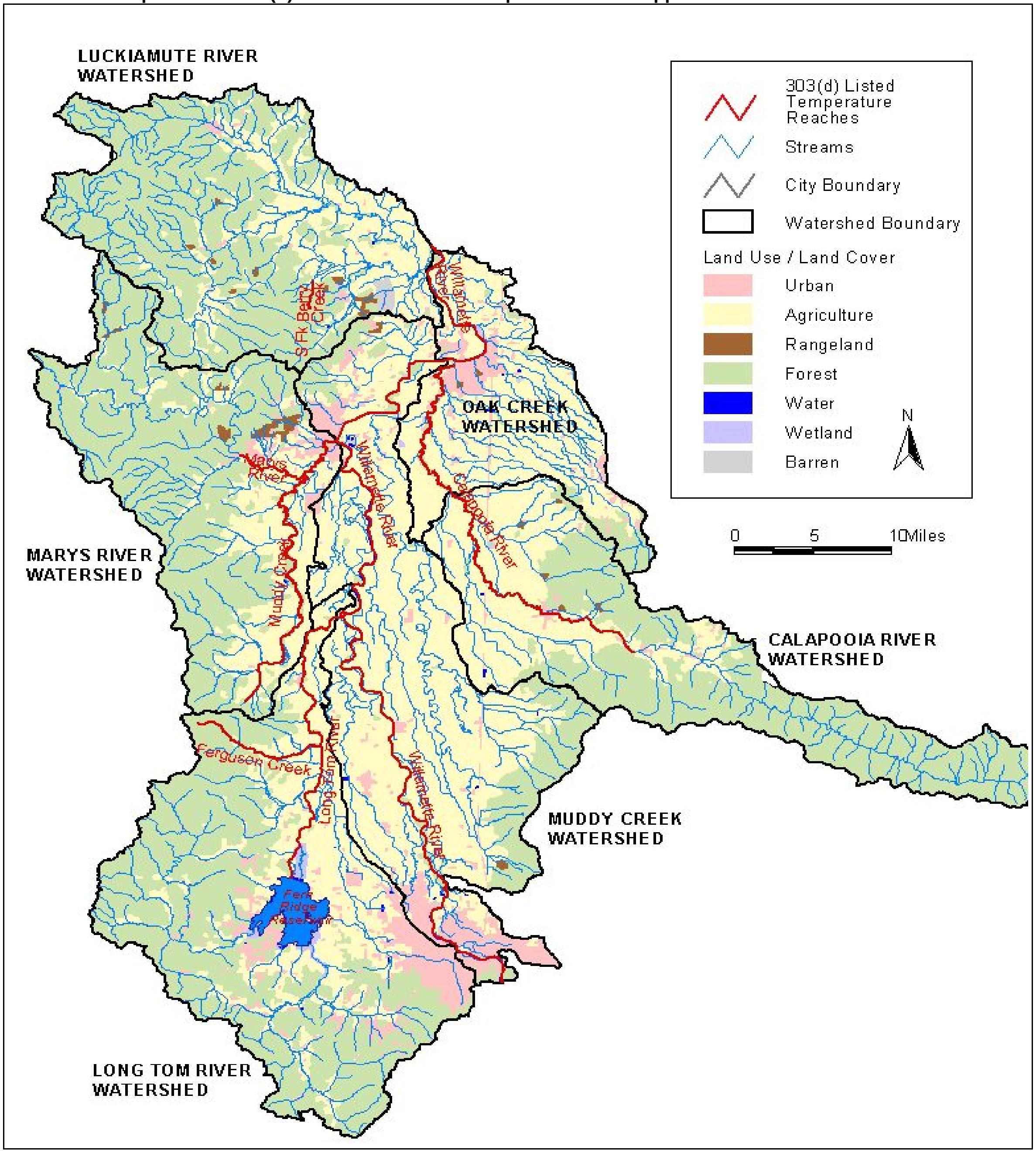
The Upper Willamette Subbasin has five stream segments on the 303(d) list for exceeding the water temperature criteria during the summer season, July through September: Calapooia River, Ferguson Creek, Marys River, Muddy Creek, and South Fork Berry Creek (Table 10.3 and Map 10.3). The Long Tom River downstream of Fern Ridge Reservoir Foster and the Willamette River are also listed for exceeding the temperature criteria. They are addressed in Chapter 4 of this document.

Stream segments were listed under the previous temperature criterion because they exceeded the temperature criterion of 17.8^{o}C (64^{o}F) for salmonid migration and rearing, Table 10.3. However, in December 2003 the new temperature criteria was adopted by the Environmental Quality Commission and approved by USEPA in March 2004. The new temperature criterion for salmon and trout rearing and migration is 18.0°C (64.4°F). A review of the temperature data for the streams listed in the Upper Willamette Subbasin indicates that these streams exceed the recently adopted numeric criterion.

Table 10. 3 Upper Willamette Subbasin 303(d) Temperature Listed Segments

Waterbody Name	Listed River Mile	Parameter	Criteria	Season
Calapooia River	0 to 42.8	Temperature	Rearing: 17.8 C	Summer
Ferguson Creek	0 to 10	Temperature	Rearing: 17.8 C	Summer
Marys River	0 to 13.9	Temperature	Rearing: 17.8 C	Summer
Muddy Creek	0 to 33	Temperature	Rearing: 17.8 C	Summer
South Fork Berry Creek	0 to 2.1	Temperature	Rearing: 17.8 C	Summer

Map 10.3 303(d) Listed Streams for Temperature in the Upper Willamette Subbasin



Pollutant Identification

OAR 340-042-0040(4)(b)

ODEQ must establish a TMDL for any waterbody designated on the 303(d) list as exceeding water quality criteria. Although temperature criteria are designed to protect beneficial uses from excessive water temperature, the pollutant of concern is heat energy.

Water temperature change is an expression of heat energy exchange per unit of volume:

$$\Delta Temperature \propto \frac{\Delta Heat\ Energy}{Volume}$$

Stream temperatures are affected by natural and human caused sources of heating. Disturbance processes such as wildfire, flood, and insect infestation influence the presence, height and density of riparian vegetation which in turn determines the amount of solar radiation reaching the stream. Such processes are recognized and incorporated as a natural condition in the TMDL. This temperature TMDL does address stream heating caused by human activities that affect characteristics of riparian vegetation in addition to point sources that discharge heat directly into surface waters in the Upper Willamette Subbasin.

Beneficial Use Identification

OAR 340-042-0040(4)(c)

Numeric and narrative water quality criteria are applied to protect the most sensitive beneficial uses. The most sensitive beneficial uses to temperature in the Upper Willamette Subbasin are:

- Resident fish and aquatic life
- Salmonid spawning, rearing and migration
- Anadromous fish passage

At a minimum, beneficial uses are considered attainable wherever feasible or wherever attained historically. The waterbody's beneficial use for salmonid spawning, rearing, and migration were based on new fish use designations established by the Oregon Department of Fish and Wildlife and are presented in the next section "Target Criteria Identification".

Salmonid Stream Temperature Requirements

This temperature TMDL is focused on the protection of cold water salmonids, specifically steelhead and salmon. In general, there are three levels of thermally induced fish mortality. If stream temperatures become greater than 32 °C (>90°F), fish die almost instantly due to denaturing of critical enzyme systems in their bodies (Hogan, 1970). This level is termed *instantaneous lethal limit.* The second level is termed *incipient lethal limit* and can cause fish mortality in hours to days when temperatures are in the 21°C to 25°C (70°F to 77°F) range. The time period to death depends on the acclimation and life-stage of the fish. The cause of death is from the breakdown of physiological regulation, such as respiration and circulation, which are vital to fish health (Heath and Hughes, 1973). The third level is the most common and widespread cause of thermally induced fish mortality, termed *indirect or sub-lethal limit* and can occur weeks to months after the onset of elevated stream temperatures of 17.8°C to 23°C (64°F to 74°F). The cause of death is from interactive effects such as: decreased or lack of metabolic energy for feeding, growth, and reproductive behavior; increased exposure to pathogens (viruses, bacteria and fungus); decreased food supply because the macroinvertebrate populations are also impaired by high stream temperature; and increased competition from warm water tolerant species. Table 10.4 summarizes the modes of cold water fish mortality.

Table 10. 4 Thermally Induced Cold Water Fish Mortality Modes (Brett, 1952; Bell, 1986, Hokanson et al., 1977)

Modes of Thermally Induced Fish Mortality	Temperature Range	Time to Death
Instantaneous Lethal Limit – Denaturing of bodily enzyme systems	> 32°C (> 90°F)	Instantaneous
Incipient Lethal Limit – Breakdown of physiological regulation of vital bodily processes, namely: respiration and circulation	21°C - 25°C (70°F - 77°F)	Hours to Days
Sub-Lethal Limit – Conditions that cause decreased or lack of metabolic energy for feeding, growth or reproductive behavior, encourage increased exposure to pathogens, decreased food supply and increased competition from warm water tolerant species	17.8°C - 23°C (64°F - 74°F)	Weeks to Months

Target Criteria Identification

OAR 340-041-0028(4)(c), OAR 340-041-0028(4)(d),OAR 340-041-0028(9) CWA 303(d)(1)

Oregon's water quality criteria for temperature are designed to protect beneficial uses, such as cold-water salmon and trout species, based on specific salmonid life stages. The temperature criteria include both narrative and numeric criteria. Table 10.5 lists the temperature criteria that are applicable in the Upper Willamette Subbasin. Maps 10.4 and 10.5 illustrate designated subbasin fish use and salmonid spawning use. The maps indicate where salmonid spawning through fry emergence criterion, core cold water habitat criterion, salmonid rearing and migration criterion, and cool water species criterion apply. For subbasin waters where fisheries uses are not identified the applicable criteria are the same as the nearest downstream waterbody that is identified in fish use maps. Willamette Basin fish use and spawning use maps are available for electronic download on ODEQs website at:

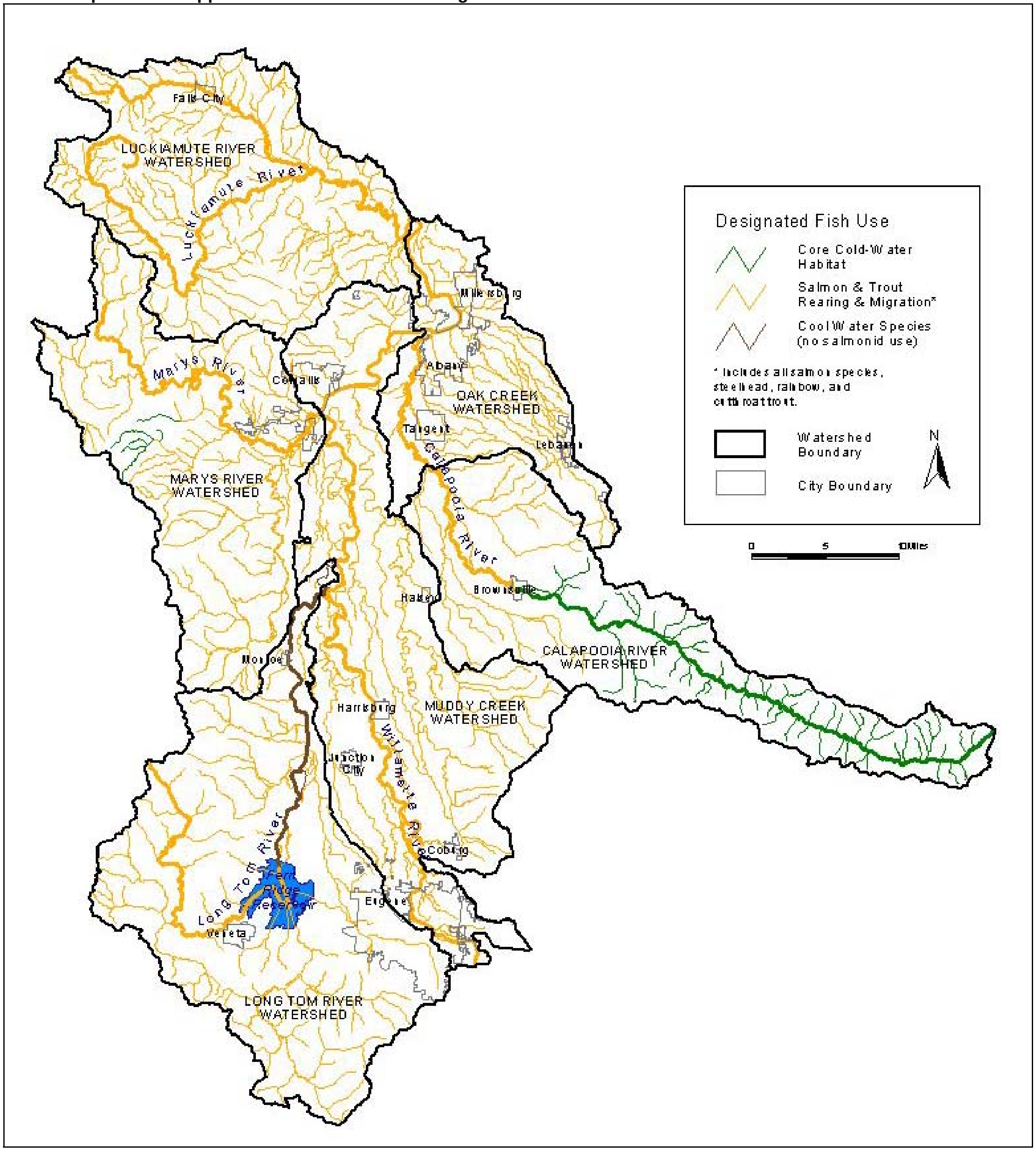
http://www.deq.state.or.us/wq/standards/FishUseMapsFinal/FFigure340A_Willamette.pdf
and
http://www.deq.state.or.us/wq/standards/FishUseMapsFinal/FFigure340B_Willamette.pdf

Table 10. 5 Oregon's Biologically Based Temperature Criteria.

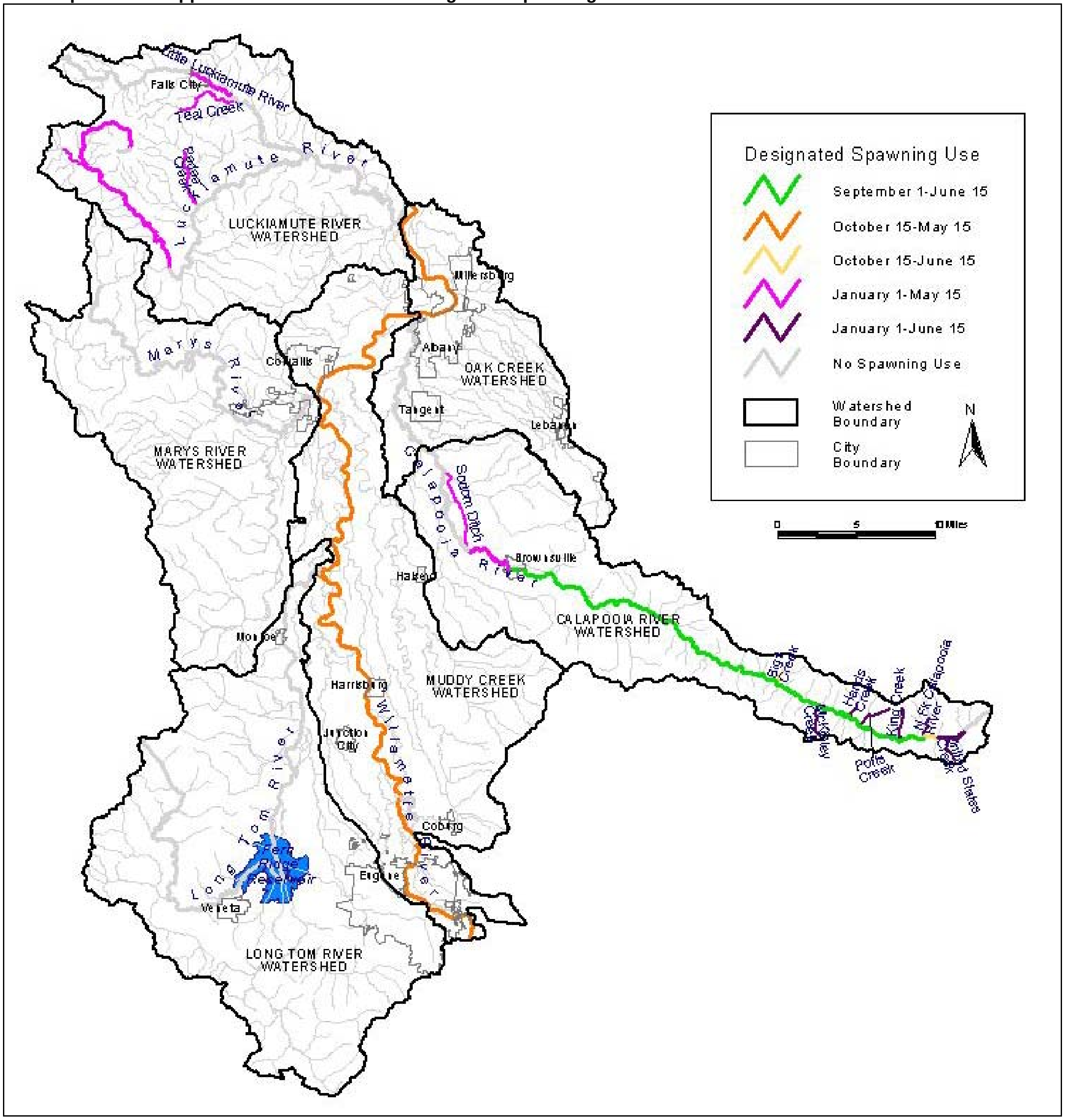
Beneficial Use	Criteria
Salmon and Steelhead Spawning	∗13.0°C (55.4°F)
Core Cold Water Habitat Identification	*16.0°C (60.8°F)
Salmon and Trout Rearing and Migration	∗18.0°C (64.4°F)
Waters that support cool water species may not be warmed by more than 0.3 degrees Celsius (0.5 degrees Fahrenheit) above the ambient condition unless a greater increase would not reasonably be expected to adversely affect fish or other aquatic life.	Cool Water Species

∗ Stream temperature is calculated using the average of seven consecutive daily maximum temperatures on a rolling basis (7-day calculation).

Map 10.4 Upper Willamette Subbasin Designated Fish Use Distribution of Anadromous Salmonids



Map 10.5 Upper Willamette Subbasin Designated Spawning Use Distribution of Anadromous Salmonids



The narrative criteria that apply to the Upper Willamette Subbasin describe the conditions under which biological numeric criteria may be superseded. The criteria acknowledge that in some instances the biologically based numeric criteria may not be achieved because the natural thermal potential of the stream temperature is warmer than the biologically based numeric criteria. A stream that is free from anthropogenic influence is considered to be at natural thermal potential. When it exceeds the appropriate biologically based criterion, the natural thermal potential becomes the natural condition numeric temperature criterion for that specific stream or stream segment. This often occurs in low elevation streams in the basin during summer months.

Following a temperature TMDL or other cumulative effects analysis, waste load and load allocations will restrict all NPDES point sources and nonpoint sources to a cumulative increase of no greater than 0.3 degrees Celsius (0.5Fahrenheit) above the applicable criteria after complete mixing in the water body, and at the point of maximum impact.

A more extensive analysis of water temperature related to aquatic life and supporting documentation for the temperature standard can be found in the 1992-1994 Water Quality Standards Review Final Issue Papers (ODEQ, 1995) and in EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (USEPA, 2003).

Existing Heat Sources

OAR 340-042-0040(4)(f), CWA 303(d)(1)

Sources of heat pollution include nonpoint sources and point sources. Nonpoint sources are generally more diffuse in nature and often cannot be traced back to a particular location. These sources are defined below in terms of land use. Dams and reservoir operations are also included as nonpoint sources of pollution although their effects on water quality are generally more identifiable than dispersed land use activities. Point sources are individual facilities that discharge a pollutant from a defined conveyance (e.g. an outfall pipe) and are regulated by permit.

Nonpoint Sources of Heat

Land use activities. Riparian vegetation, stream morphology, hydrology (including groundwater interactions), 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. Disturbance or removal of vegetation near a stream reduces stream surface shading because of decreased vegetation height, width and density. This results in greater amounts of solar radiation reaching the stream surface.

Riparian vegetation also influences channel morphology. Vegetation supports stream banks during erosive, high flow events, slows floodwaters and promotes sediment deposition when floodwaters overtop the banks. Loss or disturbance of riparian vegetation may precede lateral stream bank erosion and channel widening. This decreases the effectiveness of remaining vegetation to shade the stream and increases the stream surface area exposed to heat exchange processes, particularly solar radiation.

Dam and Reservoir operations. Dams and reservoir operations affect stream temperature through the modification of flow regimes and through the delivery of heat stored within the system. Flow augmentation during the low flow periods of the year may be beneficial to stream segments below the dam as higher flows increase stream volume and therefore the loading capacity of the segment. Higher volumes increase stream velocities and reduce travel times through stream reaches exposed to solar radiation. However, operations that divert flows from natural channels during low flow periods may substantially diminish the loading capacity of the stream while also increasing solar loading to the stream because of lower velocities and greater travel times through exposed reaches.

The release of water from reservoirs may also increase downstream temperatures as the heat held by the impounded water is released. The timing, duration and magnitude of such impacts are dependent upon reservoir characteristics such as surface area, depth, and whether water is released from the bottom of the reservoir or selectively withdrawn from various depths.

There is one reservoir in the Upper Willamette Subbasin, Fern Ridge Reservoir, on the Long Tom River. A discussion of the impact of this reservoir on the lower Long Tom River is discussed in Chapter 4.

Point Sources of Heat

Point source discharges play a role in stream heating in the streams of the Upper Willamette Subbasin. There are 42 individual NPDES permitted sources in the Upper Willamette Subbasin, 14 sources discharge directly into the Willamette River and will be discussed in Chapter 4. The remaining 28 individual NPDES point sources consist of 13 domestic permits and 15 industrial permits, Map 10.6 and Table 10.6. Wah Chang and Oremet are the only two major individual NPDES point sources in the subbasin discharging to Truax Creek and Oak Creek, respectively. The remaining individual NPDES point sources are classified as minor discharges. There are also 270 general NPDES permits, consisting of 228 stormwater permits for facilities located within the Upper Willamette Subbasin. Stormwater sources are not considered to have reasonable potential to contribute to exceedances of numeric temperature criteria.

Map 10.6 Upper Willamette Subbasin NPDES Permit Locations. April, 2003.

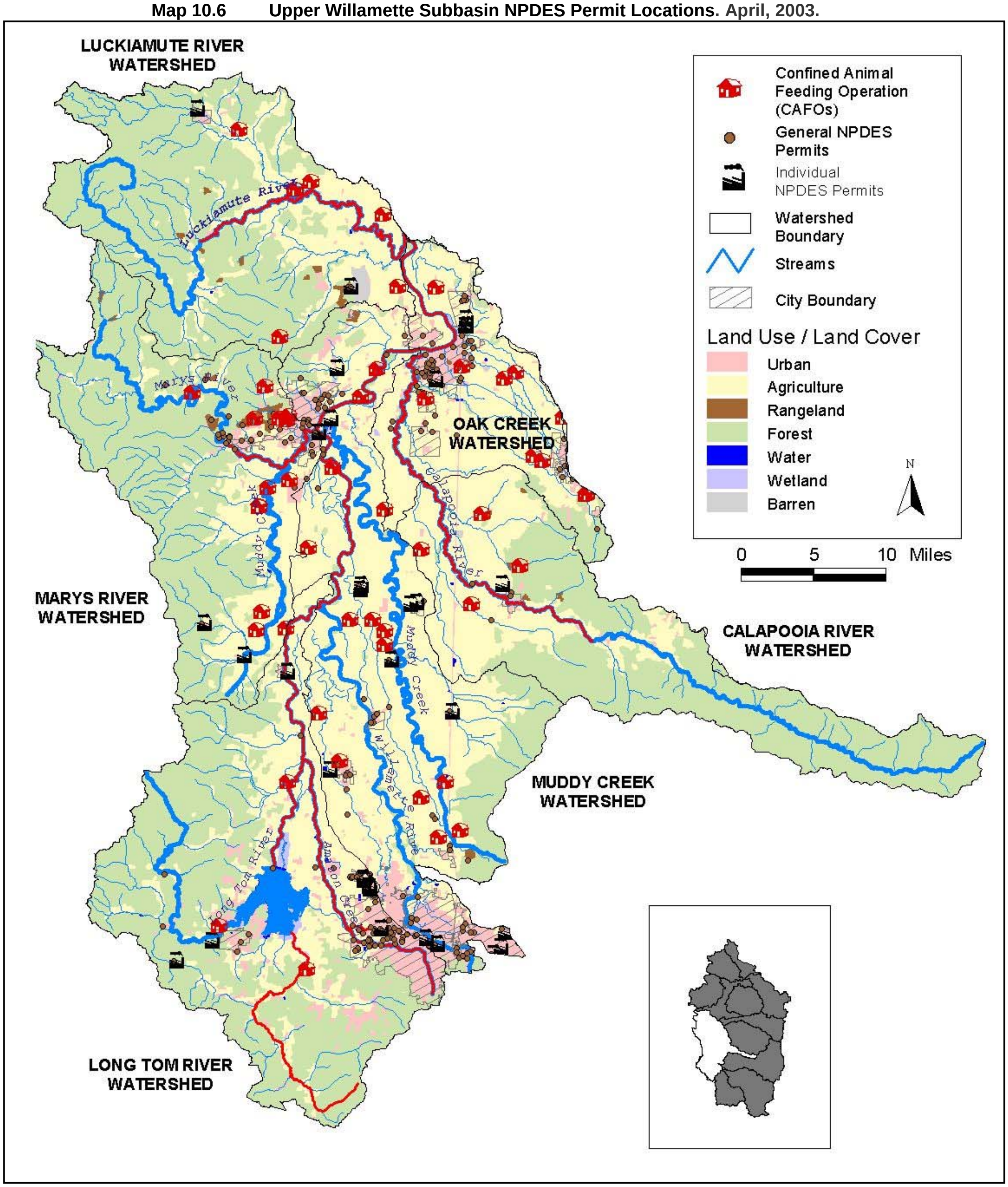


Table 10. 6 Individual NPDES facilities in the Upper Willamette Subbasin, which do not discharge to the mainstem Willamette River and Long Tom River. April, 2003.

Facitlity Name	Permit Type	Permit Description	Receiving Stream	River Mile	Type of Discharge	Season of Discharge
TRIUMPH GROUP OPERATIONS, INC., THE	NPDES-IW-O	Industrial Wastewater; NPDES process wastewater NEC	Oak Creek	1.6	Process Water	Year-Round
ALPINE COUNTY SERVICE DISTRICT	NPDES-DOM-Db	Sewage - less than 1 MGD with lagoons	Muddy Creek	25.6	Waste Water	F - W - S
BROWNSVILLE, CITY OF	NPDES-DOM-Db	Sewage - less than 1 MGD with lagoons	Calapooia River	31.6	Waste Water	F - W - S
CCF, L.P., A LIMITED PARTNERSHIP OF DELAWARE	NPDES-DOM-Db	Sewage - less than 1 MGD with lagoons	Mountain View Creek	0.4	Waste Water	F - W - S
DIAMOND HILL L.L.C.	NPDES-DOM-Db	Sewage - less than 1 MGD with lagoons	Little Muddy Creek	8	Waste Water	F - W - S
FALLS CITY, CITY OF	NPDES-DOM-Da	Sewage - less than 1 MGD with lagoons	Little Luckiamute River	11.9	Waste Water	F - W - S
HALSEY, CITY OF	NPDES-DOM-Db	Sewage - less than 1 MGD with lagoons	Muddy Creek	23	Waste Water	F - W - S
JUNCTION CITY, CITY OF	NPDES-DOM-Db	Sewage - less than 1 MGD with lagoons	Flat Creek	9.15	Waste Water	F - W - S
LANE COMMUNITY COLLEGE	NPDES-DOM-Db	Sewage - less than 1 MGD with lagoons	Russel Creek	0.66	Waste Water	F - W - S
PHILOMATH, CITY OF	NPDES-DOM-Db	Sewage - less than 1 MGD with lagoons	Marys River	10.2	Waste Water	F - W - S
SHELL OIL PRODUCTS COMPANY LLC	NPDES-DOM-Da	Sewage - less than 1 MGD with lagoons	Courtney Creek	2.7	Waste Water	F - W - S
TANGENT, CITY OF	NPDES-DOM-Db	Sewage - less than 1 MGD with lagoons	Santiam Canal	10.8	Waste Water	F - W - S
VENETA, CITY OF	NPDES-DOM-Db	Sewage - less than 1 MGD with lagoons	Long Tom River	34.9	Waste Water	F - W - S
WILLIAMS, PAUL D.	NPDES-DOM-Da	Sewage - less than 1 MGD with lagoons	Muddy Creek	48	Waste Water	F - W - S
DYNEA U.S.A. INC.	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Patterson Slough	1.83	Process Water	Year-Round
GEORGIA-PACIFIC RESINS, INC.	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Amazon Creek	2.7	Process Water	F - W - S
J.H. BAXTER & CO., INC.	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Amazon Diversion Canal	1.5	Process Water	Year-Round
KINGSFORD MANUFACTURING COMPANY	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Patterson Slough	3.7	Process Water	F - W - S
MCFARLAND CASCADE POLE & LUMBER COMPANY	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Un-named	1.8	Process Water	Year-Round
WEYERHAEUSER COMPANY	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Murder Creek	0.57	Process Water	Year-Round
WEYERHAEUSER COMPANY	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Noti Creek	6.3	Process Water	Year-Round
GEORGIA-PACIFIC CORPORATION	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Un-named	1.46	Storm Water	F - W - S
GEORGIA-PACIFIC RESINS, INC.	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Murder Creek	0.6	Storm Water	F - W - S
HULL-OAKES LUMBER CO.	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Oliver Creek	4.78	Storm Water	Year-Round
OREGON METALLURGICAL CORPORATION	NPDES-IW-G	Industrial Wastewater; NPDES primary metals smelting, refining NEC	Oak Creek	1.6	Storm Water	Year-Round
SENECA SAWMILL COMPANY	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Un-named	6.95	Storm Water	Year-Round
TDY INDUSTRIES, INC, DBA WAH CHANG	NPDES-IW-F	Industrial Wastewater; NPDES primary metals smelting, refining, using sand chlorination separation	Truax Creek	2	Storm Water	Year-Round
VALLEY LANDFILLS, INC.	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Un-named	4.52	Storm Water	Year-Round

F-W-S = Fall-Winter-Spring; approximately October through May
NEC = Not Elsewhere Classified

Temperature TMDL Approach Summary

Upper Willamette Subbasin stream temperature TMDLs were developed at the watershed scale. These TMDLs include all surface waters that affect the temperatures of 303(d) listed water bodies because stream temperature is affected by heat loads from upstream as well as local sources. Point and nonpoint sources of heat may not cause an increase in temperature of more than the human use allowance (0.3˚C) when fully mixed with a stream and at the point of maximum impact. For the purposes of Willamette Basin TMDLs, the human use allowance has been divided among various sources using a framework established by DEQ with input from the Willamette TMDL Council. The framework allocates to point sources heat loads that yield a cumulative increase in stream temperature of no more than 0.2˚C. The framework allocates nonpoint sources an increase in temperatures of 0.05˚C and a heat load equivalent to 0.05˚C is held as reserve capacity. Where less than the 0.2˚C cumulative increase in temperature is actually used by point source discharges, the remainder is allocated to reserve capacity. The actual allocation of heat within the human use allowance is not specified in the water quality standards and this framework is used simply as guidance for implementation of the TMDL.

Point Source Approach. Allocations or permit limits are developed for individual point source discharges that ensure the combined increase in temperature for all discharges does not exceed 0.2˚C at the point of maximum impact. Wasteload allocations for individual point sources are generally based on a quarter of the human use allowance and yield less than a 0.08ºC increase in temperature at the point of maximum impact. Individual waste load allocations may be greater than 0.08 based on an analysis of site specific needs provided the overall point source allocation is within the established human use allowance framework. The specific methods and equations used to develop wasteload allocations are contained in the Allocation section of this chapter.

Nonpoint Source Approach. Removal or disturbance of riparian vegetation is the primary nonpoint source activity with respect to stream temperatures in the subbasin. The temperature model Heat Source was used to calculate load allocations. Surrogate measures are used to represent nonpoint source heat loads. While heat from solar radiation in excess of natural background rates is considered the pollutant, the surrogate measure is effective shade. Effective shade targets, through the use of the Shade-a-lator Model and shade curves can be translated into site-specific load allocations such as langleys per day. Both shade curves and system potential vegetation objectives were developed for the fifteen geomorphic units in the Upper Willamette Subbasin.

Temperature TMDL Analytical Methods Overview

Load capacity is the assimilative capacity of each stream when anthropogenic sources of heat warm the stream no more than 0.3ºC above its natural thermal potential. Natural thermal potential is realized when point sources discharges of heat are eliminated and vegetation near the stream is undisturbed by management activities. Small additional heat load allocations can be made once these conditions are identified. Wasteload allocations for individual point sources are based on a change in river temperature at the point of maximum impact. These allocations are expressed in energy units such as kilocalories per day. Load allocations for nonpoint sources for Coyote Creek, Luckiamute River, and Calapooia River are based on kilocalories per day, and the surrogate measure of percent effective shade.

Development of stream temperature TMDLs requires the identification of load capacity for each impaired stream. This often demands extensive data collection to support the development of detailed and complex models that are in turn used to simulate system responses to changes in pollutant loads. However, in many stream systems in the Upper Willamette Subbasin the primary sources of anthropogenic heat are land use activities that affect riparian and near-stream vegetation. Identification of load capacity in these systems first requires determination of stream shade conditions when these disturbances of vegetation are eliminated. This drives the need to determine system potential vegetation and its shade producing characteristics.

System potential vegetation is vegetation that can grow and reproduce at a near-stream site given climate, elevation, soil properties, plant community requirements and hydrologic processes, see Appendix C; "Potential Near-Stream Land Cover". System potential vegetation is an estimate of the riparian condition where land use activities that cause stream warming are minimized. It is not intended to be an estimate of pre-settlement conditions, but is an important element in the determination of the natural thermal potential of a stream. In the absence of significant point sources of heat or stream flow modification, system potential vegetation is the basis for identification of natural thermal potential temperatures. These natural thermal potential temperatures serve as the natural conditions temperature criterion in many low elevation streams throughout the Willamette Basin.

The Oregon Administrative Rule for temperature has defined both natural conditions and natural thermal potential.

- OAR 340-041-0002(34) states:
  "Natural conditions" means conditions or circumstances affecting the physical, chemical, or biological integrity of a water of the State that are not influenced by past or present anthropogenic activities. Disturbances from wildfire, floods, earthquakes, volcanic or geothermal activity, wind, insect infestation, diseased vegetation are considered natural conditions.

- OAR 340-041-0002(35) states:
  "*Natural Thermal Potential" means the determination of the thermal profile of a water body using best available methods of analysis and the best available information on the site potential riparian vegetation, stream geomorphology, stream flows and other measures to reflect natural conditions.*

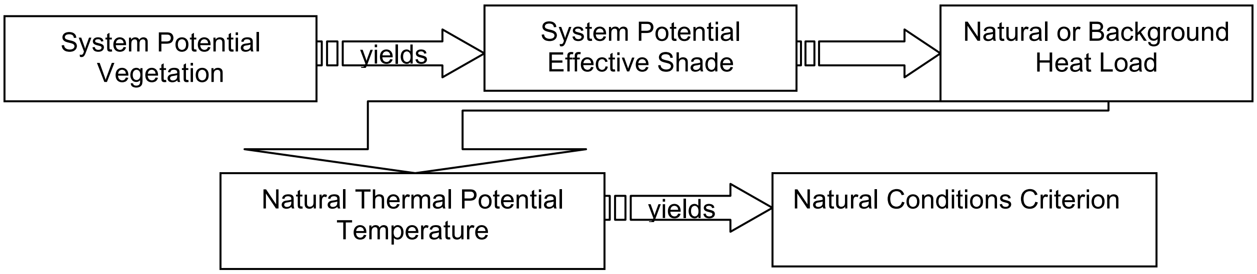
Upper Willamette Subbasin temperature TMDLs are based on the identification of system potential vegetation for each impaired waterbody and the calculation of the amount of shade provided by that vegetation to the stream. System potential vegetation in this analysis does allow for some level of natural disturbance such as fire and this is reflected as smaller tree heights and lower canopy densities in the calculation of shade levels. Put another way, mature vegetation was not used to simulate target conditions throughout the subbasin.

Effective shade is the percent of daily solar radiation that is blocked by vegetation and topography. System potential vegetation characteristics are used to estimate effective shade for each riparian community. These estimated effective shade values are often referred to as system potential effective shade when in the absence of human disturbance.

Solar radiation is a function of regional and local characteristics and is a factor in determining water temperature in the absence of significant point source influences. Regional factors such as latitude and topography determine potential solar radiation loading whereas local factors such as stream aspect, stream width and streamside vegetation characteristics determine actual solar radiation loading to the stream. Streamside vegetation characteristics that determine effective shade include vegetation height, canopy density, overhang, setback or distance from the edge of the stream, and the width of the riparian buffer. Mature, well-stocked riparian stands generally provide more effective shade to a stream than sparsely stocked riparian stands or stands of early successional plant communities. For more information on system potential vegetation refer to Appendix C, "Potential Near-Stream Land Cover for Willamette Basin".

Effective shade is a surrogate measure used for development of temperature load allocations. The use of effective shade targets alone will not support calculation of natural thermal potential stream temperatures. Extensive modeling is required to describe heat and water movement through the stream system and support the estimation of stream temperatures. Stream temperature estimation at system potential vegetation is calculated using the Heat Source Model. The Heat Source Model version 6.5 was used to calculate stream temperatures and effective shade at system potential vegetation. A description of the Heat Source and Shade-a-lator models, model calibration statistics, and overview of the analytical analysis are described in Appendix C. An overview of Heat Source is also found on-line: http://www.heatsource.info/ Effective shade targets will allow for the calculation of the amount of solar loading reaching the stream and perhaps most importantly shade targets translate nonpoint source load allocations into site specific vegetation targets for land owners and managers.

The diagram below illustrates this process:



Stream temperature analysis discussed in this chapter is limited to stream systems in the Upper Willamette Subbasin. The water quality restoration strategies identified are applicable to all streams in the subbasin. Application of these strategies contributes to the basin-scale effort to restore and protect cooler water temperatures in other Willamette River tributaries. This broad scale application to all tributaries is an important element in the protection of coldwater aquatic life in the Willamette Basin. Although these streams are not likely to individually affect temperatures in the Willamette River, collectively they provide important localized sources of cool water and temporary thermal refugia for resident or migrating coldwater fish.

Seasonal Variation

OAR 340-042-0040(4)(j), CWA 303(d)(1)

Streams in the Upper Willamette Subbasin exceed biologically based rearing criteria starting in late spring and through late summer. Maximum temperatures typically occurred in late July and early August, Figure 10.1. Long-term temperature recorders deployed by ODEQ, BLM, and USGS indicate that summer stream temperatures exceed the 18.0ºC (64.4ºF) migration and rearing, 16.0ºC (60.8ºF) core cold water habitat, and 13.0ºC (55.4ºF) salmon and steelhead spawning criteria. Temperatures in Upper Willamette River tributary streams were commonly above the criterion during summer months. Temperatures in the Luckiamute River ranged from 13.0°C (55.4°F) in the headwaters to 25.0°C (77.0°F) at RM 29.4 during summer. Temperatures in the Calapooia River ranged from 13.0°C (55.4°F) in the headwaters to 26.0°C (78.8°F) at RM 17.1 during summer. Streams exceeding the temperature criteria include Calapooia River, Coyote Creek, Amazon Creek, Luckiamute River, Ferguson Creek, Marys River, Muddy Creek, and South Fork Berry Creek.

In June 2001, ODEQ placed temperature thermisters in-stream at various locations throughout the Upper Willamette Subbasin. BLM and USGS also collected in-stream temperature data, Map 10.7. The longitudinal profiles of the seven day moving maximum for Luckiamute River and the Calapooia River are shown in Figure 10.1. Thermisters were removed from the stream in late August 2001 before stream flow conditions became hazardous. In early August, ODEQ staff conducted field surveys to record instantaneous flow, characterize the stream channel, audit in-stream temperatures, and characterize the riparian vegetation. Digital photos were taken and a Geographical Positioning System (GPS) was used to determine the latitude and longitude position of each survey site location. Several streams in the Upper Willamette Subbasin lack sufficient riparian vegetation and have incised stream banks, see photos in Figures 10.2 to 10.6. USGS real-time flow gage information was also recorded when available, specifically for Heat Source hydrology development.

Map 10.7 Temperature Monitoring Locations in the Upper Willamette Subbasin

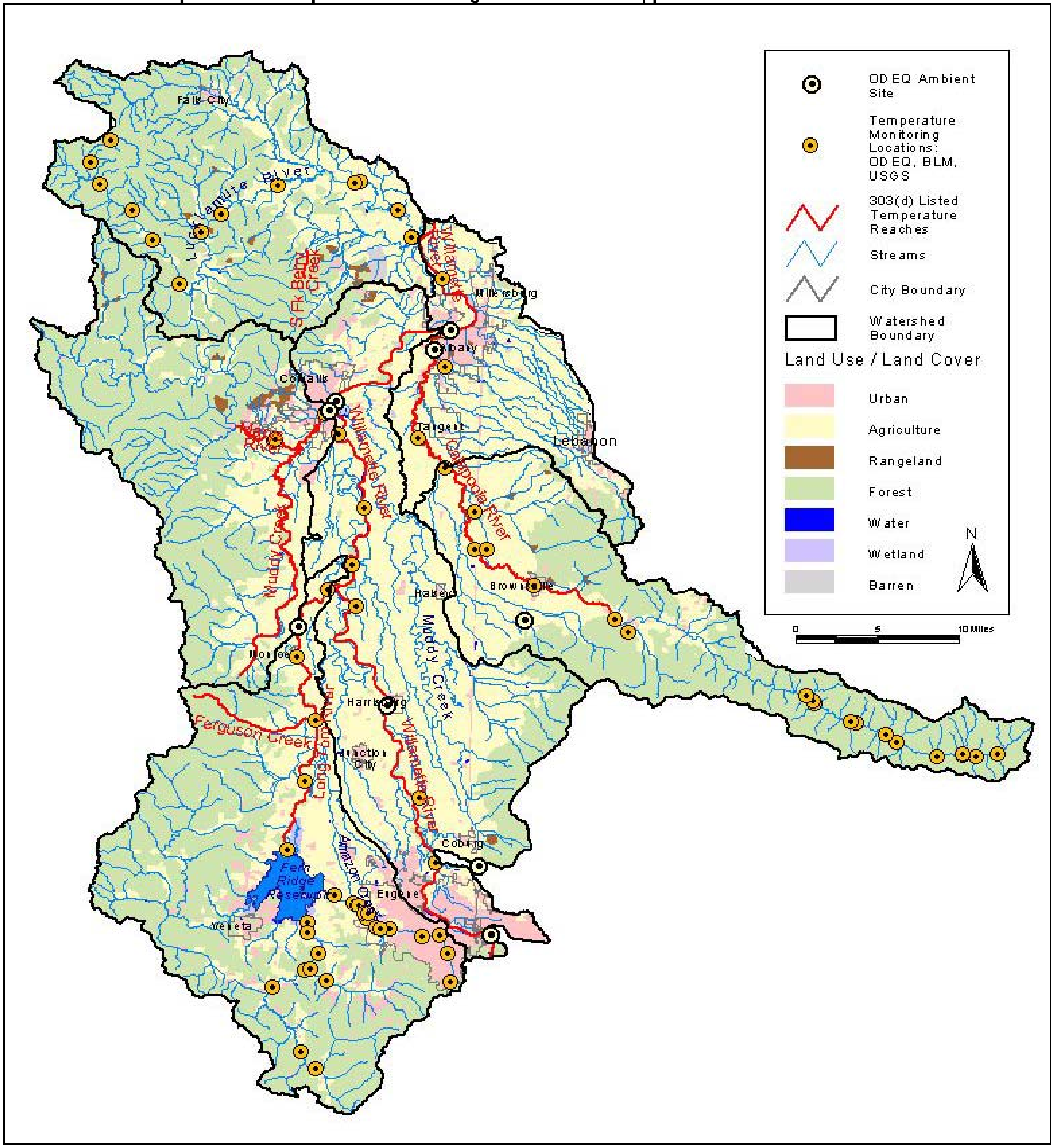
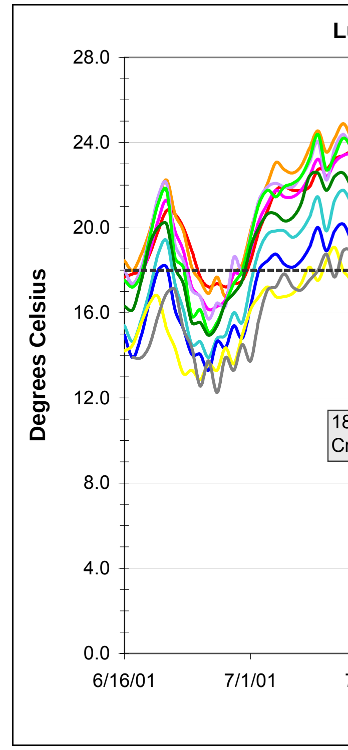


Figure 10.1 **Temperature Profiles for Luckiamute River and Calapooia River.**



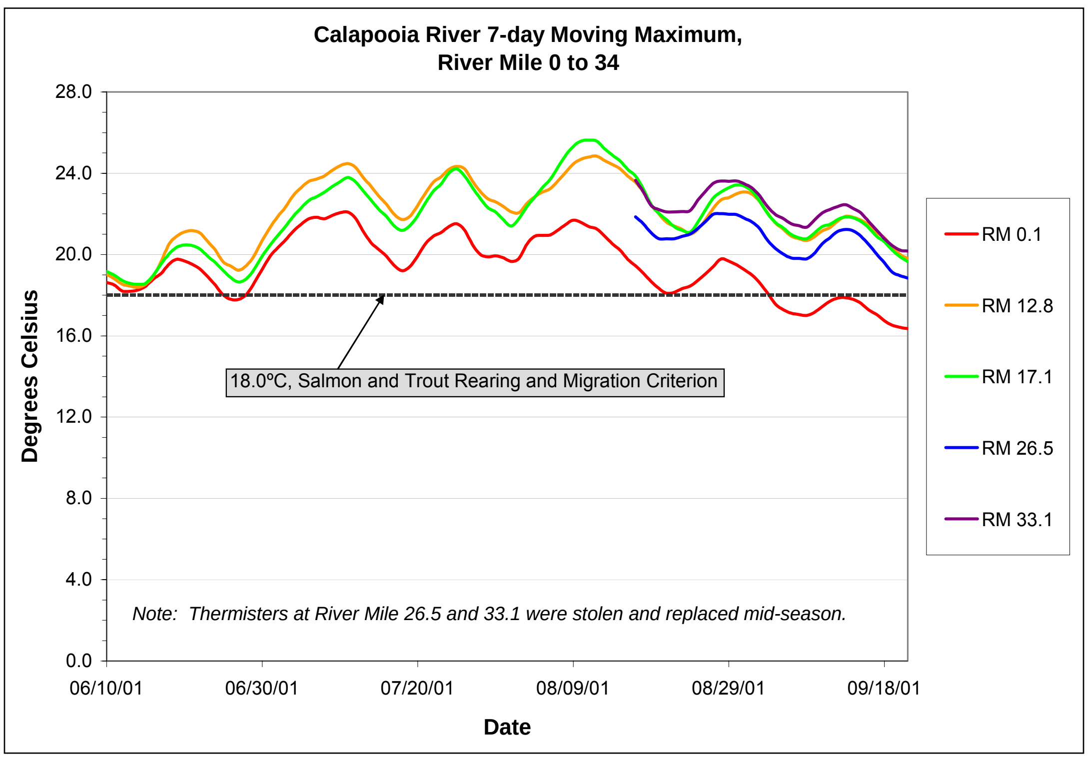


Figure 10.1 continued

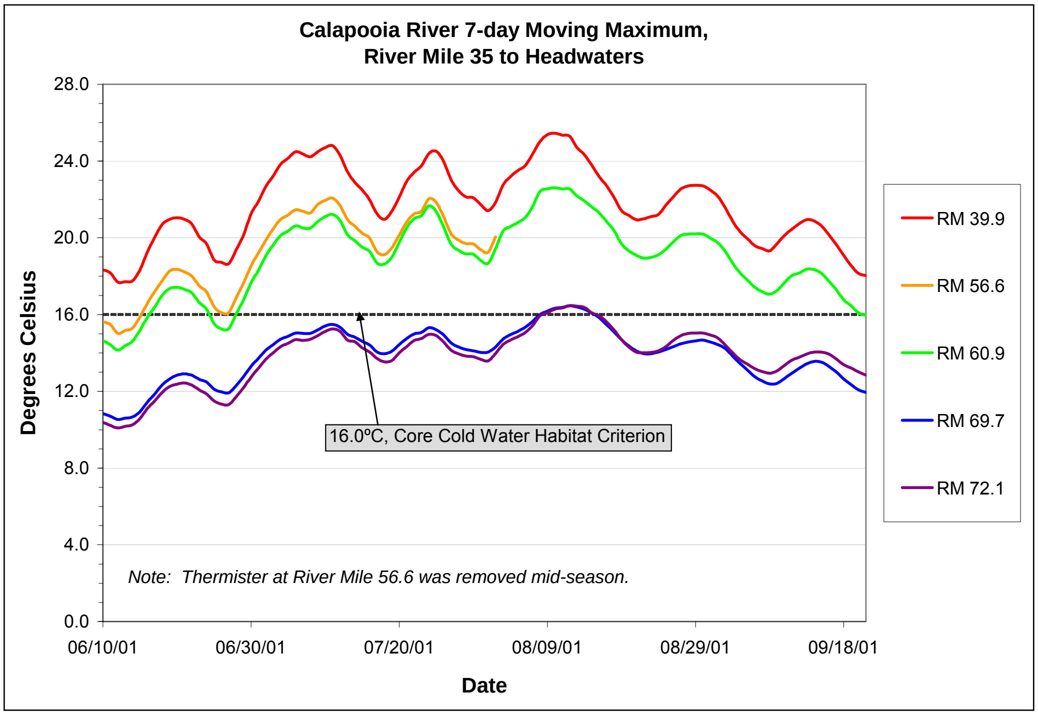


Figure 10.2 **Luckiamute River at RM 2, LASAR# 10658, during high flows narrow riparian buffer and upstream processes increase river turbidity and solar loading.**

Figure 10.3 **Luckiamute River at RM 29, no riparian buffer allows for direct overland runoff flow and increase in solar radiation.**

Figure 10.4 Calapooia River at RM 17, LASAR# 11182, severe incision and lack of riparian buffer.

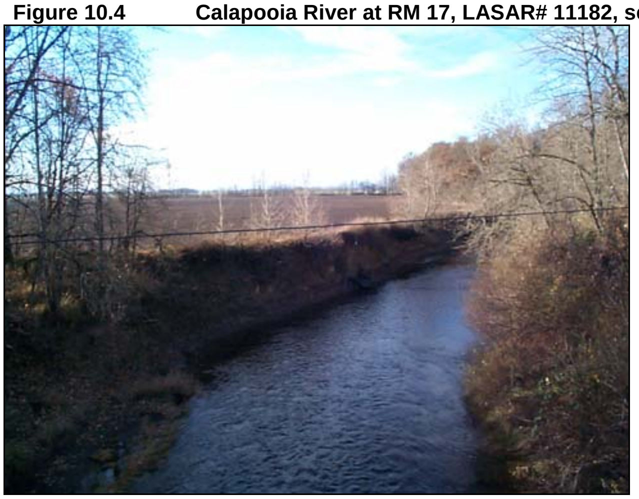


Figure 10.5 Muddy Creek at RM 46, LASAR# 28781, lack of riparian buffer.

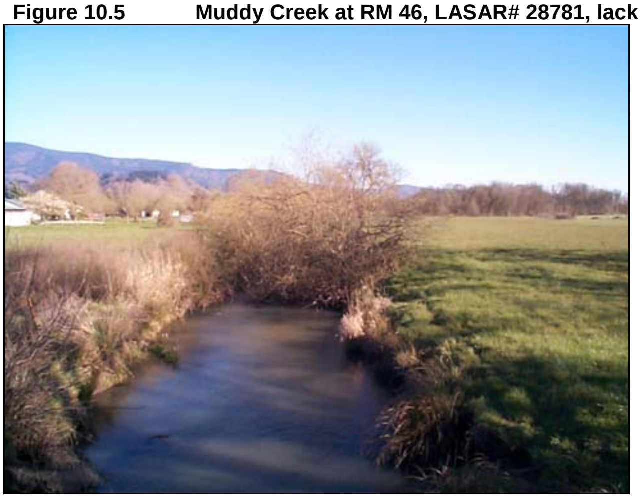


Figure 10.6 Long Tom River at RM 1, LASAR #11475, lack of riparian buffer with significant population of invasive blackberry brush in riparian area.

Loading Capacity

OAR 340-042-0040(4)(d, 40 CFR 130.2 (f)

The loading capacity is the total amount of a pollutant that a water body can assimilate without exceeding a water quality criterion or impairing a beneficial use. This is the pollutant load that may be divided among all point and nonpoint sources as allocations.

The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring water into compliance with water quality criteria. USEPA's current regulation defines loading capacity as "*the greatest amount of loading that a water can receive without violating water quality standards*" (40 CFR § 130.2(f)). Oregon's temperature criteria states that a surface water temperature increase of no more than 0.3°C (0.54ºF) above the applicable criterion is allowed from all anthropogenic sources at the point of maximum impact.

The loading capacity is dependent on the available assimilative capacity of the receiving water. For water bodies whose natural thermal potential temperatures are at or above the temperature criterion for a given period, there is no available assimilative capacity beyond the 0.3°C (0.54ºF) human use allocation. The loading capacity is essentially consumed by non-anthropogenic sources. When natural thermal potential temperatures are less than biological based numeric criteria, the load capacity may be somewhat greater than the human use allowance provided additional heat loads do not prevent attainment of water quality criteria in downstream waters.

Critical Condition

The critical condition for stream temperature and heat loading is the seasonal period of maximum stream temperatures and lowest stream flows. Maximum stream temperatures are a function of combining the effects of atmospheric inputs (solar radiation) and low stream flows that usually occur during the summer period. For many point sources the most critical condition for complying with the human use allowance occurs during the combined effect of low stream flow and the greatest difference between effluent and river temperatures, usually in late summer to early fall.

Allocations

40 CFR 130.2(g), 40 CFR 130.2(h)

Loading capacity is allocated among point sources as wasteload allocations and to nonpoint sources as load allocations. Load allocations to anthropogenic sources are only available where surface water temperatures throughout a given stream meet the applicable water quality criteria plus the human use allowance. The general principle for allocation in the Upper Willamette Subbasin is to target natural background heat inputs from nonpoint sources and to limit point source loads to small allocations within the human use allowance.

Wasteload Allocations

OAR 340-042-0040(4(g)

A wasteload allocation (WLA) is the amount of pollutant that a point source can contribute to the stream without violating water quality criteria. Waste load allocations for temperature are expressed as heat load limits assigned to individual point sources of treated industrial and domestic waste. Waste load allocations are provided for all NPDES facilities that have reasonable potential to warm the receiving stream when the applicable criteria are exceeded. The WLAs in this chapter are for point sources to waterbodies other than the Willamette River and the Long Tom River downstream of Fern Ridge Reservoir in the Upper Willamette Subbasin. Point sources that discharge directly to the Willamette River and Long Tom River downstream of Fern Ridge Reservoir have been considered as part of Chapter 4. Point source facilities in the Upper Willamette Subbasin that may require allocated heat load based on this TMDL are identified in Table 10.7.

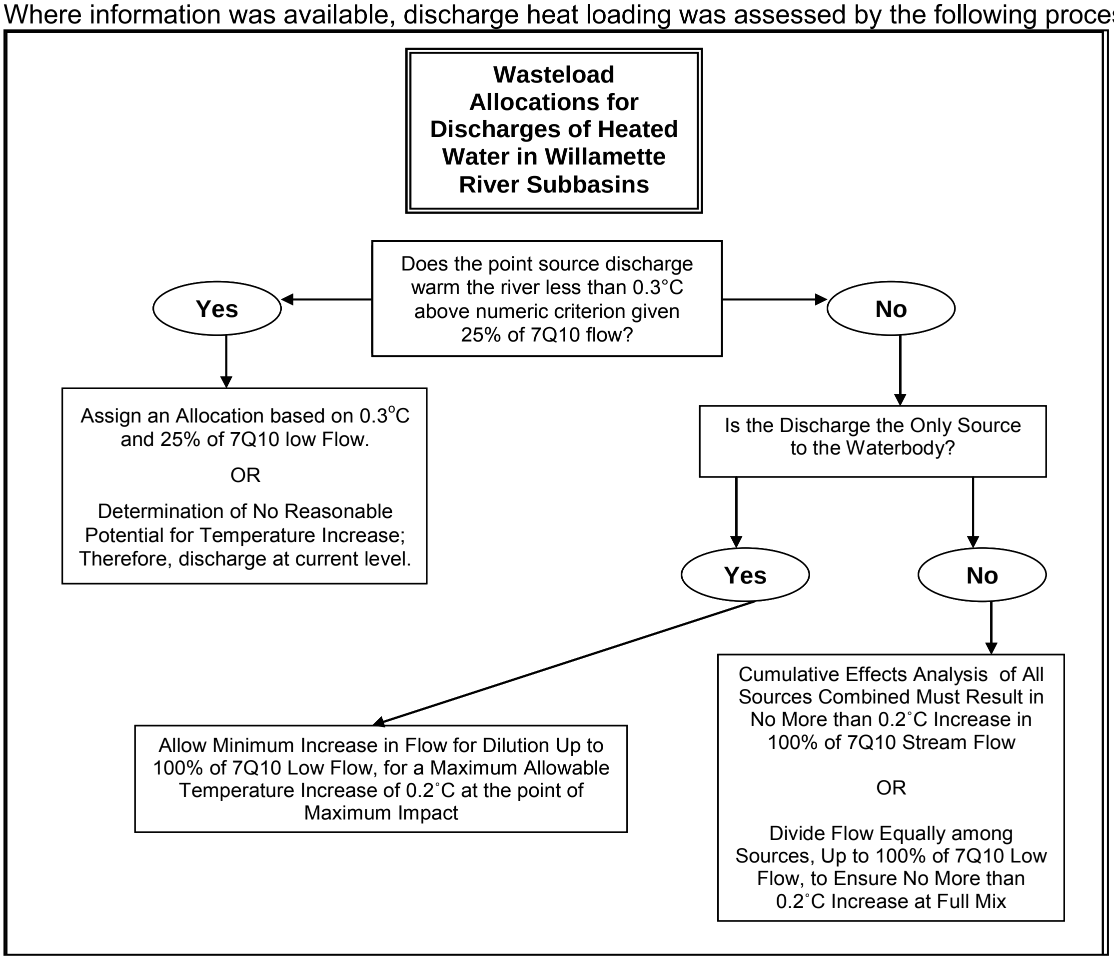
Wasteload Allocations in Small Streams

Discharges were screened to determine which would probably receive a wasteload allocation based on the type of discharge, and the volume and temperature of the effluent. General permits that are unlikely to discharge significant volumes of warm water during critical periods (e.g., stormwater permits) are not expected to have a reasonable potential to increase in-stream temperatures. General permits that discharge heated effluent (e.g., boiler blowdown, log ponds) were considered as potential sources. For discharges with insufficient information (absence of stream flow data) to screen for effects or develop a wasteload allocation (WLA), a WLA will be calculated at the time of permit renewal by the method described below.

Oregon's temperature standard [OAR 340-041-0028(12)] allows an insignificant increase in temperature from all point source and nonpoint sources combined as a Human Use Allowance (HUA = 0.3˚C). Prior to development of a TMDL, the standard allows the assumption that a 0.3˚C (0.54˚F) increase in one-quarter (¼) of the receiving stream flow or the volume of the temperature mixing zone (whichever is more restrictive) will not cause an impairment.

The waste load allocation scheme below assumes an allowable change in temperature above criteria of 0.3˚C within 25% of the 7Q10 low flow (a calculation of the seven-day, consecutive low flow with a ten year return frequency). This is the initial step in the development of a waste load allocation on smaller streams or when information is insufficient to allow a greater proportion of receiving water flow for mixing. The resultant temperature increase in fully mixed receiving water would be limited to 0.08˚C. More than the minimum flow allowance (25% of 7Q10 low flow) may be allocated to an individual source when analysis demonstrates standards attainment. The resulting temperature increase in this scenario depends on the proportion of low flow allocated, but should not exceed the point source sector allocation of 0.2°C over the entire waterbody. Moreover, each discharge is also required to ensure the local effects of discharge will not cause impairment to health of fish by meeting thermal plume requirements adopted under OAR 340-41-0053(2)(d).

Where information was available, discharge heat loading was assessed by the following process:



The pre-TMDL limits in the flow chart above refer to currently permitted discharge limits for existing point sources. Wasteload allocations are expressed in terms of heat load (kilocalories per day). These heat loads are calculated from estimates of river flow, effluent flow, effluent temperature, and either the appropriate biologically based criterion or the natural thermal potential at the point of discharge. Heat load is calculated with Equation 1 (below). Where in-stream and effluent flow information is sufficient, allocations, and effluent limits may be developed based on flow rates for time periods other than monthly or an entire season (e.g., daily loads). The QZOD term may vary depending upon the situation for the discharger as explained in the decision tree above, but will usually be ¼ of the 7Q10 low flow on either a monthly or a yearly basis dependent on data availability.

Equation 1:

$$H_{PS} = (Q_{ZOD} + Q_{PS}) \cdot \frac{1\ ft^3}{1\ sec} \cdot \frac{1\ m^3}{35.31\ ft^3} \cdot \frac{1{,}000\ kg}{1\ m^3} \cdot \frac{86{,}000\ sec}{1\ day} \cdot \Delta T_{ZOD} \cdot c = \frac{Kcal}{day}$$

where:

- H_{PS}: Heat from point source effluent received by river (kcal/day)
- Q_{ZOD}: River flow volume allowed for mixing- ¼ of 7Q10 low flow statistic (cfs)
- Q_{PS}: Point source effluent discharge (cfs)
- ΔT_{ZOD}: Change in river temperature at point of discharge - 0.3^oC allowable (^oC)
- c: Specific heat of water (1 Kcal / 1kg 1ºC)

Estimates of effluent temperature were calculated using mass loading equations (**Equation 2**) taking into account river flow and temperature, and effluent flow and temperature. Allocations are usually calculated to ensure an increase in temperature of no more than 0.3°C (0.54°F) in one-quarter of the volume of the receiving stream. When this volume is fully mixed with the receiving stream, this increase in temperature would be limited to 0.08°C. Where more than the minimal flow volume is allocated, either to allow more heat load to an individual discharger on a stream, or to calculate the cumulative effects of multiple discharges, the allocation is no more than 0.2°C (0.36°F) increase given the entire flow of the river receiving the cumulative discharges. If new or more comprehensive information (e.g. flow data, temperature data, mixing zone characteristics) is available at the time permits are renewed, permit limits will reflect revised wasteload allocations as calculated using **Equation 1** above and the best information available.

Equation 2:

$$T_{WLA} = \frac{[(Q_{PS} + Q_{ZOD}) \cdot (T_R + \Delta T_{ZOD})] - (Q_{ZOD} \cdot T_R)}{Q_{PS}}$$

where:

- T_R: Temperature Criterion or Upstream potential river temperature (^oC)
- T_{WLA}: Maximum allowable point source effluent temperature (^{o} C)
- ΔT_{ZOD}: Change in river temperature at point of discharge - 0.3^oC allowable (^oC)
- Q_{ZOD}: River flow volume allowed for mixing- ¼ of 7Q10 low flow statistic (cfs)
- Q_{PS}: Point source effluent discharge flow volume (cfs)

Six permitted discharges to subbasin streams in the Upper Willamette Subbasin may require permit limits to ensure water quality standards are met, Table 10.7. These facilities are all industrial dischargers. All discharges have the potential to increase water temperature, but currently available information is insufficient to allow calculation of wasteload allocations. This information will be gathered prior to renewal of these permits, and limits will be developed as described above to ensure temperature in receiving waters is not increased beyond permissible limits.

Table 10. 7 Individual NPDES facilities in the Upper Willamette Subbasin, which do not discharge to the mainstem Willamette River or the lower Long Tom River.

File Nbr	Facitlity Name	Permit Type	Permit Description	Receiving Stream	River Mile	Type of Discharge	Season of Discharge
102788	TRIUMPH GROUP OPERATIONS, INC., THE (Northwest Industries)	NPDES-IW-O	Industrial Wastewater; NPDES process wastewater NEC	Oak Creek	1.6	Process Water	Year-Round
16037	DYNEA U.S.A. INC.	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Patterson Slough	1.83	Process Water	Year-Round
6553	J.H. BAXTER & CO., INC.	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Amazon Diversion Canal	1.5	Process Water	Year-Round
54370	MCFARLAND CASCADE POLE & LUMBER COMPANY	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Un-named	1.8	Process Water	Year-Round
97047	WEYERHAEUSER COMPANY	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Murder Creek	0.57	Process Water	Year-Round
9341	WEYERHAEUSER COMPANY	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Noti Creek	6.3	Process Water	Year-Round

FWS = Fall-Winter-Spring; approximately October through May
NEC = Not Elsewhere Classified

Load Allocations

OAR 340-042-0040(h)

Load Allocations are portions of the loading capacity divided among natural, current anthropogenic, and future anthropogenic nonpoint pollutant sources. Load allocations (i.e. distributions of the loading capacity) are provided in Table 10.9 for Coyote Creek, Calapooia and Luckiamute Rivers.

In this TMDL, load allocations are allowed 0.05˚C of the human use allowance (0.3˚C). This heat allowance is in addition to the load that streams would receive when they are at system potential and would allow activities that might increase the loading (such as riparian management activities) or for human disturbance that may not easily be addressed (e.g. presence of a road near a stream that would limit shading). The 0.05°C increase in temperature above criteria (1/6th of the HUA) is dedicated to nonpoint sources but is not allocated to individual sources at this time.

The current loading from nonpoint sources is much greater than that which would exist under natural thermal potential. This requires nonpoint sources to reduce thermal inputs to reach natural thermal potential conditions through allocation of a surrogate measure, effective shade. The principal means of achieving this condition is through protection and restoration of riparian vegetation. Additional measures may also be taken to improve summer temperatures. For example, water conservation measures that improve summer stream flows will benefit stream temperatures through an increase in load capacity. Stream restoration efforts that result in narrower stream channel widths will improve the effectiveness of existing vegetation to shade the stream surface.

Nonpoint source allocations were assigned natural background loads and are implemented as shade curves for upland forests and each geomorphic unit. This allocation also applies to tributaries of temperature listed waterbodies. Shade curves illustrate the relationship between each potential vegetation cover type, channel width and the resulting effective shade level.

The total nonpoint source solar radiation heat load was derived for Coyote Creek, Luckiamute River and Calapooia River. Current solar radiation loading was calculated by simulating current stream and vegetation conditions using the Heat Source Model version 6.5 for Coyote Creek and Luckiamute River. Calapooia River current solar radiation loading was calculated using the Shade-a-lator Shade Model derived from the Heat Source Model. Background loading was calculated by simulating the solar radiation heat loading that resulted with system potential vegetation. This background condition, based on system potential vegetation, reflects an estimate of nonpoint source heat load that would occur while meeting the temperature criterion. The relationships below were used to determine solar radiation heat loads for the current condition, anthropogenic contributions, and loading capacity derivations based on system potential, Table 10.8.

Table 10. 8 Solar Radiation Heat Load Calculation Diagram

Total Solar Radiation Heat Load from All Nonpoint Sources,

$$H_{\text{Total NPS}} = H_{\text{SP NPS}} + H_{\text{Anthro NPS}} = \Phi_{\text{Total Solar}} \cdot A$$

Solar Radiation Heat Load from Background Nonpoint Sources (*System Potential*),

$$H_{\text{SP NPS}} = \Phi_{\text{SP Solar}} \cdot A$$

Solar Radiation Heat Load from Anthropogenic Nonpoint Sources,

$$H_{\text{Anthro NPS}} = H_{\text{Total NPS}} - H_{\text{SP NPS}}$$

Note: All solar radiation loads are the clear sky received loads that account for Julian time, elevation, atmospheric attenuation and scattering, stream aspect, topographic shading, near stream vegetation stream surface reflection, water column absorption and stream bed absorption.

where,

$H_{\text{Total NPS}}$: Total Nonpoint Source Heat Load (kcal/day)
$H_{\text{SP NPS}}$: Background Nonpoint Source Heat Load based on *System Potential* (kcal/day)
$H_{\text{Anthro NPS}}$: Anthropogenic Nonpoint Source Heat Load (kcal/day)
$\Phi_{\text{Total Solar}}$: Total Daily Solar Radiation Load (ly/day)
$\Phi_{\text{SP Solar}}$: Background Daily Solar Radiation Load based on *System Potential* (ly/day)
$\Phi_{\text{Anthro Solar}}$: Anthropogenic Daily Solar Radiation Load (ly/day)
A: Stream Surface Area - calculated at each 100 foot stream segment node (cm^2)

System Potential vegetation characteristics were developed to include the effects of natural disturbance on riparian vegetation distribution and attributes within each geomorphic unit. The term "geomorphic unit" refers to quaternary geologic units shown as polygons that were differentiated on the basis of stratigraphic, topographic, pedogenic, and hydrogeologic properties (O'Connor et al, 2001). In other words, surface deposits of unconsolidated material above bed rock shaped by processes of erosion, sediment transport and deposition.

Natural disturbance includes among other processes:

- Flood
- Wind Throw
- Fire
- Insect Infestation

System potential vegetation includes the random distribution of conifer, mix conifer-hardwood, and hardwood species in each geomorphic unit. This random distribution of attributes within each geomorphic unit is intended to include the effects of natural disturbance in the system potential riparian vegetation condition. Some geomorphic units may also incorporate prairie. The proportions of forest, savanna and prairie to be used in each geomorphic unit were developed following rules detailed Table 1 and on page 14 of the Potential Near-Stream Land Cover document included in Appendix C. As an example, in the quaternary alluvium unit (Qalc) which is unconsolidated silt, sand, and gravel of the Willamette River and major Cascade Range tributaries the vegetation distribution includes 80% forest, 17% savanna and 3% prairie. Forest land includes a mix of conifer (4%), hardwood (3%) and mixed (93%) forests which determines the shade characteristics of the near stream plant community.

A total of 81 river miles in the Upper Willamette Subbasin were analyzed and simulated during the critical period. Coyote Creek and Luckiamute River were modeled using Heat Source on July 11th, 2001and August 12th, 2001, respectively, because the warmest stream temperatures were recorded on these dates. The Coyote Creek model started at RM 1.6 because the lower portion of the creek is influenced by Fern Ridge Reservoir and surrounding wetlands. The stream temperatures that result from system potential riparian conditions for Coyote Creek, Figure 10.7, and Luckiamute, Figure 10.8, are presented. These graphs represent the maximum daily stream temperatures observed. A decrease in the observed daily maximum stream temperatures occurs for both streams when system potential riparian vegetation is applied. The stream temperatures that result from system potential riparian vegetation are the allocated condition.

Figure 10.7 Coyote Creek distribution of maximum daily stream temperatures at current conditions and system potential vegetation.

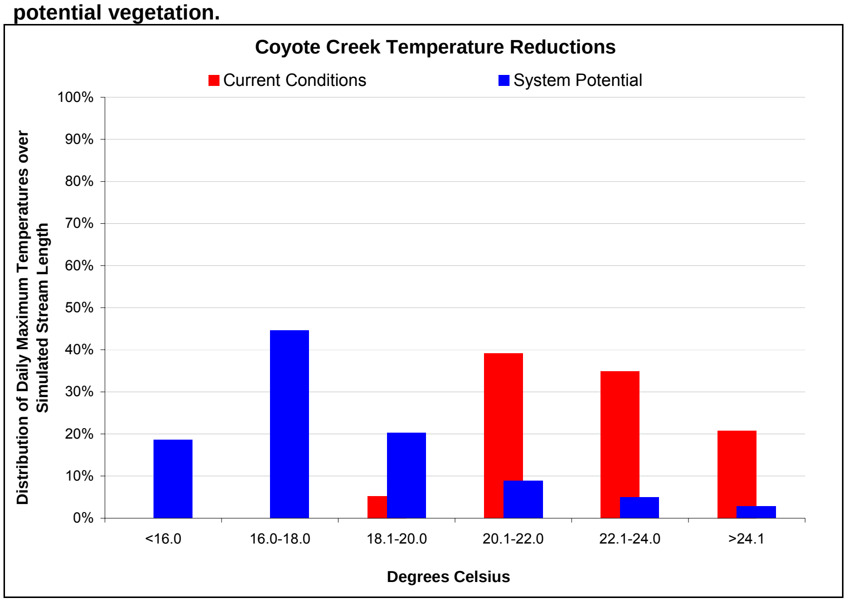
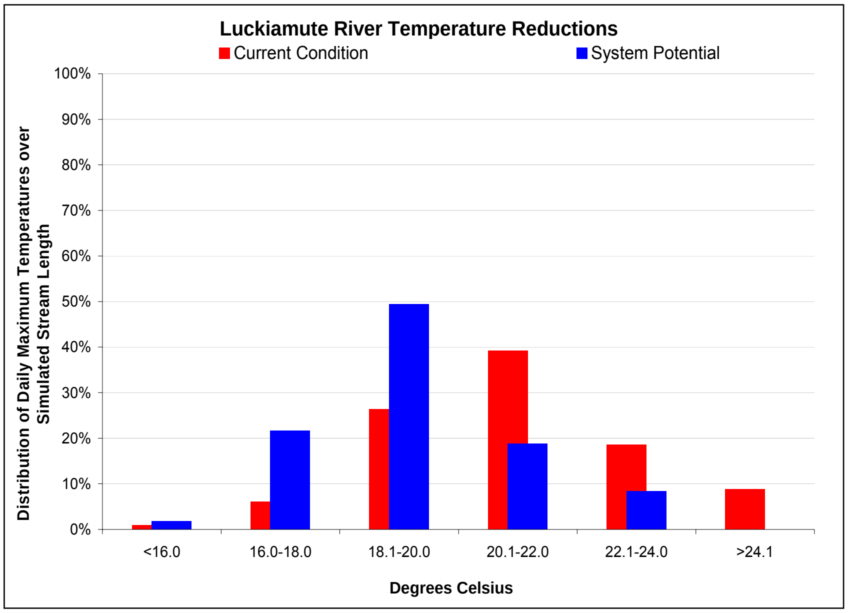


Figure 10.8 Luckiamute River distribution of maximum daily stream temperatures at current conditions and system potential vegetation.



The percent effective shade calculated for current conditions versus system potential vegetation conditions for Coyote Creek, Luckiamute River, and Calapooia River averaged over a 1 km (0.6 miles) distance are shown in Figures 10.9, 10.10 and 10.11. The shade model Shade-a-lator was used to model 72 river miles of the Calapooia River. Typically system potential vegetation provides greater percent effective shade values to the stream, however for selected reach portions the currently simulated system potential vegetation conditions have lower percent effective shade calculated values than at current conditions. This decrease in effective shade under system potential conditions is due in part to the Monte Carlo simulated natural disturbance developed as part of the system potential vegetation scenario as described in Appendix C. For example, the system potential condition in the headwaters of a creek may have accounted for a disturbance in the riparian community when in fact under current conditions there may not be disturbance in the riparian community.

It is expected that effective shade values would increase if stream channel widths decreased. Decreasing channel widths would increase the effectiveness of the system potential vegetation to shade the stream and in effect decrease in-stream temperatures, as well as reduce the width-to-depth ratio of the stream. On a system average there is about a 25% increase in effective shade in Coyote Creek, a 10% increase in Luckiamute River, and a 10% increase in Calapooia River under system potential vegetation conditions.

Figure 10.9 Coyote Creek Longitudinal Percent Effective Shade Profile of Current Conditions versus System Potential Vegetation, averaged over a 1 km distance.

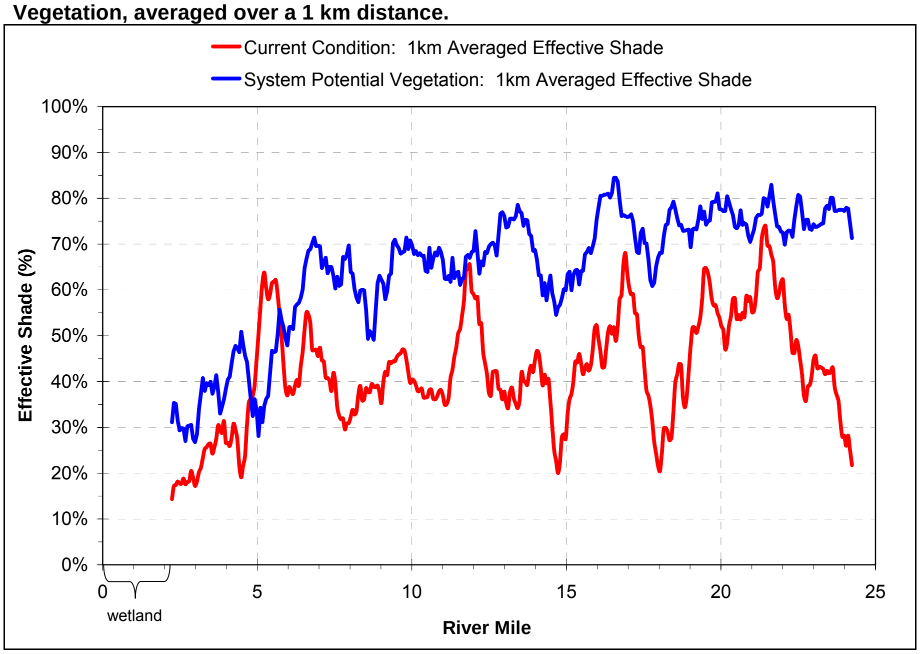


Figure 10.10 Luckiamute River Longitudinal Percent Effective Shade Profile of Current Conditions versus System Potential Vegetation, averaged over a 1 km distance.

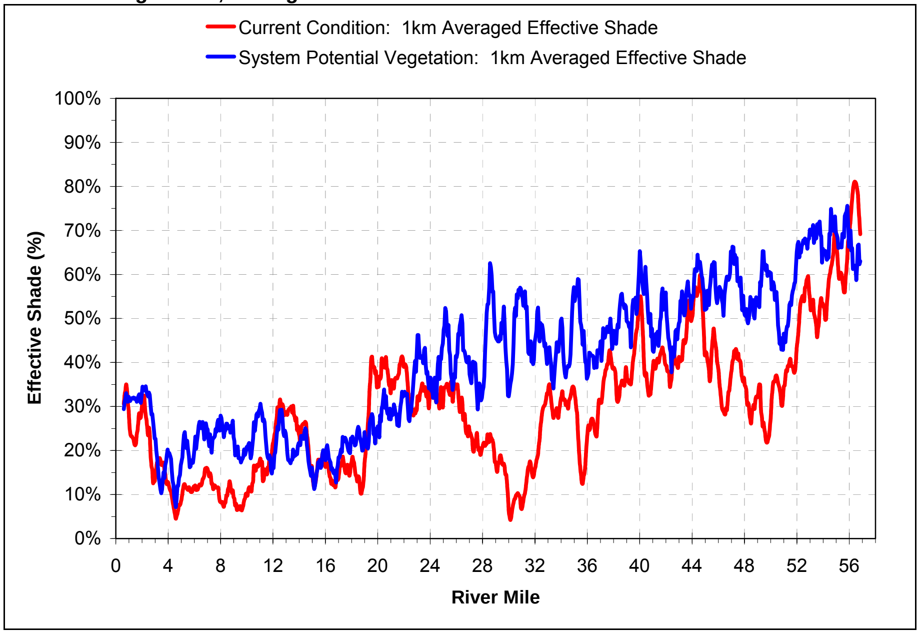
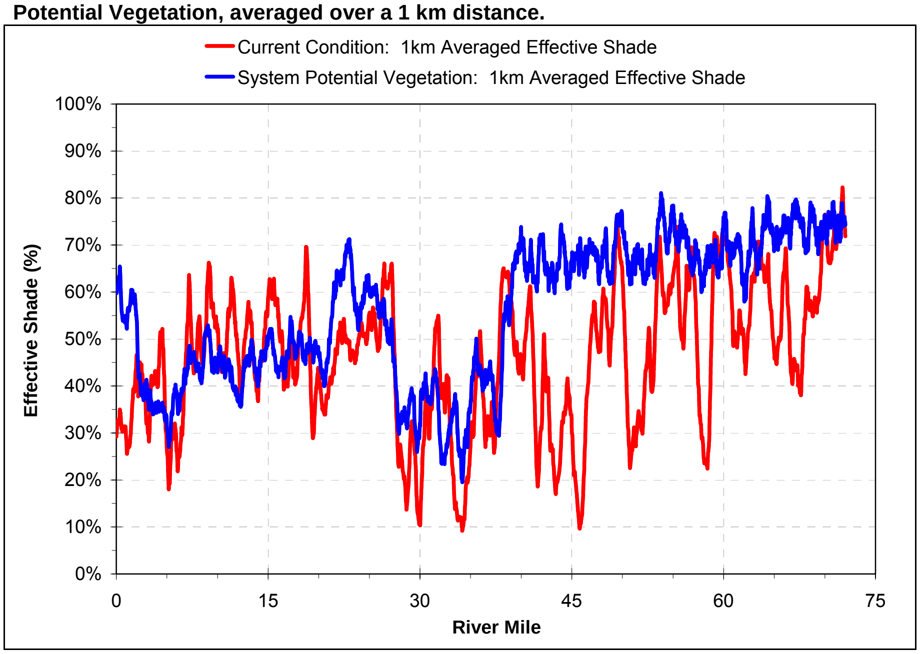


Figure 10.11 Calapooia River Longitudinal Percent Effective Shade Profile of Current Conditions versus System Potential Vegetation, averaged over a 1 km distance.



A summary of the solar radiation loads for Coyote Creek, Luckiamute River, and Calapooia River at current and system potential conditions is shown in Table 10.9. The difference between current and system potential conditions is the calculated anthropogenic load for nonpoint sources. This table does not represent all listed waterbodies in the subbasin but only those where resources and priority allow for load calculation. Modeling of Coyote Creek with system potential riparian vegetation indicates that 1.87×10^8 kcal/day heat load is attributed to system potential condition and 8.7×10^7 kcal/day is due to anthropogenic sources. Modeling of the Luckiamute River with system potential riparian vegetation indicates that 11.17×10^8 kcal/day heat load is attributed to system potential condition and 2.0×10^8 kcal/day is due to anthropogenic sources. Modeling of the Calapooia River with system potential riparian vegetation indicates that 19.4×10^8 kcal/day heat load is attributed to system potential condition and 4.6×10^8 kcal/day is due to anthropogenic sources.

Table 10. 9 Coyote Creek, Luckiamute River, and Calapooia River Solar Radiation Load Summary.

Stream	Current Condition (10^8 kcal/d) $H_{Total\ NPS}$	System Potential Condition (background) (10^8 kcal/d) $H_{SP\ NPS}$	Anthropogenic $H_{Anthro\ NPS}$ (10^8 kcal/d)
Coyote Creek	2.74	1.87	0.87
Luckiamute River	13.17	11.17	2.0
Calapooia River	24.01	19.40	4.6
Totals	39.92	32.44	7.47

The point of maximum impact for anthropogenic sources of heat is defined as the point in the stream where the maximum change in temperature between natural thermal potential temperature and current temperatures are observed. In Coyote Creek and Luckiamute River this is where the differences between system potential vegetation and current vegetation conditions most affect stream temperatures. In Coyote Creek the point of maximum impact occurs at RM 17.7, downstream of Powell Road. The change between current condition stream temperatures and system potential vegetation temperatures at the point of maximum impact is 8.5°C (15.3°F). At the mouth of Coyote Creek the maximum current condition temperature is 27.5°C (81.5°F), and system potential vegetation simulations suggest this temperature would decrease to 25.2°C (77.4°F). The point of maximum impact for Luckiamute River occurs at RM 26.5, downstream of McTimmonds Creek. The change between current condition and system potential vegetation stream temperatures is 3.6°C (6.5°F). At the mouth of the river the current condition temperature is 24.6°C (76.3°F), simulations state that this temperature would decrease under system potential vegetation to 24.3°C (75.7°F).

In addition to system potential vegetation other methods may decrease stream temperatures and increase effective shade, such as:

- Improving stream channel morphology
- Increasing stream channel complexity
- Increasing stream flow
- Decreasing tributary stream temperatures
- Decreasing channel width

Excess Load

OAR 340-042-0040(4)(e)

The excess load is the difference between the actual pollutant load and the loading capacity of a water body. Load allocations for nonpoint sources are based on system potential vegetation. Riparian information provided by the ODEQ and BLM indicates that there is inadequate shade throughout the Upper Willamette Subbasin. ODEQ data also suggest shade levels are less than system potential in the Luckiamute River, Calapooia Creek, Amazon Creek, and Coyote Creek. Excess heat loading occurs wherever inadequate shade levels are widespread.

Surrogate Measures

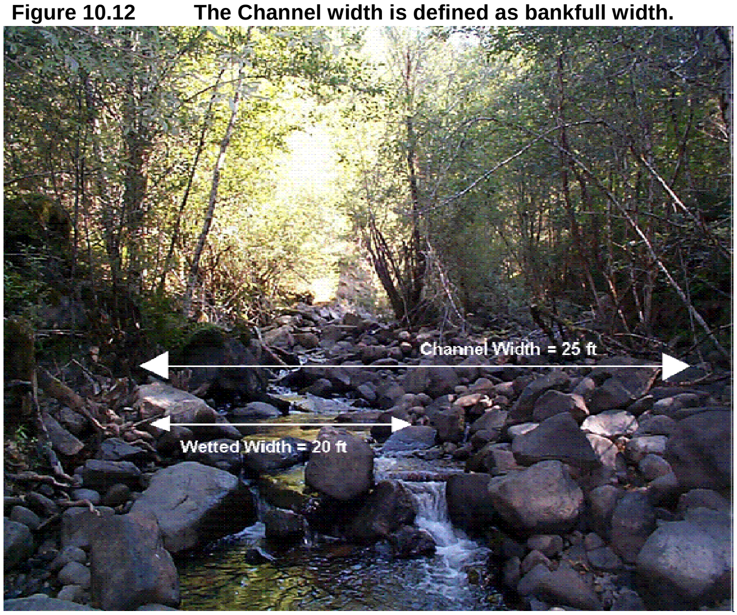
OAR 340-042-0040(5)(b), 40 CFR 130.2(i)

The Upper Willamette Subbasin Temperature TMDL incorporates measures other than “daily loads” in allocating heat to nonpoint sources. These measures are termed surrogate measures. The applied surrogate measure in this temperature TMDL is percent effective shade expressed as a shade curve. Shade curves have been developed for each geomorphic unit in the Willamette Valley and upland forest area of the Cascade and Coast Ranges in the Willamette Basin. Shade curves determine the nonpoint source load allocation. They were developed using trigonometric equations estimating the shade underneath tree canopies.

Percent effective shade is perhaps the most straightforward stream parameter to monitor and calculate. It is easily translated into quantifiable water quality management and recovery objectives. Percent effective shade is defined as the percentage of direct beam solar radiation attenuated and scattered before reaching the ground or stream surface, commonly measured with a Solar Pathfinder.

Shade curves represent general relationships between the percent effective shade reaching the stream surface, solar radiation loading of the stream, system potential vegetation, stream aspect from north, and the width of the channel. The channel width, Figure 10.12, is the distance from the edge of right bank vegetation to the edge of left bank vegetation.

Figure 10.12 The Channel width is defined as bankfull width.



System potential vegetation has been developed for each geomorphic unit in the Willamette Basin. It is defined as the riparian vegetation which can grow and reproduce on a site given the plant biology, site elevation, soil characteristics, and local climate. However, it does not include considerations for resource management, human use, and other human disturbances. A natural disturbance regime has been incorporated into the riparian composition for each geomorphic region that includes provisions for fire, disease, wind-throw, and other natural occurrences. Each shade curve translates the amount of percent effective shade that each geomorphic unit tree composition provides to the stream based on the streams channel width (bankfull width) and stream aspect from north. Each geomorphic unit is composed of a percentage of forest, savannah, and prairie and reflects the tree species composition that will grow and reproduce in each geomorphic unit. For a detailed description of the system potential vegetation development and of the riparian tree species composition for each geomorphic unit please see “System Potential Vegetation”, Appendix C. A shade curve has been developed for each geomorphic and upland forest unit in the Upper Willamette Subbasin, Map 10.8 to 10.14 and Figure 10.13. Watershed geomorphic maps that represent more than one geomorphic unit are shown for the Luckiamute River Watershed, Oak Creek Watershed, Calapooia River Watershed, Muddy Creek Watershed, Long Tom River Watershed, and Marys River Watershed.

The relative areas of the geomorphic classifications of the Upper Willamette Subbasin are presented in Table 10.10. Despite the relatively fine scale of the geomorphic classifications, the differences among the various shade curves are subtle in some cases.

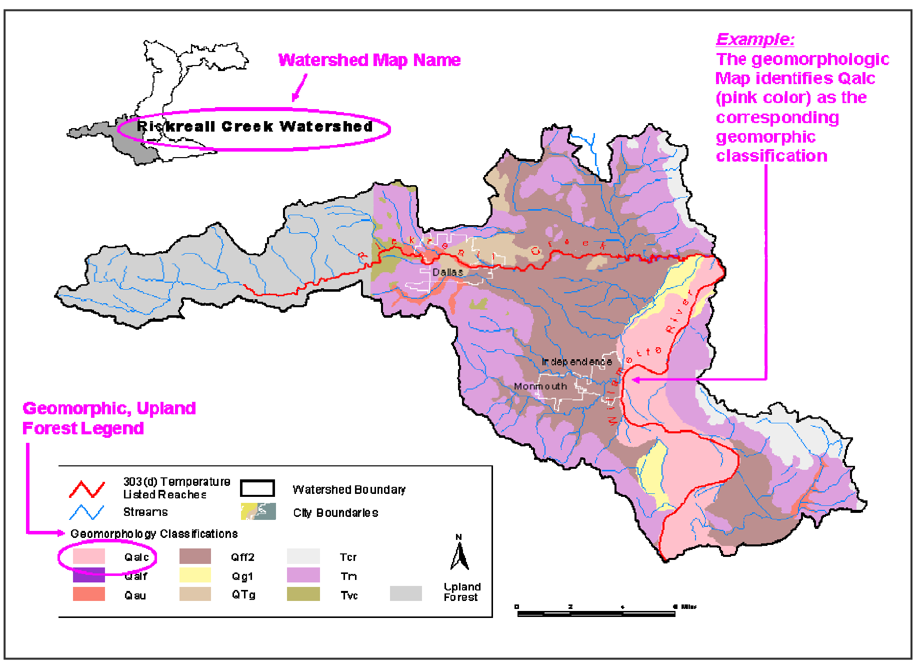
Table 10. 10 Area of Geomorphic Units in the Upper Willamette Subbasin. Values are ranked in order of increasing area.

Geomorphic Class	Acres	Square Miles	Relative Area (%)
Quaternary Landslide deposits (Qls)	1,583	2	0.1
Undifferentiated Quaternary Alluvium (Qau)	16,066	25	1.3
Fine-grained quaternary alluvium (Qalf)	21,228	33	1.8
Quaternary terrace gravels (QTg)	36,776	57	3.1
Pre-Flood Quaternary sand/gravel (Qg2)	38,441	60	3.2
Tertiary Volcanics Coast Range (Tvc)	39,134	61	3.3
Quaternary fine-grained alluvium (Qbf)	45,894	72	3.8
Post Flood Quaternary sand/gravel (Qg1)	54,289	85	4.5
Quaternary alluvium floodplain deposits (Qalc)	79,258	124	6.6
Western Cascades tertiary volcanics (Tvw)	81,909	128	6.8
Tertiary Marine sedimentary rock (Tm)	104,445	163	8.7
Quaternary fine-grained Flood deposits (Qff2)	218,368	341	18.2
Upland Forests (Uf)	451,803	706	37.7
Total	**1,197,459**	**1,871**	**100.0**

How to Use a Shade Curve:

1. Determine the applicable geomorphic or upland forest unit that applies to the stream reach you are applying a Shade Curve to.

Example: You are located in the Rickreall Creak watershed, in the city of Independence along the west bank of the Willamette River. By using the appropriate map, below, you identify the geomorphic unit on your property to be Qalc (Quaternary alluvium floodplain deposits).



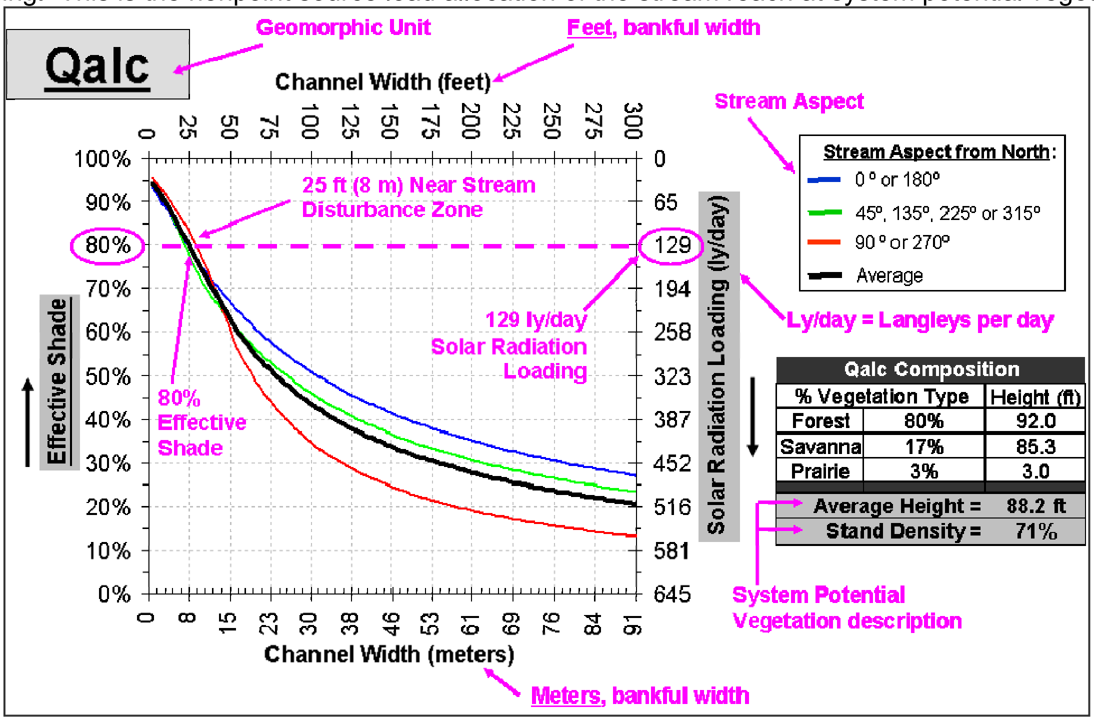
2. Determine the stream aspect from north.

Example: Based on your location on a tributary to the west bank of the Willamette River in Independence, standing in-stream mid-channel, facing north you determine the river's aspect as 0º or 180º from north (this means the river reach runs south to north).

3. Determine the channel width of the stream reach.

Example: At your location you measure the channel width using a tape measure or lasar range finder, you determine the stream width is 25 feet.

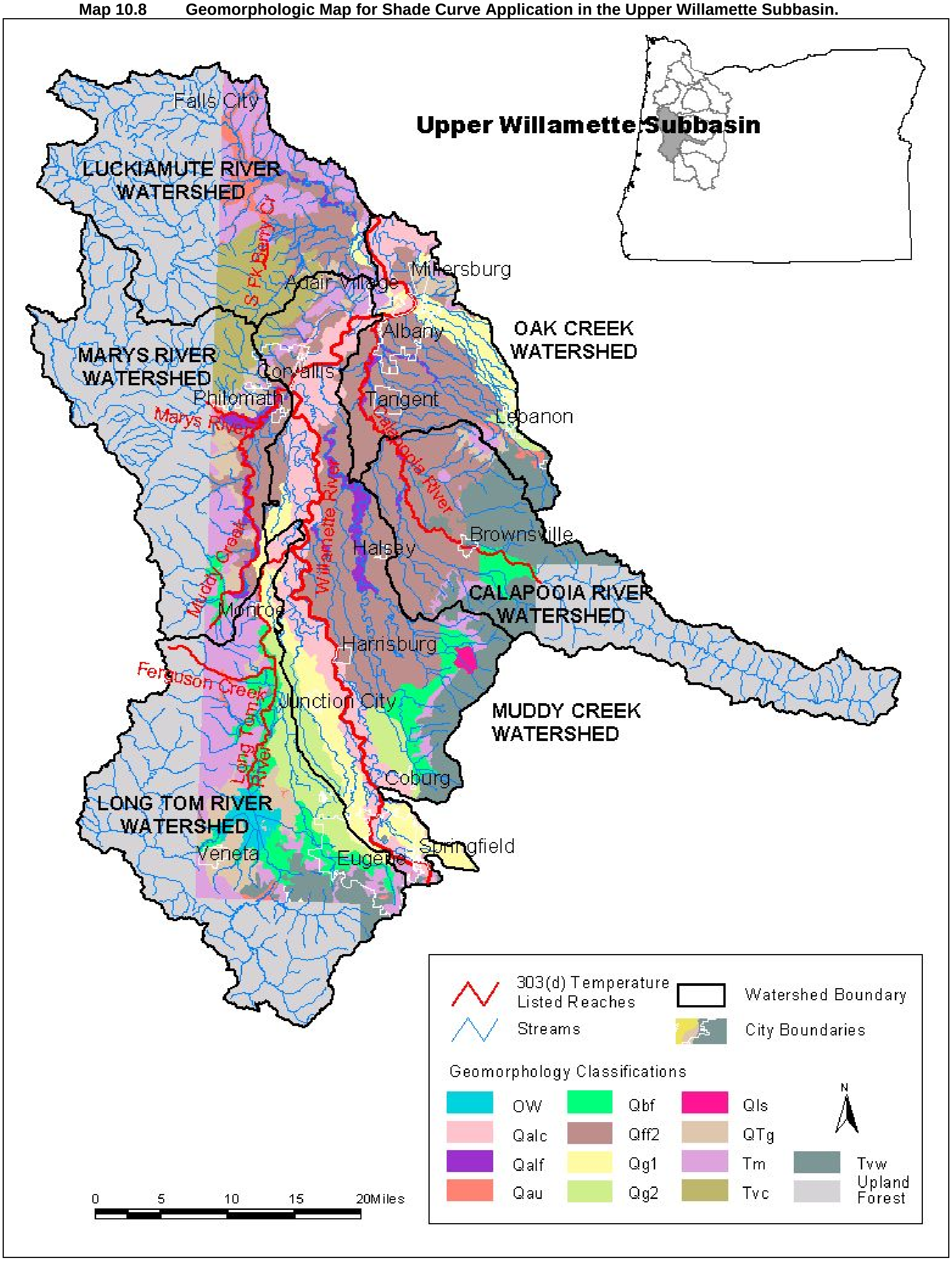
4. Using the appropriate geomorphic or upland forest Shade Curve and the appropriate stream aspect line and channel width (x-axis), read the y-axis to determine the percent effective shade and solar radiation loading. This is the nonpoint source load allocation of the stream reach at system potential vegetation.



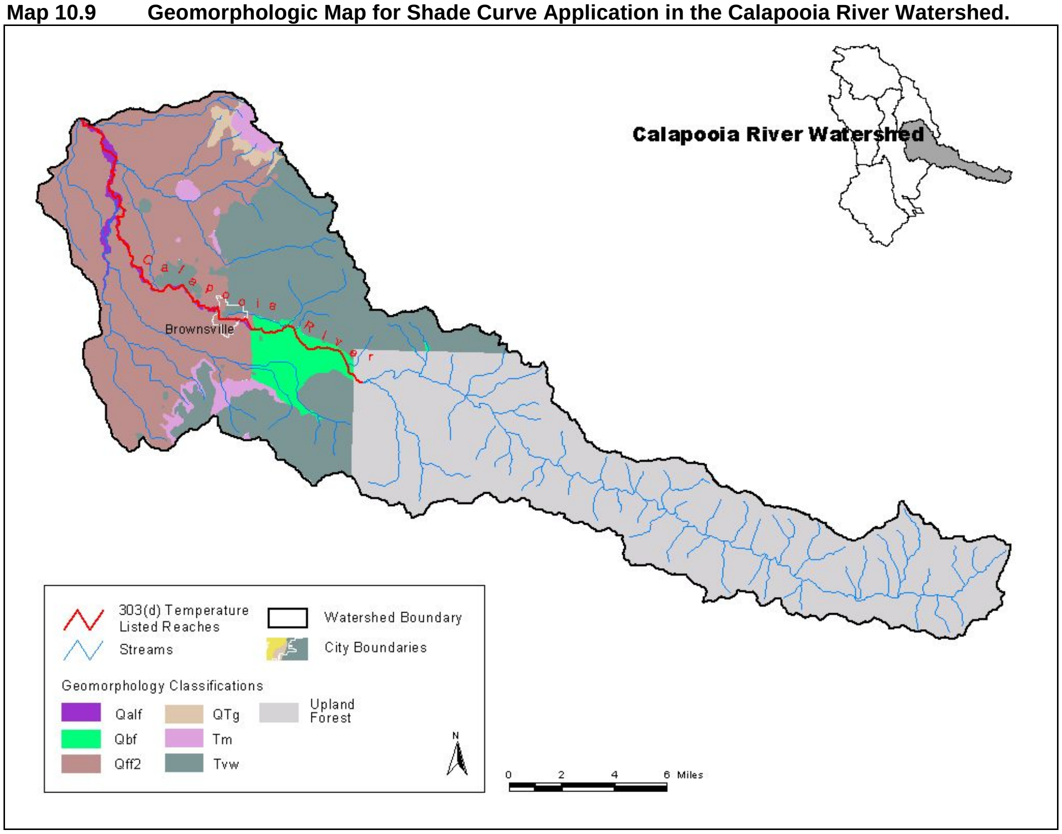
Example: A tributary to the Willamette River on the west bank near Independence with a stream aspect from north of 0º or 180º (blue line) and a channel width of 25 feet: using the blue line to determine the loading capacity from the x-axis identify the 25 feet (8 m) mark and read the y-axis, the solar radiation loading would be 129 Langleys/day with 80% effective shade when system potential vegetation is applied to the left and right bank of the stream reach. System potential vegetation identifies the riparian average height, 88.2 feet (26.9 m), and stand density (tree canopy density), 71 %, that would be established in the riparian area. If it is difficult to determine the streams aspect from north, the average stream aspect from north, black line, can be used to determine the solar radiation loading and effective shade.

Conclusion: A land owner or manager living on the west side of the Willamette River near the city of Independence, measures the channel width of the tributary stream as 25 feet (8 m), with a stream aspect from north of 0º or 180º. By using the geomorphic map for shade curve development that is specific to the areas watershed, provided by ODEQ, in this case Rickreall Creek Watershed geomorphic map, the land owner identifies their location and the corresponding geomorphic unit as Qalc in this example. The land owner then uses the Qalc shade curve to identify what the effective shade and solar radiation loading reaching the stream would be when the land owner establishes a riparian area corresponding to the system potential vegetation description. This is considered the nonpoint source load allocation.

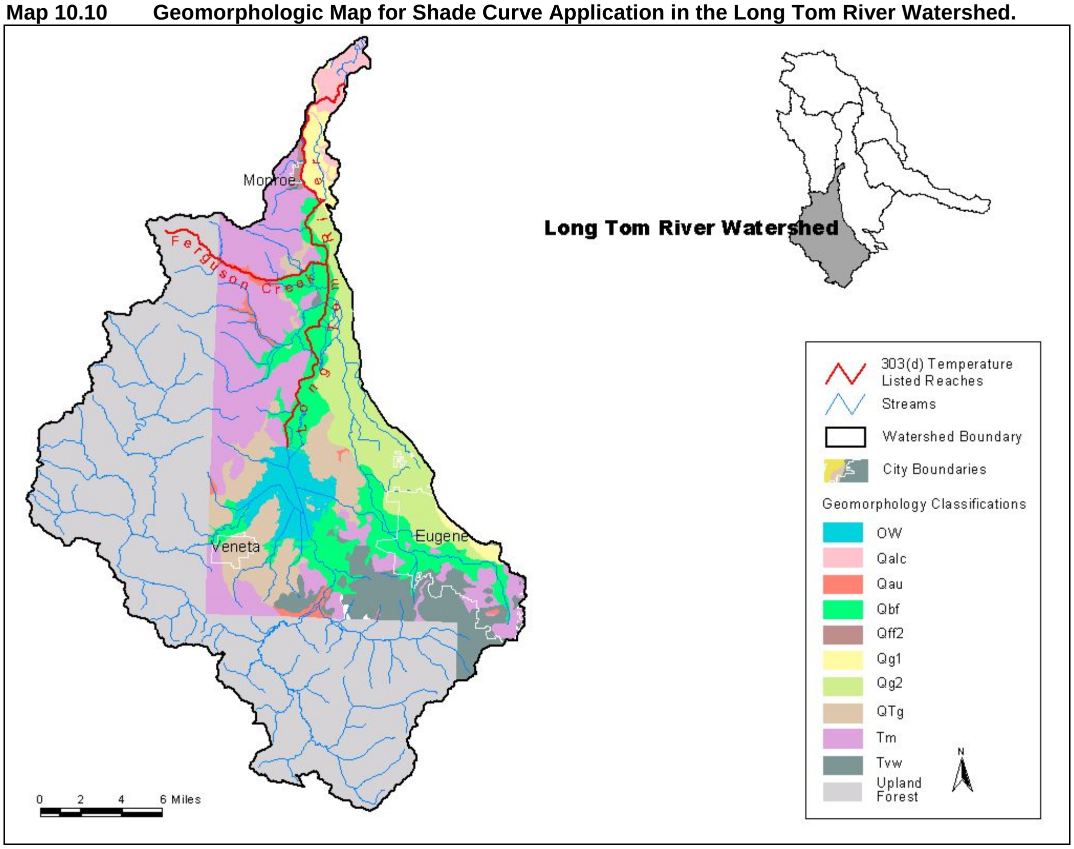
Map 10.8 Geomorphologic Map for Shade Curve Application in the Upper Willamette Subbasin.



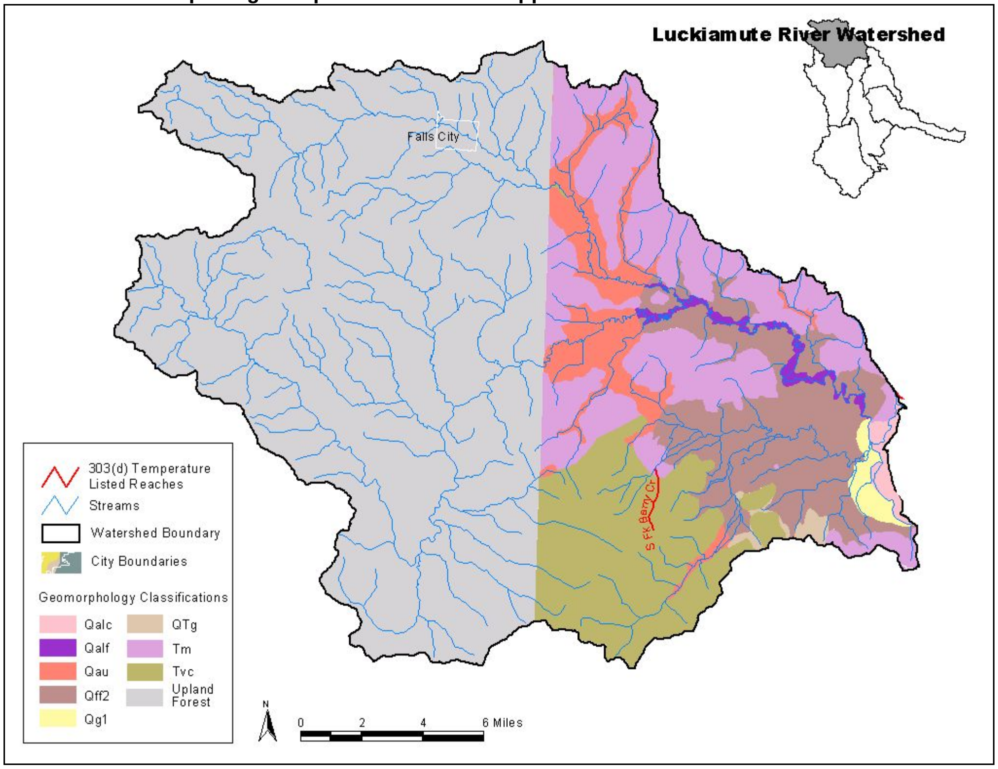
Map 10.9 Geomorphologic Map for Shade Curve Application in the Calapooia River Watershed.



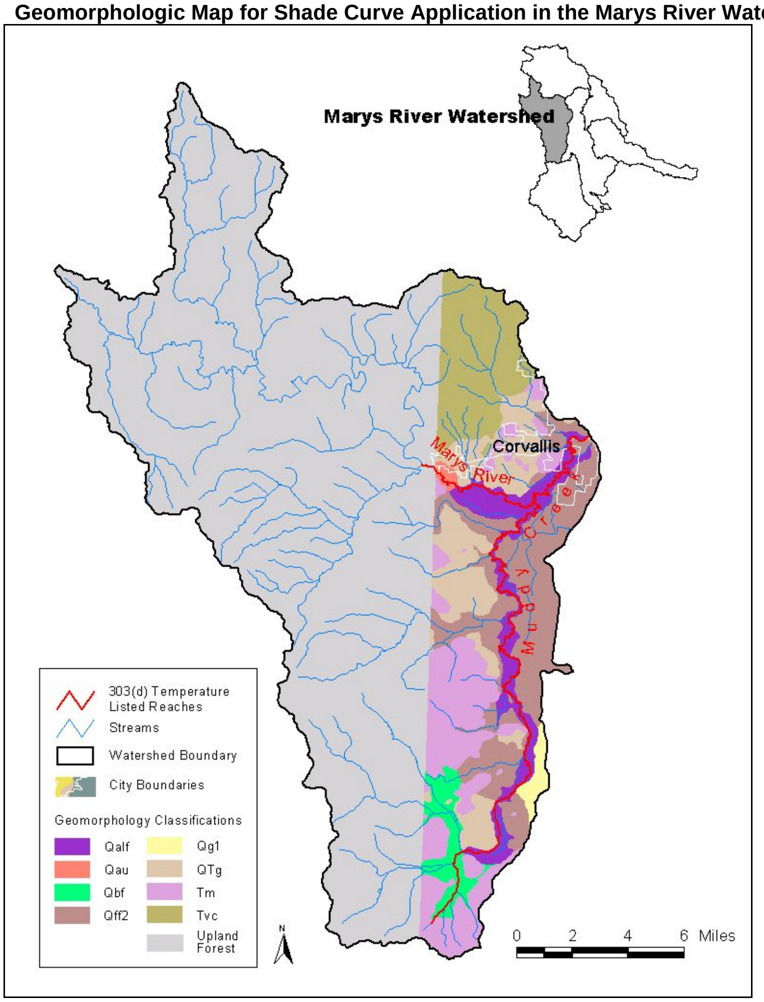
Map 10.10 Geomorphologic Map for Shade Curve Application in the Long Tom River Watershed.



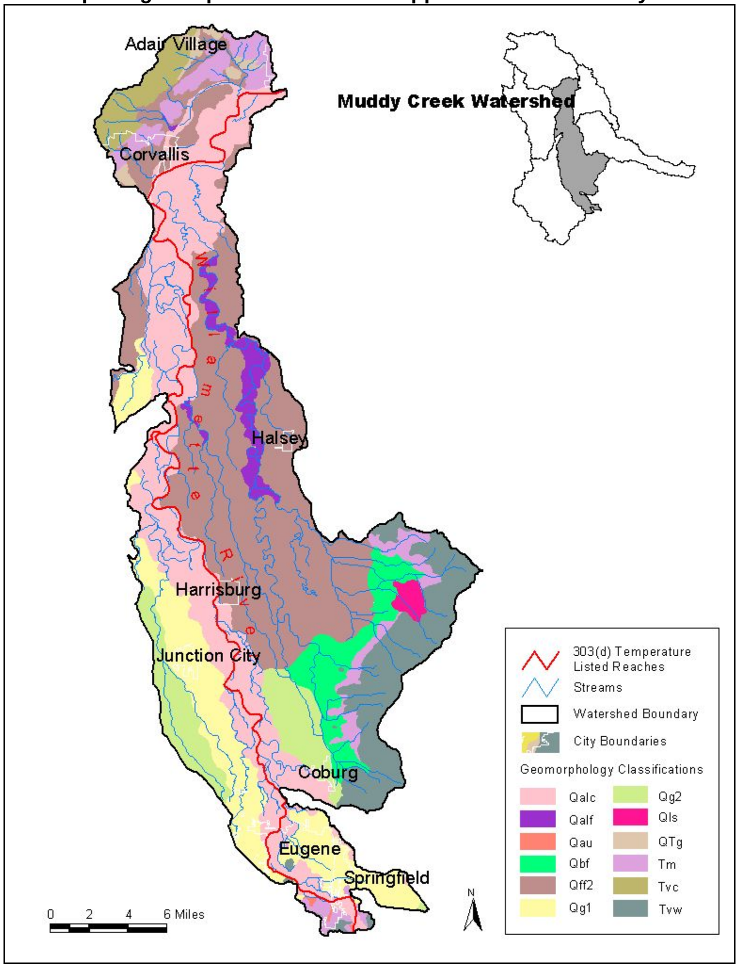
Map 10.11 Geomorphologic Map for Shade Curve Application in the Luckiamute River Watershed.



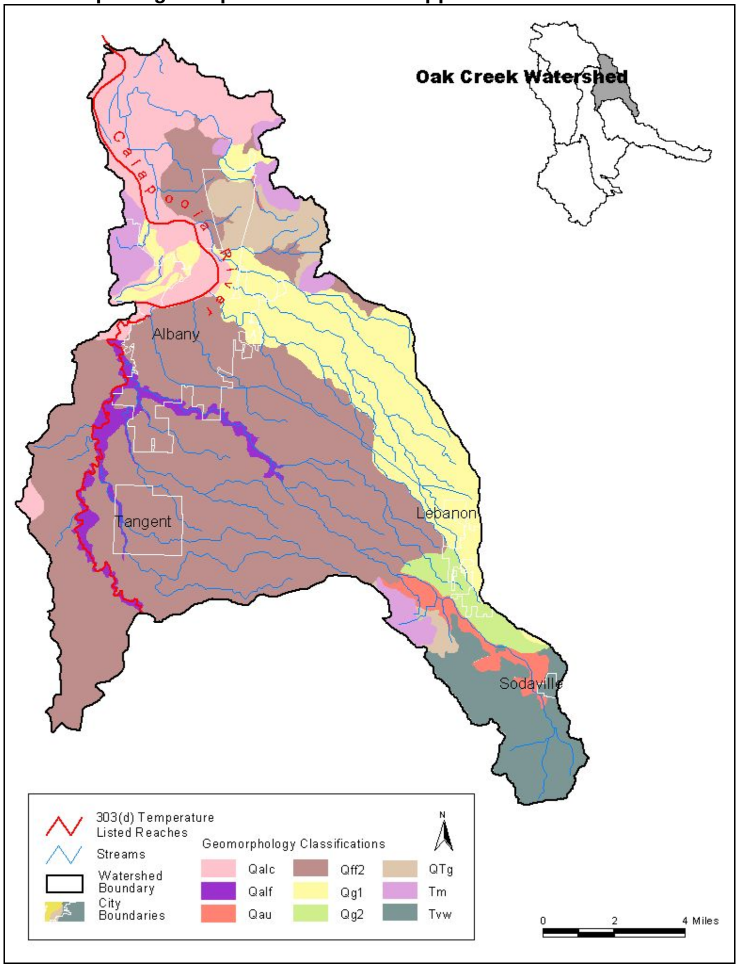
Map 10.12 Geomorphologic Map for Shade Curve Application in the Marys River Watershed.



Map 10.13 Geomorphologic Map for Shade Curve Application in the Muddy Creek Watershed.



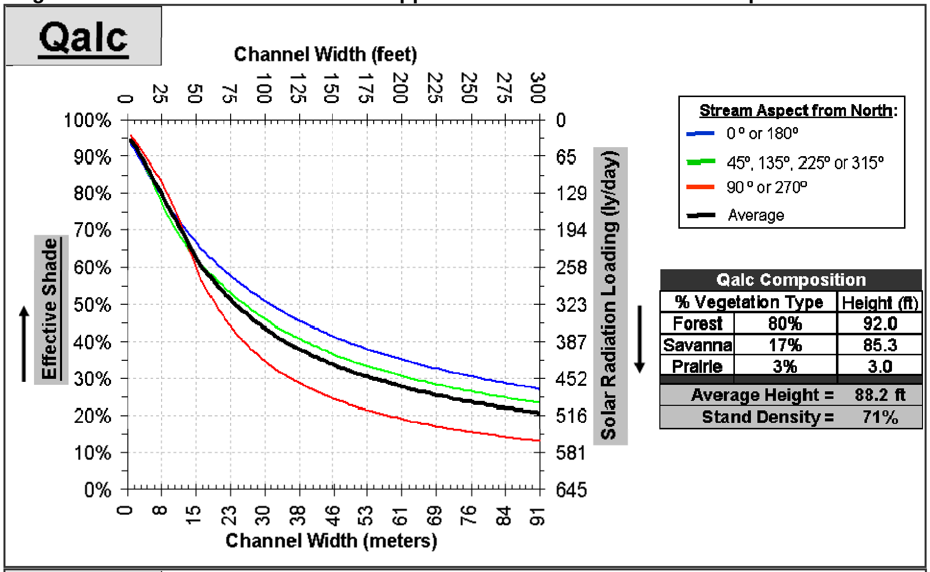
Map 10.14 Geomorphologic Map for Shade Curve Application in the Oak Creek Watershed.

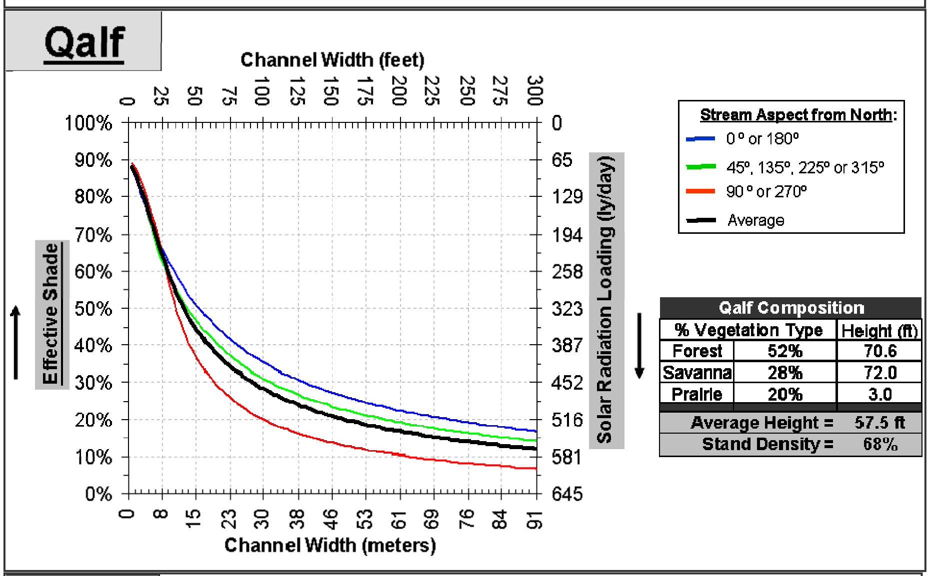


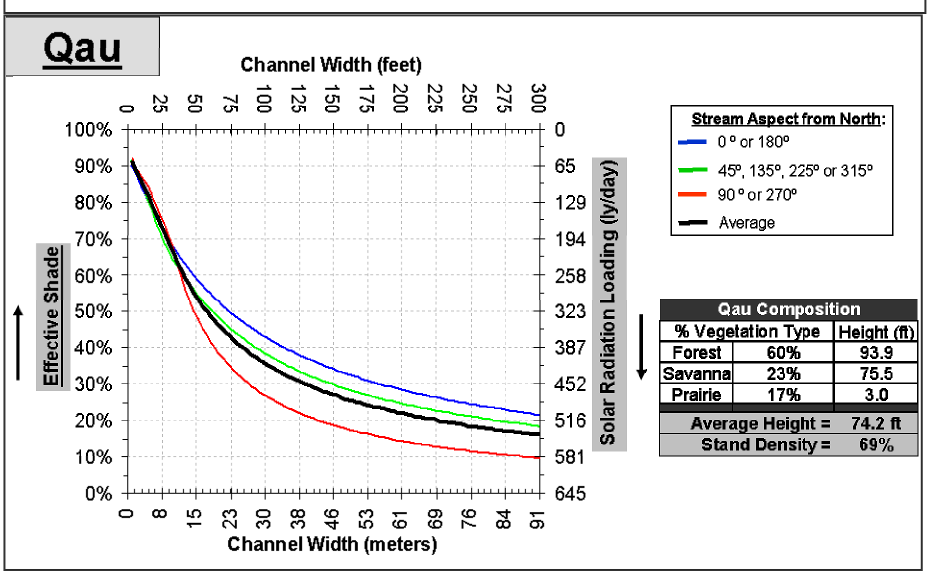
The shade curve method provides no information on existing shade conditions or the expected system potential stream temperature. It does provide quick and accurate estimates of the allocations necessary to eliminate temperature increases resulting from anthropogenic impacts on stream shading. The shade curves presented in Figure 10.13 apply to all water bodies in the Upper Willamette Subbasin based on the geomorphic and upland forest unit of the reach. The shade curves represented in each figure have been calculated based on the average height for each unit as defined by system potential vegetation. Interpretation and implementation of the shade curves requires the identification of the geomorphic or upland forest unit that applies to the stream reach (Map 10.8 to 10.14), measuring the streams channel width (bankful width), and then depending on the streams aspect from north reading the shade curves graph to determine the percent effective shade and solar radiation loading that the system potential vegetation composition will provide. For a list of geomorphic class abbreviations for each shade curve please see the Table 10.10 “Area of Geomorphic Units in the Upper Willamette Subbasin”.

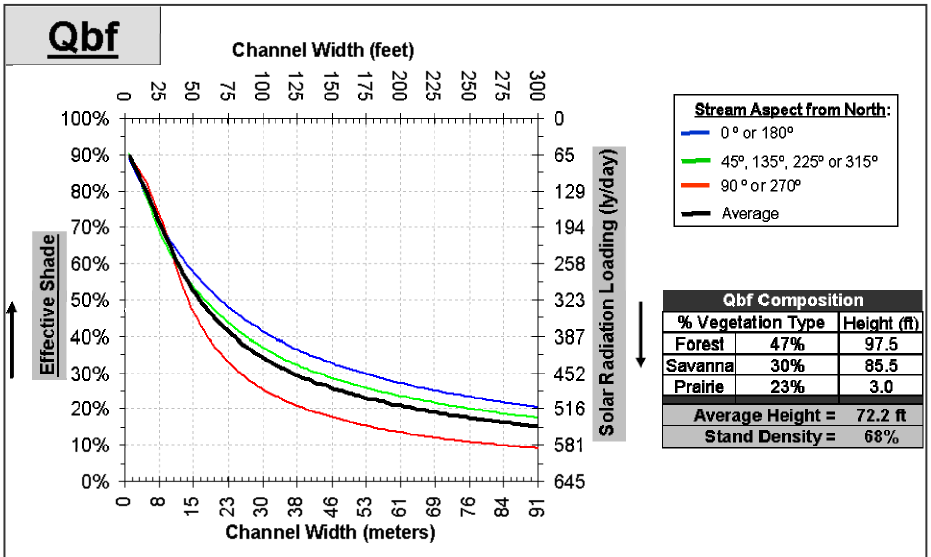
Geomorphic unit code Pre Flood Quaternary Sand/Gravel (Qg2) is represented in the Upper Willamette Subbasin. The shade curve for Qg2 has not been developed. Historically the geomorphic unit code Qg2 had 90% prairie vegetation along streams that historically became subsurface in the summer and for which water is currently artificially diverted to maintain summer flows, historic vegetation is probably not a good guideline for modeling potential present day stream temperature. Instead, ODEQ will use the nearest adjacent geomorphic code as determined by the geomorphologic maps, Map 10.8 to 10.14.

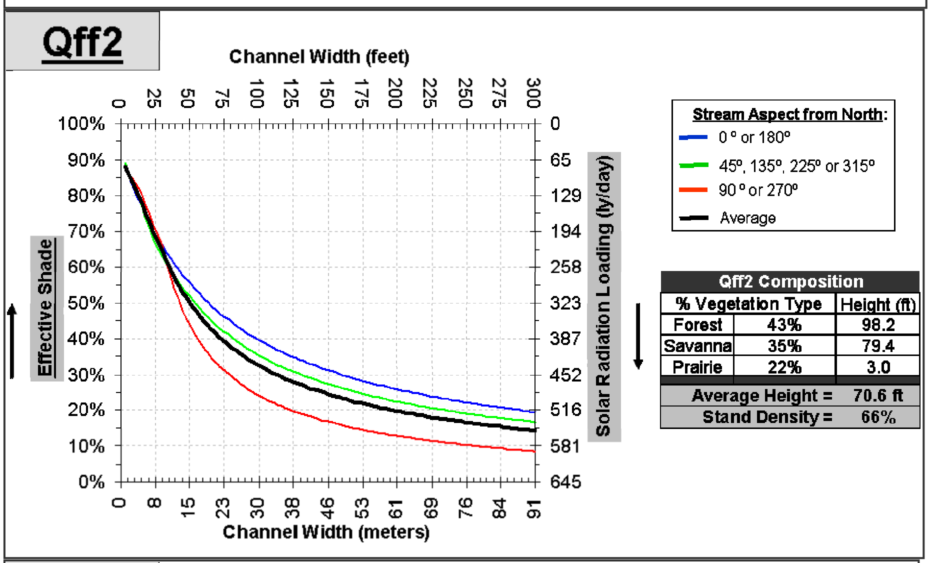
Figure 10.13 Shade Curves for Upper Willamette Subbasin Geomorphic Classifications.

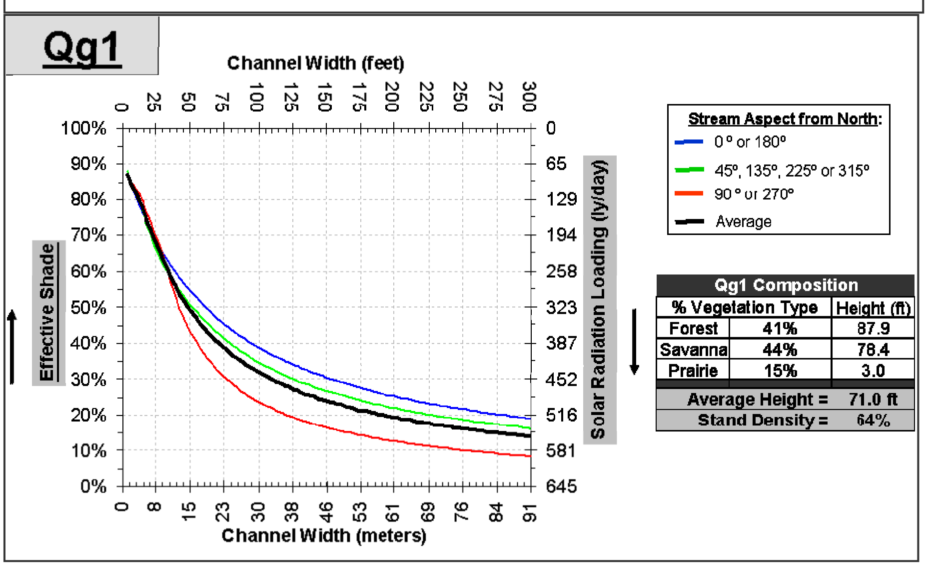


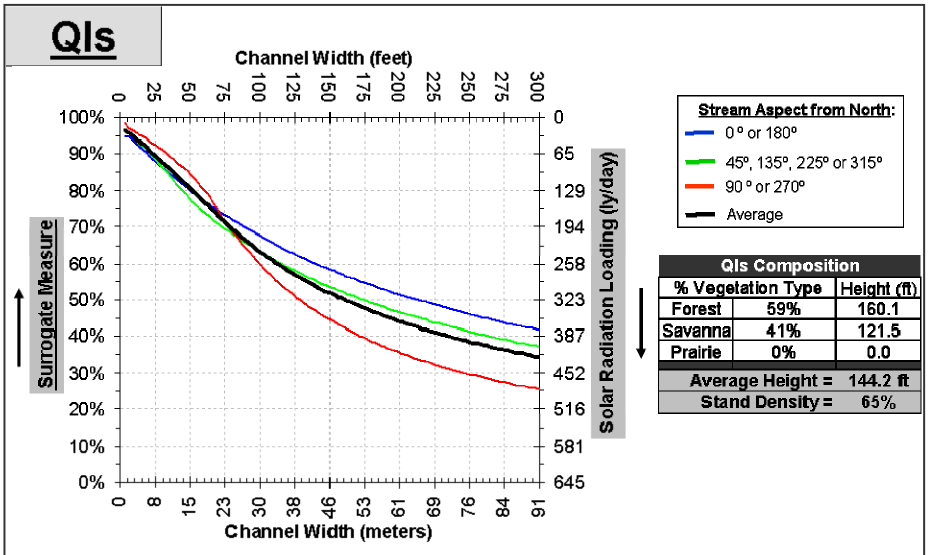




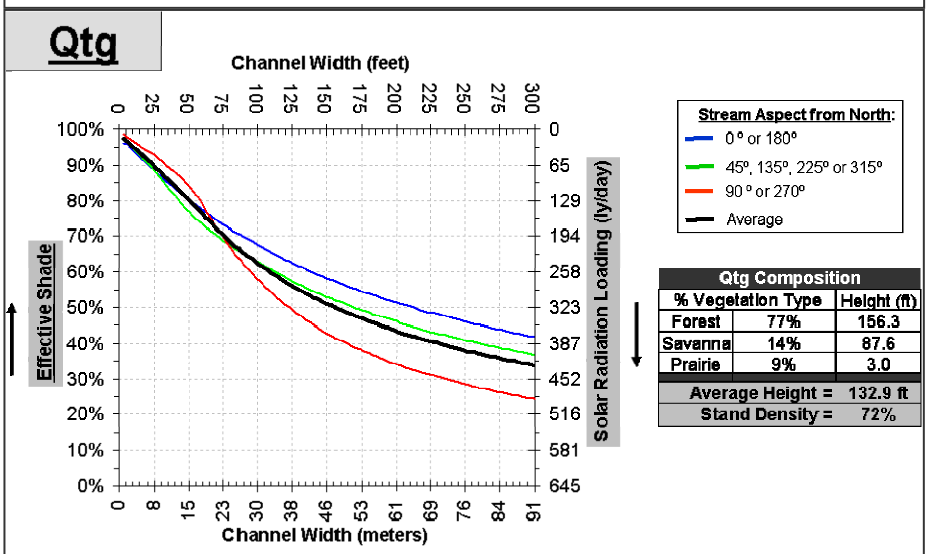

Qbf
Channel Width (feet)
Effective Shade
Solar Radiation Loading (ly/day)
Channel Width (meters)
Stream Aspect from North:
0 ° or 180°
45°, 135°, 225° or 315°
90 ° or 270°
Average
Qbf Composition
% Vegetation Type | Height (ft)
Forest 47% 97.5
Savanna 30% 85.5
Prairie 23% 3.0
Average Height = 72.2 ft
Stand Density = 68%


Qff2
Channel Width (feet)
Effective Shade
Solar Radiation Loading (ly/day)
Channel Width (meters)
Stream Aspect from North:
0 ° or 180°
45°, 135°, 225° or 315°
90 ° or 270°
Average
Qff2 Composition
% Vegetation Type | Height (ft)
Forest 43% 98.2
Savanna 35% 79.4
Prairie 22% 3.0
Average Height = 70.6 ft
Stand Density = 66%

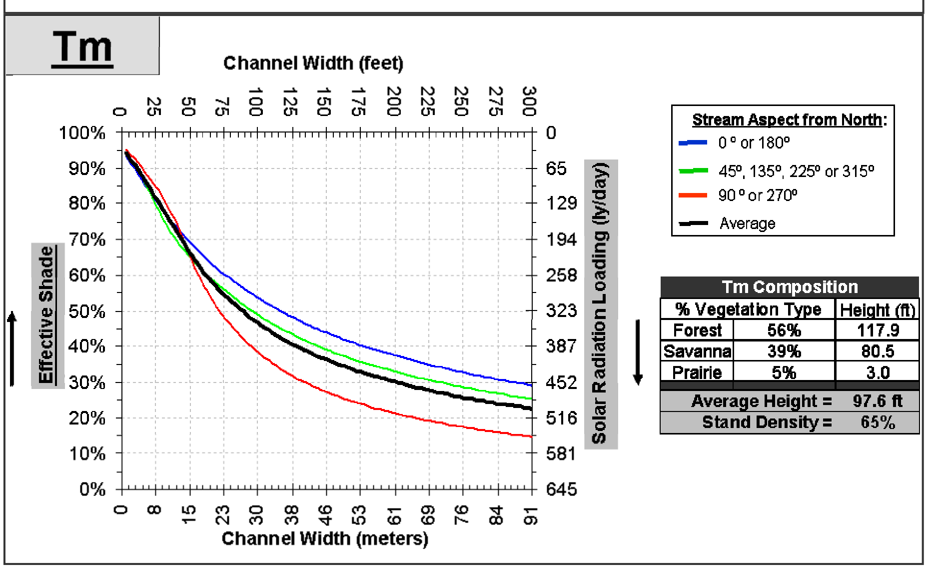

Qg1
Channel Width (feet)
Effective Shade
Solar Radiation Loading (ly/day)
Channel Width (meters)
Stream Aspect from North:
0 ° or 180°
45°, 135°, 225° or 315°
90 ° or 270°
Average
Qg1 Composition
% Vegetation Type | Height (ft)
Forest 41% 87.9
Savanna 44% 78.4
Prairie 15% 3.0
Average Height = 71.0 ft
Stand Density = 64%



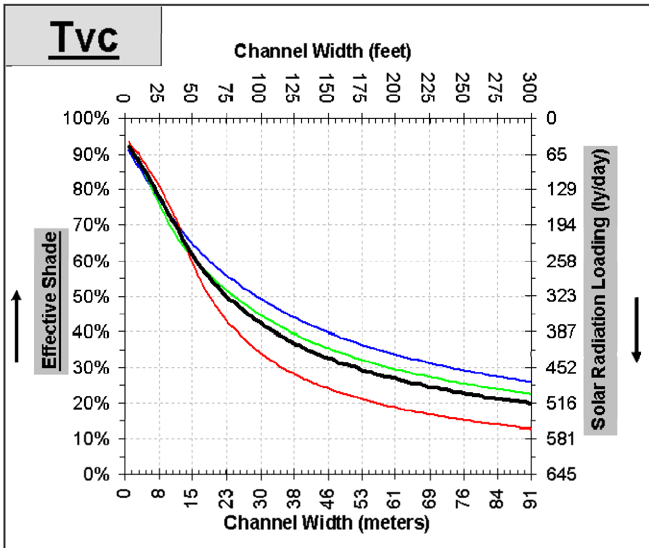
Qls Composition		
% Vegetation Type		Height (ft)
Forest	59%	160.1
Savanna	41%	121.5
Prairie	0%	0.0
Average Height =		144.2 ft
Stand Density =		65%



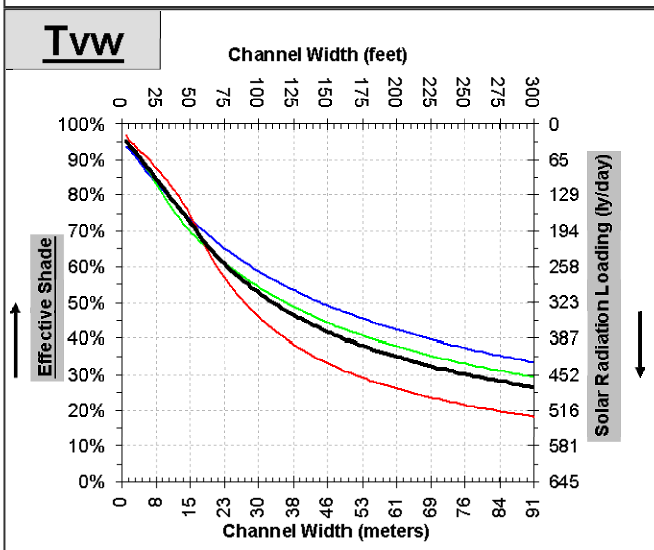
Qtg Composition		
% Vegetation Type		Height (ft)
Forest	77%	156.3
Savanna	14%	87.6
Prairie	9%	3.0
Average Height =		132.9 ft
Stand Density =		72%



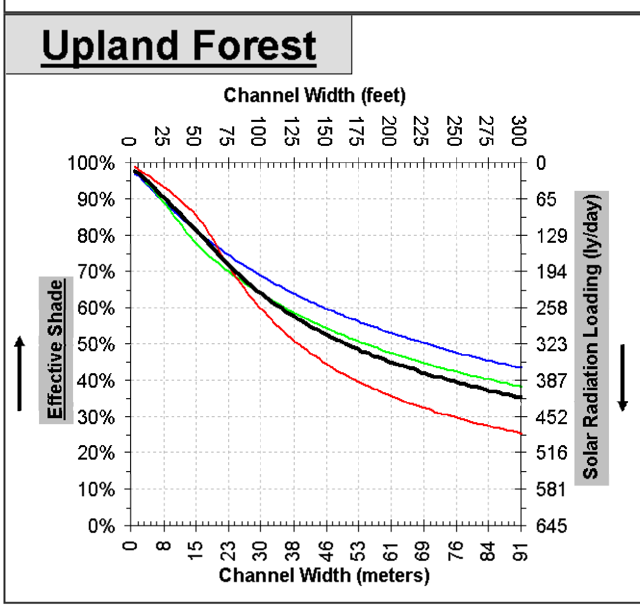
Tm Composition		
% Vegetation Type		Height (ft)
Forest	56%	117.9
Savanna	39%	80.5
Prairie	5%	3.0
Average Height =		97.6 ft
Stand Density =		65%



Tvc Composition		
% Vegetation Type		Height (ft)
Forest	60%	104.6
Savanna	39%	72.9
Prairie	1%	3.0
Average Height =		91.2 ft
Stand Density =		65%



Tvw Composition		
% Vegetation Type		Height (ft)
Forest	57%	148.8
Savanna	39%	77.2
Prairie	4%	3.0
Average Height =		115.1 ft
Stand Density =		65%



Upland Forest Composition		
% Vegetation Type		Height (ft)
Forest No Disturbance	75%	160.0
Forest Disturbed	25%	56.0
Average Height =		134.1 ft
Stand Density =		75%

Margin of Safety

OAR 340-042-0040(4)(i), CWA 303(d)(1)

A margin of safety (MOS) is intended to account for uncertainty in available data or in the effect controls will have on loading reductions and water quality. A margin of safety is expressed as unallocated assimilative capacity or conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions).

The margin of safety may be implicit, as in conservative assumptions used in calculating the Loading Capacity, Wasteload Allocations, and Load Allocations. It may also be explicitly stated as an added, separate quantity in the TMDL calculation. In any case, assumptions should be stated and the basis behind the margin of safety documented. The margin of safety is not meant to compensate for a failure to consider known sources. Table 10.11 presents six approaches for incorporating a margin of safety into TMDLs.

The following factors may be considered in evaluating and deriving an appropriate MOS:

- ✓ *The analysis and techniques used in evaluating the components of the TMDL process and deriving an allocation scheme.*
- ✓ *Characterization and estimates of source loading (e.g., confidence regarding data limitation, analysis limitation or assumptions).*
- ✓ *Analysis of relationships between the source loading and instream impact.*
- ✓ *Prediction of response of receiving waters under various allocation scenarios (e.g., the predictive capability of the analysis, simplifications in the selected techniques).*
- ✓ *The implications of the MOS on the overall load reductions identified in terms of reduction feasibility and implementation time frames.*

A TMDL and associated margin of safety, which results in an overall allocation, represent the best estimate of how criteria can be achieved. The selection of the margin of safety should clarify the implications for monitoring and implementation planning in refining the estimate if necessary (adaptive management). The TMDL process accommodates the ability to track and ultimately refine assumptions within the TMDL implementation-planning component.

Table 10. 11 Approaches for Incorporating a Margin of Safety into a TMDL

Type of Margin of Safety	*Available Approaches*
Explicit	1. Set numeric targets at more conservative levels than analytical results indicate. 2. Add a safety factor to pollutant loading estimates. 3. Do not allocate a portion of available loading capacity; reserve for margin of safety.
Implicit	1. Conservative assumptions in derivation of numeric targets. 2. Conservative assumptions when developing numeric model applications. 3. Conservative assumptions when analyzing prospective feasibility of practices and restoration activities.

A margin of safety has been incorporated into the temperature assessment methodology. Wasteload allocations are based on critical conditions that are unlikely to occur simultaneously. For example, it is unlikely that maximum effluent flows and maximum effluent temperatures are likely to occur simultaneously however those values were used to calculate point source heat loads. Furthermore, receiving stream values were also based on attainment of biological based criteria during low flow periods defined as the low flow of a ten year cycle.

Calculating a numeric margin of safety for nonpoint source loads is not easily performed with the methodology presented in this document. In fact, the basis for the loading capacities and load allocations is system potential conditions and it is not the purpose of this plan to promote riparian conditions and shade levels that exceed natural conditions.

Reserve Capacity

OAR 340-042-0040(5)(k)

Reserve capacity has been allocated for temperature through much of the Willamette Basin. Explicit allocations have generally only been made in conjunction with point source wasteload allocations. Where there are multiple point sources in a waterbody, point sources in combination have been allocated 0.2˚C of the Human Use Allowance. Another 0.05˚C is allocated to nonpoint sources of heat. Nonpoint sources have generally been limited to natural solar radiation levels determined by shade curves for a given area. The final 0.05˚C is allocated to reserve capacity, and will be available for use by point sources or nonpoint sources by application to ODEQ. In total, these allocations may not increase temperature in a water quality limited waterbody by more than 0.3°C (0.54°F) at the point of maximum impact.

In situations where the point source allocation is less than 0.2˚C or if there are no point sources, the remaining portion of the Human Use Allowance will be set aside as reserve capacity. The nonpoint source allocation will remain at 0.05˚C unless special circumstances exist that require a larger or smaller allocation. More information regarding the use of reserve capacity may be found in Chapter 14, Water Quality Management Plan, Part 2, under Temperature Implementation.

UPPER WILLAMETTE BACTERIA TMDL

The bacteria TMDL for the Upper Willamette Subbasin has been developed for tributaries to the Willamette River within hydrologic unit 17090003, specifically for the Long Tom, Coyote Creek, Upper Amazon, A-3 Drain, Luckiamute River, Calapooia River, and Marys River watersheds, as well as Fern Ridge Reservoir. In addition to these list streams, ODEQ has developed land use specific average percent reductions that apply to stream reaches not otherwise analyzed in this TMDL. Required TMDL components as per OAR 340-042-0042 are listed in Table 10.12.

Table 10. 12 Upper Willamette Subbasin Bacteria TMDL Components.

Name & Location of Waterbodies **OAR 340-042-0040(4)(a)**	Waterbodies within the Upper Willamette Subbasin, HUCs 170900301, 170900302, 170900303, 170900304, 170900305, and 170900306.
Pollutant Identification **OAR 340-042-0040(4)(b)**	<u>Pollutants</u>*:* Fecal bacteria from various mammal and bird sources; fecal coliform as an indicator of human pathogens prior to 1996 and *E. coli* as an indicator of human pathogens as of 1996.
Beneficial Uses **OAR 340-042-0040(4)(c)**	Water contact recreation is the most sensitive beneficial use to bacteria pollution in the Upper Willamette Subbasin.
Target Criteria Identification **OAR 340-042-0040(4)(c)** **OAR 340-041-0009(1)(a)(A)** **OAR 340-041-0009(1)(a)(B)** ***CWA §303(d)(1)***	(1) <u>Numeric Criteria:</u> Organisms of the *E. coli* group commonly associated with fecal sources (MPN or equivalent membrane filtration using a representative number of samples) shall not exceed the criteria described in subparagraphs (a) and (b) of this paragraph: (a) Freshwaters and Estuarine Waters Other than Shellfish Growing Waters: (A) A 30-day log mean of 126 E. coli organisms per 100 ml, based on a minimum of five (5) samples; (B) No single sample shall exceed 406 E. coli organisms per 100 ml.
Existing Sources **OAR 340-042-0040(4)(f)** ***CWA §303(d)(1)***	There are multiple point and nonpoint sources during runoff and non-runoff events, including urban storm water discharge and agricultural run-off.
Seasonal Variation **OAR 340-042-0040(4)(j)** ***CWA §303(d)(1)***	Violations of the bacteria criteria occur throughout the year and under all observed flow conditions.
TMDL **Loading Capacity and Allocations** **OAR 340-042-0040(4)(d)** **OAR 340-042-0040(4)(e)** **OAR 340-042-0040(4)(g)** **OAR 340-042-0040(4)(h)** ***40 CFR 130.2(f)*** ***40 CFR 130.2(g)*** ***40 CFR 130.2(h)***	<u>*Loading Capacity:*</u> The loading capacity is expressed as a count that will achieve the 126 E. coli organisms per 100 ml and not exceed 406 E. coli organisms per 100 ml water quality criteria under all flow conditions, thereby protecting beneficial uses. <u>*Excess Load*</u>: The difference between the actual pollutant load and the loading capacity of a waterbody. <u>*Waste Load Allocations (Point Sources)*</u>: Waste load allocations applicable to municipal stormwater permits are expressed as a percent reduction necessary to meet the numeric criteria. <u>*Load Allocations (Nonpoint Sources)*</u>: Load allocations are expressed as a percent reduction necessary to meet the numeric criteria.
Surrogate Measures **OAR 340-042-0040(5)(b)** ***40 CFR 130.2(i)***	<u>*Translates Nonpoint Source Load Allocations*</u> Allocations are in terms of percent reduction needed to achieve the numeric criteria. This translates load allocations into more applicable measures of performance.
Margins of Safety **OAR 340-042-0040(4)(i)** ***CWA §303(d)(1)***	<u>*Margins of Safety*</u> are applied as conservative assumptions in the development and percent reduction of current E. coli counts. No numeric margin of safety is developed.
Reserve Capacity **OAR 340-042-0040(4)(k)**	Allocation for increases in pollutant loads from future growth and new or expanded sources.
Water Quality Management Plan **OAR 340-042-0040(4)(l)** ***CWA §303(d)(1)***	The Water Quality Management Plan (WQMP) is addressed in Chapter 14.
Criteria Attainment & Reasonable Assurance **OAR 340-042-0040(4)(l)(J)** **OAR 340-042-0040(4)(l)(E)**	These components are addressed in the WQMP as per OAR 340-042-0040(4)(l)(E) & (J).

Waterbodies Listed for Bacteria

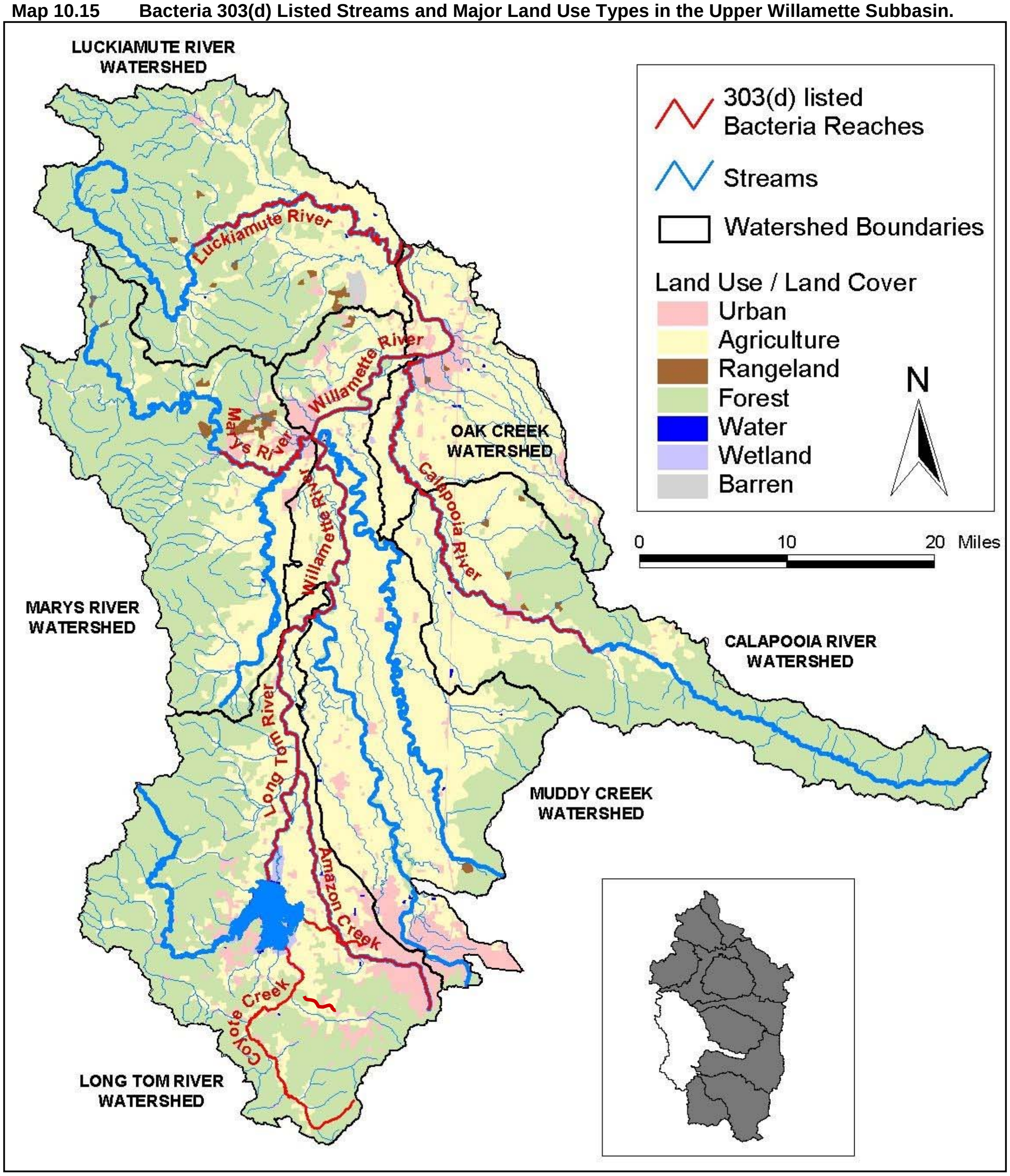
OAR 340-042-0040(4)(a)

A-3 Drain, Amazon Creek, Amazon Diversion Channel, and Coyote Creek are listed year round, and Calapooia River, Fern Ridge Reservoir, Long Tom River, Luckiamute River, and the Marys River are listed during the fall-winter-spring on Oregon's 303(d) List for exceeding water quality criteria for bacteria (Table 10.13 and Map 10.15. The following bacteria TMDL assessment addresses only the tributaries to the Willamette River. The Willamette River bacteria listings are addressed in the mainstem Willamette River Bacteria TMDL, Chapter 2.

Table 10. 13 Upper Willamette Subbasin 303(d) Bacteria Listings.

Waterbody	Listed Reaches	Parameter	Season	Criteria
A3 Drain	Mouth to Headwaters	*E. coli*	June 1 - September 30	Log-mean of 126 organisms per 100 ml, no single sample > 406
A3 Drain	Mouth to Headwaters	*E. coli*	October 1 - May 31	Log-mean of 126 organisms per 100 ml, no single sample > 406
Amazon Creek	RM 0 to 22.6	*E. coli*	June 1 - September 30	Log-mean of 126 organisms per 100 ml, no single sample > 406
Amazon Creek	RM 0 to 22.6	*E. coli*	October 1 - May 31	Log-mean of 126 organisms per 100 ml, no single sample > 406
Amazon Diversion Channel	RM 0 to 1.8	Fecal Coliform	Year Round	Geometric Mean of 200, No more than 10% > 400
Calapooia River	RM 0 to 42.8	Fecal Coliform	Fall-Winter-Spring	Geometric Mean of 200, No more than 10% > 400
Coyote Creek	RM 0 to 26.6	Fecal Coliform	Year Round	Geometric Mean of 200, No more than 10% > 400
Fern Ridge Reservoir	RM 24.2 to 31.8	Fecal Coliform	Fall-Winter-Spring	Geometric Mean of 200, No more than 10% > 400
Long Tom River	RM 0 to 24.2	Fecal Coliform	Fall-Winter-Spring	Geometric Mean of 200, No more than 10% > 400
Luckiamute River	RM 0 to 31.7	Fecal Coliform	Fall-Winter-Spring	Geometric Mean of 200, No more than 10% > 400
Marys River	RM 0 to 13.9	Fecal Coliform	Fall-Winter-Spring	Geometric Mean of 200, No more than 10% > 400

Map 10.15 Bacteria 303(d) Listed Streams and Major Land Use Types in the Upper Willamette Subbasin.



Pollutant Identification

OAR 340-0142-0040 (4)(b)

ODEQ must establish a TMDL for any waterbody listed on the 303(d) List for exceeding water quality criteria, in this case bacteria criteria. Prior to 1996 ODEQ used fecal coliform and enterococci as the bacteria indicator species to determine water quality pollution from bacteria. However, in 1996 Oregon adopted *Escherichia coli (E. coli)*, a subset of fecal coliform, as the indicator species of bacteria pollution. Even though fecal coliform and enterococci data were used to develop the 1998 303(d) List, since those data were the most commonly measured indicator of bacteria contamination at that time, this bacteria TMDL is based on *E. coli* as the water quality pollutant. There are both point and nonpoint sources of bacteria in the Upper Willamette Subbasin.

Beneficial Use Identification

OAR 340-042-0040(4)(c)

The most sensitive beneficial use to bacteria in the Upper Willamette Subbasin is:

- Water Contact Recreation

Untreated sewage, pet waste, wildlife waste, or livestock waste released into the water can expose swimmers and other recreational users to bacteria. Children, the elderly, and people with weakened immune systems are most likely to develop illnesses or infections after swimming in polluted water. The most common illness associated with swimming in water polluted with elevated levels of bacteria is gastroenteritis. In highly polluted water, swimmers may occasionally be exposed to more serious diseases like dysentery, hepatitis, cholera, and typhoid fever. Most of these diseases require ingestion of polluted water by drinking or swallowing some water, although some illnesses can be transmitted through wounds exposed to water. The TMDL targets bacteria counts that are protective of the most sensitive beneficial use, water contact recreation.

Target Criteria Identification

OAR 340-042-0040(4)(c), OAR 340-041-0009(1)(a)(A), OAR 340-041-0009(1)(a)(B), CWA 303(d)(1)

Oregon's water quality criteria for bacteria are designed to protect the beneficial use of recreational water contact. Table 10.14 presents the bacteria criteria that are applicable to the Upper Willamette Subbasin.

Table 10. 14 Prior and current bacteria criteria applicable in the Upper Willamette Subbasin.

Beneficial Use	Bacteria Criteria
Water Contact Recreation	Prior to July 1995: • a geometric mean of 200 fecal coliform per 100 milliliters (ml) based on a minimum of 5 samples in a 30-day period with no more than 10% of the samples in the 30-day period exceeding 400 per 100 ml. Prior to January 1996: • a geometric mean of 33 enterococci per 100 ml based on no fewer than 5 samples collected in a period of 30 days • no single sample should exceed 61 enterococci per 100 ml. **Effective January 1996 to present: OAR 340-041-0009(1)(a)(A) & (B)** Freshwaters and Estuarine Waters other than shellfish growing waters: • a 30-day log mean of 126 *E. coli* organisms per 100 ml, based on a minimum of five samples; • no single sample may exceed 406 *E. coli* organisms per 100 ml.

Existing Bacteria Sources

OAR 340-042-0040(4)(f) CWA §303(d)(1)

Bacteria reach surface waters from a variety of point and nonpoint sources, during both precipitation driven run-off events and non run-off dry weather periods. The following sections describe many likely sources of bacteria, but this source assessment is not exhaustive. Watershed managers from the designated management agencies must conduct further investigations of watershed-specific bacteria sources in order to develop an effective strategy for bacteria control.

Nonpoint Sources of Bacteria

Urban runoff, rural residential runoff, failing septic systems, pet waste, wildlife waste and livestock waste all produce bacteria and are nonpoint sources in the Upper Willamette Subbasin. Urban areas in the subbasin include the cities of Eugene, Springfield, Corvallis, and Albany. Rural residential areas are widespread in the subbasin, but are more common on lowlands near rivers and streams. Failing septic systems are generally associated with rural residential uses and pet wastes are normally associated with urban areas.

Run-Off Related Sources of Bacteria

The following is a list of potential runoff related bacteria sources in the Upper Willamette Subbasin:

Urban Runoff

The urban runoff sources of bacteria are multiple and may include:

- Pet, wildlife, and other animal waste
- Illegal dumping of sanitary waste
- Failing septic systems
- Sanitary sewer overflows

It is important to note that urban runoff, especially stormwater discharged via a conveyance system, may include bacteria from a variety of sources, both human and non-human in origin. Bacteria originating from pets, ducks, geese, raccoons, and other wildlife may well be present in large numbers in urban stormwater runoff. However, the paths that bacteria from these sources take and the time it takes to reach a nearby stream are often greatly reduced by modern stormwater conveyance systems.

Rural Residential Runoff

Rural runoff may contain bacteria from the same sources as urban runoff, with the possible exception of sanitary sewer overflows. Additional potential sources include "hobby" farms, horse pastures, ranchettes or small acreages and man-made instream ponds that attract wildlife. The density of septic systems is often relatively high in rural areas, especially on the fringe of urban areas.

Agricultural Runoff

The primary source of bacteria in agricultural runoff is animal waste. Livestock wastes from animals in confinement areas are often stored for later application to the land. Wastes are also deposited directly by livestock to pasture areas near streams. Depending on landscape conditions, proximity to streams, and overland flow rates, animal wastes often find their way to surface waters.

Non Run-Off Related Sources of Bacteria

The following is a list of potential dry weather, non-runoff related bacteria sources in the Upper Willamette Subbasin:

Urban

Non-runoff sources of urban bacteria may include such things as sanitary sewer cross connections, illicit discharge of sanitary waste from septic vacuum trucks and recreational vehicles, and episodic or chronic discharges from the local sanitary sewer system. Small scale discharges, a single residential cross connection for example, may not have a significant impact during runoff events or when stream flows are higher, but can cause water quality criteria violations during the summer months in the smaller streams of the Upper Willamette Subbasin.

Failing Septic Systems

Septic systems fail in a variety of different ways and may contribute to water quality problems under both runoff and non-runoff conditions. Some systems only fail when the soil is saturated or when winter storms raise the local water table. Other systems fail year round and contribute bacteria to streams during low flow conditions when there is less dilution.

Homes in areas that are not served by city sewer systems treat domestic wastes with septic systems. Septic systems installed prior to the 1970's generally have a higher failing rate due to their age and the design criteria in place at the time. These systems are common throughout the rural areas of the subbasin.

Direct Deposition

Direct deposition of pet, wildlife, and livestock waste into streams can cause water quality criteria violations during low flow conditions.

Point Sources of Bacteria

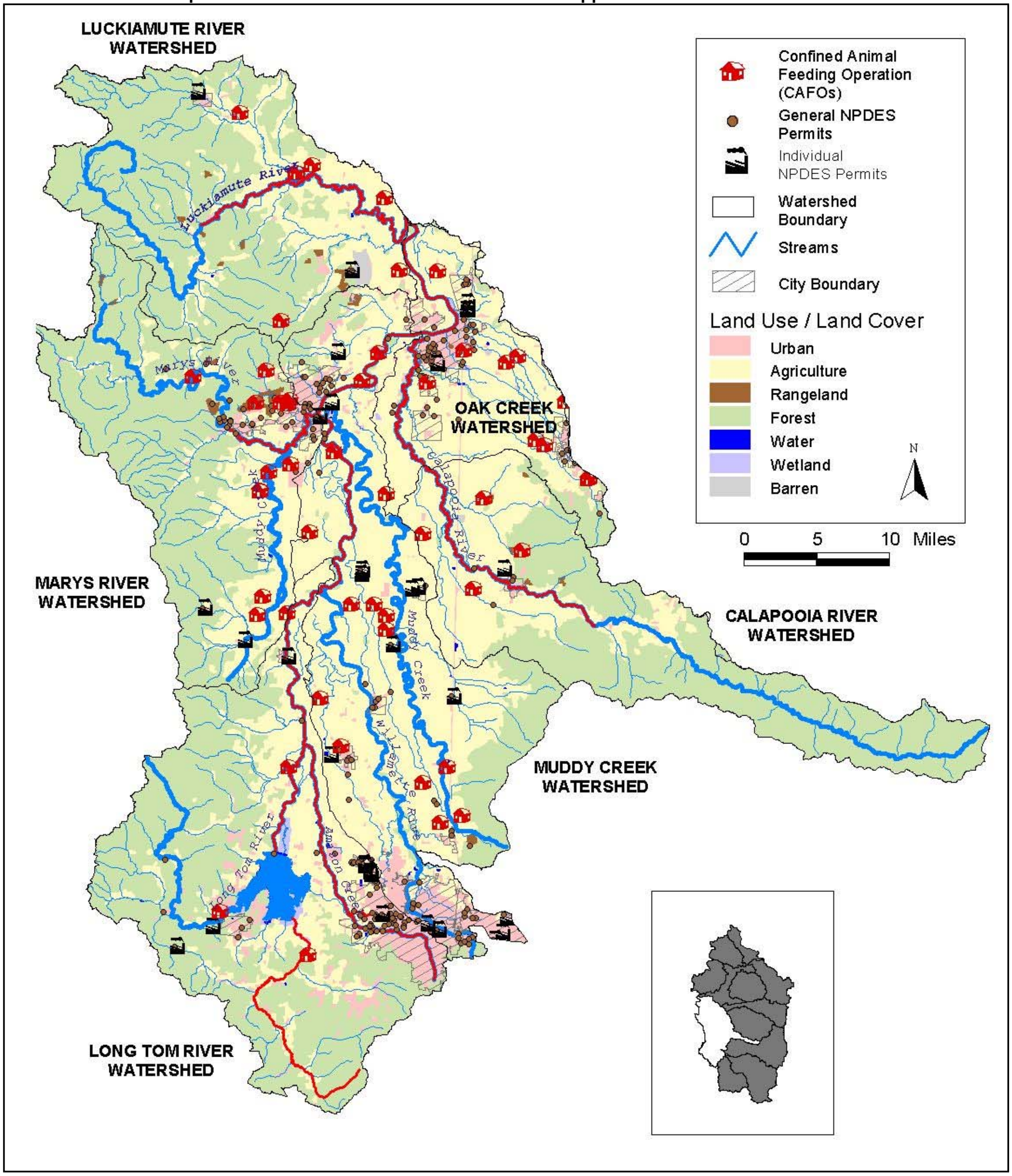
Point sources occur in each watershed in the Upper Willamette Subbasin, although they are generally small and most are located in the lower elevation areas of the subbasin. ODEQ issues National Pollutant Discharge Elimination System (NPDES) permits to point sources that may be potential sources of bacteria. There are 39 NPDES permittees in the subbasin that discharge to surface waters. Of these facilities, 14 sources discharge directly to the Willamette River and are included as sources in Chapter 2 of this document. The remaining 25 point sources (Table 10.15) include two major sources, Oregon Metallurgical Corporation (Oremet) and Wah Chang Industries, and 22 minor sources. There are 8 domestic sewage treatment plants, and 17 industrial facilities. The majority of industrial facilities are forest product manufacturing operations, and are not expected to contribute bacteria to surface waters. However, Waste Water Treatment Plants (WWTPs) that discharge wastewater are likely to contain significant amounts of bacteria.

There are also 283 general NPDES permits in the subbasin. Permits for direct discharges from industrial or municipal point sources generally limit discharge of bacteria to concentrations that meet water quality criteria at the point of discharge without benefit of dilution by receiving waters.

There are Confined Animal Feeding Operations (CAFOs) in all of the watersheds in the Upper Willamette Subbasin, Map 10.16 The Upper Willamette Subbasin has 53 CAFOs as reported by the Department of Agriculture in March 2003, consisting of 25 dairies, five feed lots, six swine lots, two horse lots, two mink lots, one poultry lot, and 12 unidentified CAFO lots.

Part of normal CAFO facility operation is to manage the accumulated manure. The facilities are regulated as point sources under a general NPDES permit issued by ODEQ and administered by Oregon Department of Agriculture (ODA). Under the terms of these permits, no discharge is allowed from areas of animal confinement, manure management or storage.

Map 10.16 Point sources and CAFOs in the Upper Willamette Subbasin.



The cities of Eugene and Springfield have Municipal Separate Storm Sewer Systems (MS4) NPDES permits that set limits for stormwater runoff from urban areas. MS4 permits are based in part on urbanized areas as defined by the U.S. Bureau of Census.

Table 10. 15 Individual NPDES Permits in the Upper Willamette Subbasin, which do not discharge to the Willamette River.

Facility Name	Permit Type	Permit Description	Receiving Stream	River Mile
WAH CHANG	NPDES-IW-F	Industrial Wastewater; NPDES primary metal smelting, refining using	Truax Creek	2.0
DBA WAH CHANG - OREMET FACILITY	NPDES-IW-G	Industrial Wastewater; NPDES primary metals smelting, refining NEC	Oak Creek	1.6
COFFIN BUTTE LANDFILL	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Soap Creek	4.0
ROSBORO LUMBER COMPANY	NPDES-IW-O	Industrial Wastewater; NPDES non-process wastewater NEC	Patterson Slough	2.1
DYNEA	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Patterson Slough	1.8
KINGSFORD MANUFACTURING	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Patterson Slough	3.7
HULL-OAKES LUMBER CO.	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Oliver Creek	4.8
NORTHWEST INDUSTRIES, INC.	NPDES-IW-O	Industrial Wastewater; NPDES non-process wastewater NEC	Oak Creek	1.0
VAUGHN LAMINATING	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Noti Creek	0.6
G P MILLERSBURG RESIN PLANT	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Murder Creek	0.6
DURAFLAKE DIVISION	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Murder Creek	1.3
HALSEY STP	NPDES-DOM-Db	Sewage Disposal; NPDES less than 1 MGD with lagoons	Muddy Creek	23.0
ALPINE COMMUNITY	NPDES-DOM-Db	Sewage Disposal; NPDES less than 1 MGD with lagoons	Muddy Creek	25.6
BELLFOUNTAIN STP	NPDES-DOM-Db	Sewage Disposal; NPDES less than 1 MGD with lagoons	Mary's River	10.2
VENETA STP	NPDES-DOM-Db	Sewage Disposal; NPDES less than 1 MGD with lagoons	Long Tom River	34.9
FALLS CITY STP	NPDES-DOM-Da	Sewage Disposal; NPDES less than 1 MGD, NEC with discharging lagoons	Little Luckiamute	11.9
JUNCTION CITY STP	NPDES-DOM-Db	Sewage Disposal; NPDES less than 1 MGD with lagoons	Flat Creek	9.2
CITY OF PHILOMATH WWTP	NPDES-DOM-Db	Sewage Disposal; NPDES less than 1 MGD with lagoons	Mary's River	10.2
CANNERY WASTE MANAGEMENT	NPDES-IW-B	Industrial Wastewater; NPDES major vegetable and fruit processing	Flat Creek	7.4
GEORGIA PACIFIC IRVING ROAD	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Clear Lake Creek	5.6
L. D. MCFARLAND	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Clear Lake Creek	1.8
SENECA SAWMILL COMPANY	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Clear Lake Creek	7.0
TANGENT STP	NPDES-DOM-Db	Sewage Disposal; NPDES less than 1 MGD with lagoons	Calapooia River	10.8
J.H. BAXTER & CO., INC.	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Amazon Diversion	1.5
G P EUGENE RESIN PLANT	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Amazon Diversion	2.7

NEC = Not Elsewhere Classified

Bacteria TMDL Analytical Methods Overview

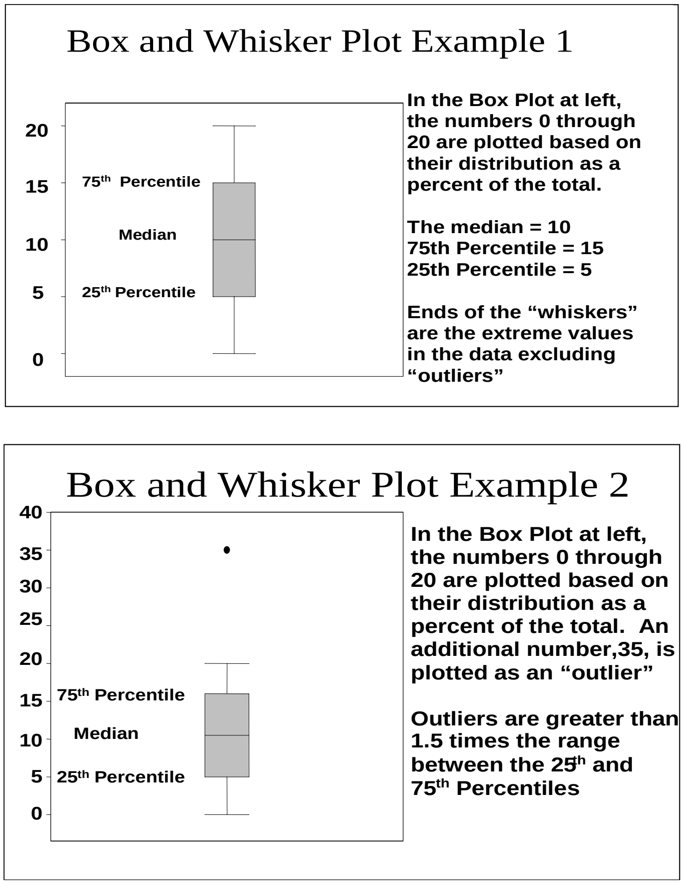
ODEQ developed the Upper Willamette Subbasin Bacteria TMDL for the Long Tom, Coyote, Upper Amazon, A-3 Drain, Luckiamute, Marys, and Calapooia Rivers and Fern Ridge Reservoir using *E coli* data collected by the ODEQ and watershed councils. ODEQ collected *E. coli* data during two intensive surveys; during the summer of 2002 (low-flow study) and during the winter of 2003 (high-flow study).

ODEQ developed the Upper Willamette Subbasin Bacteria TMDL using several methods to quantify watershed percent reductions necessary to meet water quality criteria. The methods included in this TMDL include load duration curves, simple concentration-based reductions, Event Mean Concentration (EMC) modeling, and a box model for Fern Ridge Reservoir. A description of each method is detailed in Appendix A: Bacteria Technical Appendix.

Seasonal variation of in-stream *E. coli* has been considered in the analysis of current conditions and in developing loading allocations. The *E. coli* data has been reviewed for longitudinal variability for a year-round period, summer low flow period from June 1 to October 31, and for the high flow fall-winter-spring period, November 1 to May 31.

The bacteria data were also plotted with Box and Whisker plots to assess the longitudinal and seasonal variability of bacteria counts. Box and Whisker Plots, commonly known as Box plots, illustrate the distribution of samples through time or among sample sites. Box plots are particularly useful for displaying bacteria data sets which can contain extreme organism values or “outliers”. The Box plots characterize data using the median as a measure of central tendency and the interquartile range as a measure of spread. Figure 10.14 shows two examples of box-and-whisker plots and how to interpret their data distribution.

Figure 10.14 Two Box and Whisker Plot Examples.



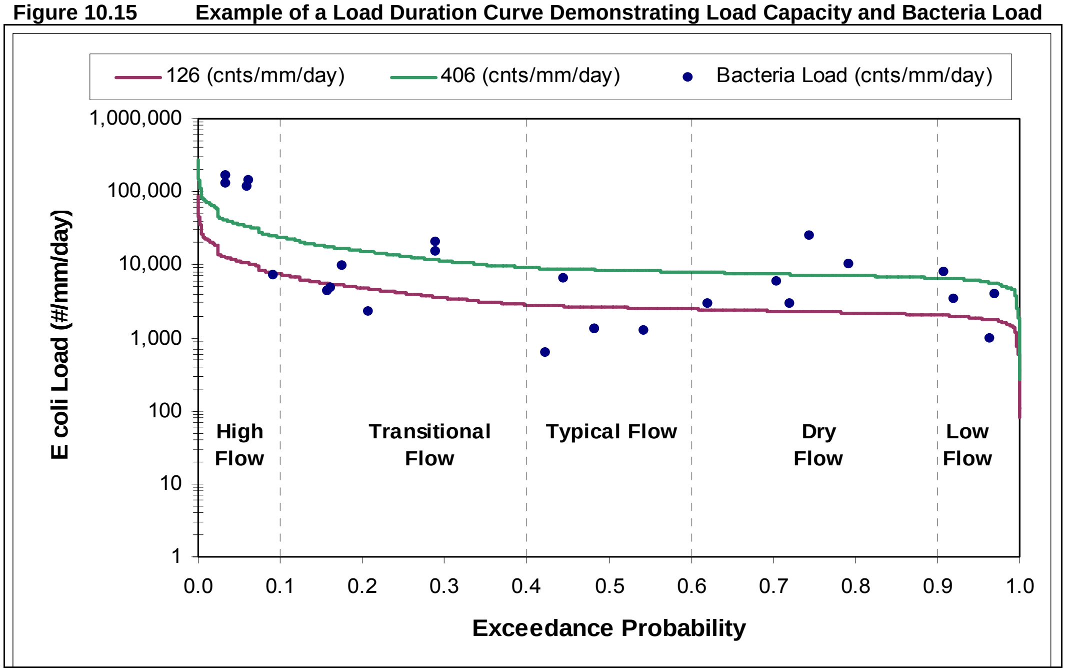
A logarithmic mean (log mean) was calculated to approximate the deviation from the 30-day log mean criterion of 126 counts / 100 mL. A log mean is a measure of central tendency useful in summarizing highly skewed data.

ODEQ chose to calculate the percent reduction necessary to achieve water quality criteria. The reductions were calculated to reach both the 126 *E. coli* counts/100 ml log mean criterion and the maximum concentration of 406 *E. coli* counts / 100 ml. The percent reduction was determined conservatively by using a percentile of the measured concentrations that met the maximum criterion or the greatest reduction that resulted in meeting the log mean criterion. Log mean load reductions were calculated for five different flow regimes through the use of load duration curves. The greatest percent reduction in load among these flow regimes was applied to the entire waterbody as a conservative assumption to meet the log-mean criterion. The reduction was applied to all samples to determine if it was protective of the 406 criterion as well. ODEQ believes that this approach is protective of beneficial uses and will aid in implementation of the TMDL, because it sets a tangible goal for nonpoint source management practices and programs.

Load duration curves are a method of determining a flow-based loading capacity, assessing current conditions, likely source types, and calculating the necessary reductions to comply with water quality criteria. The methodology is primarily based on TMDLs completed by Kansas Department of Health and Environment and through technical assistance provided by Bruce Cleland of USEPA and America's Clean Water Foundation (www.acwf.org). Load duration curves were chosen because they offer a relatively simple and accurate methodology for determining the degree of water quality impairment and because they illustrate relative impacts under various flow conditions for targeting appropriate water quality restoration efforts (Cleland 2002).

Load duration curves were developed for the upper and lower Long Tom River. Load duration curves (Figure 10.15) were used because they are capable of illustrating relative impacts under various flow conditions and can be used in targeting appropriate water quality restoration efforts (Cleland 2002). To describe bacteria conditions within different flow regimes, the load duration curve was separated into five categories (High, Transitional, Typical, Dry, and Low). Zones are broken down relative to exceedence probability ranges (High = 0.0-0.1, Transitional = 0.1 - 0.4, Typical = 0.4 - 0.6, Dry = 0.6 – 0.9, Low = 0.9–1.0). Load duration curves simply provide a method of determining a flow based assessment of current bacteria loading, and the flow conditions associated with water quality violations. Curves on the plot, Figure 10.15, represent the two bacteria criteria in terms of bacterial load as a function of flow. Points that plot above the curve represent deviations from the water quality criteria and the permissible loading function. Those points plotting below the curve represent compliance with water quality criteria.

Figure 10.15 Example of a Load Duration Curve Demonstrating Load Capacity and Bacteria Load



The percent reductions indicated by these load duration curves were developed and applied seasonally, summer (June 1 – October 31), Fall-Winter-Spring (November 1 – May 31), and year round depending on the listing criteria. The watershed specific percent reductions are based on the maximum percent reduction needed to comply with water quality criteria. Various land use categories in the watershed were compared with sample location and flow dependent violations to designate land based contribution and corresponding percent reductions. The land use for each watershed was determined from the USGS land use land cover spatial coverage developed in 1980. Percent reductions were chosen to develop the TMDL rather than loads in parts of the Upper Willamette Subbasin in order to establish a more tangible means of conveying reduction targets. Each watershed's specific land-use-based percent reductions were extrapolated to all tributaries to the 303(d) listed streams. This is necessary to ensure that the tributaries are not contributing to bacteria exceedances in receiving streams.

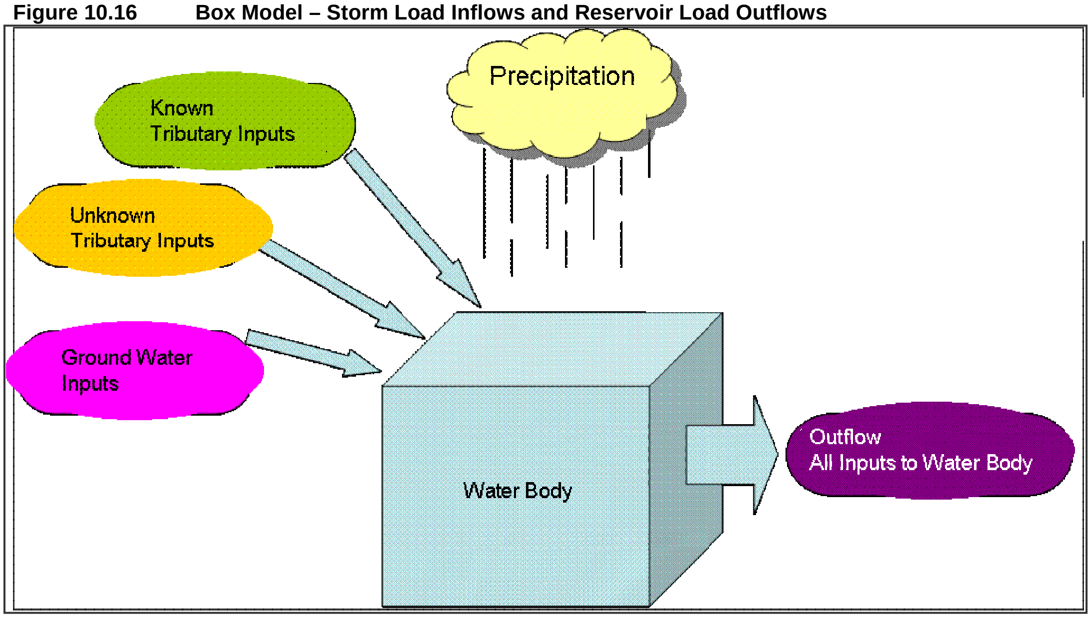
Concentration based reductions were calculated for Amazon Creek, Amazon Diversion Channel, Coyote Creek, and Fern Ridge Reservoir. This technique was applied where bacteria data did not represent all flow regimes for the use of a load duration curve or where flow data was not available due to lack of USGS flow gage on the river system.

The Event Mean Concentration Model was developed for the Luckiamute and Calapooia rivers to determine the necessary percent reductions in bacteria loading. The model estimates upland runoff volume using the Soil Conservation Service (SCS) method and applies Event Mean Concentrations (EMC) to estimate relative bacteria loading from the various land uses within the individual watersheds. Watershed composite maximum bacteria loads are then calculated to meet the state water quality criterion concentration. Soils

(SSURGO) (slope and hydrologic soil group), land use (USGS) and watershed area are the basis of this geographic database modeling exercise. The databases were overlaid in ArcView to create a composite Geographic Information System (GIS) database which was used for estimating flow volume and bacteria die-off rate as function of travel time and bacteria load. This technique was also applied to the Calapooia River in addition to the aforementioned load duration approach. A comparison of final percent reductions between the different techniques was made to better understand assumptions.

A box model was used to assess the source contributions leading to violations in Fern Ridge Reservoir. A box model was developed to represent the flow and bacteria concentrations typical of December conditions. Bacteria loads were calculated for each tributary flowing directly into the reservoir. These calculations were based on flow calculated from the drainage area, and the average of bacteria concentrations observed in stream. Overland runoff from average December precipitation was also included in the box model, as well as groundwater inputs. The total bacteria load for the reservoir was estimated and compared to the load measured at a compliance point just below Fern Ridge Dam. An illustration of the model assumptions are presented in Figure 10.16. The box model establishes the load contributed to the Reservoir by external inputs.

Figure 10.16 Box Model – Storm Load Inflows and Reservoir Load Outflows



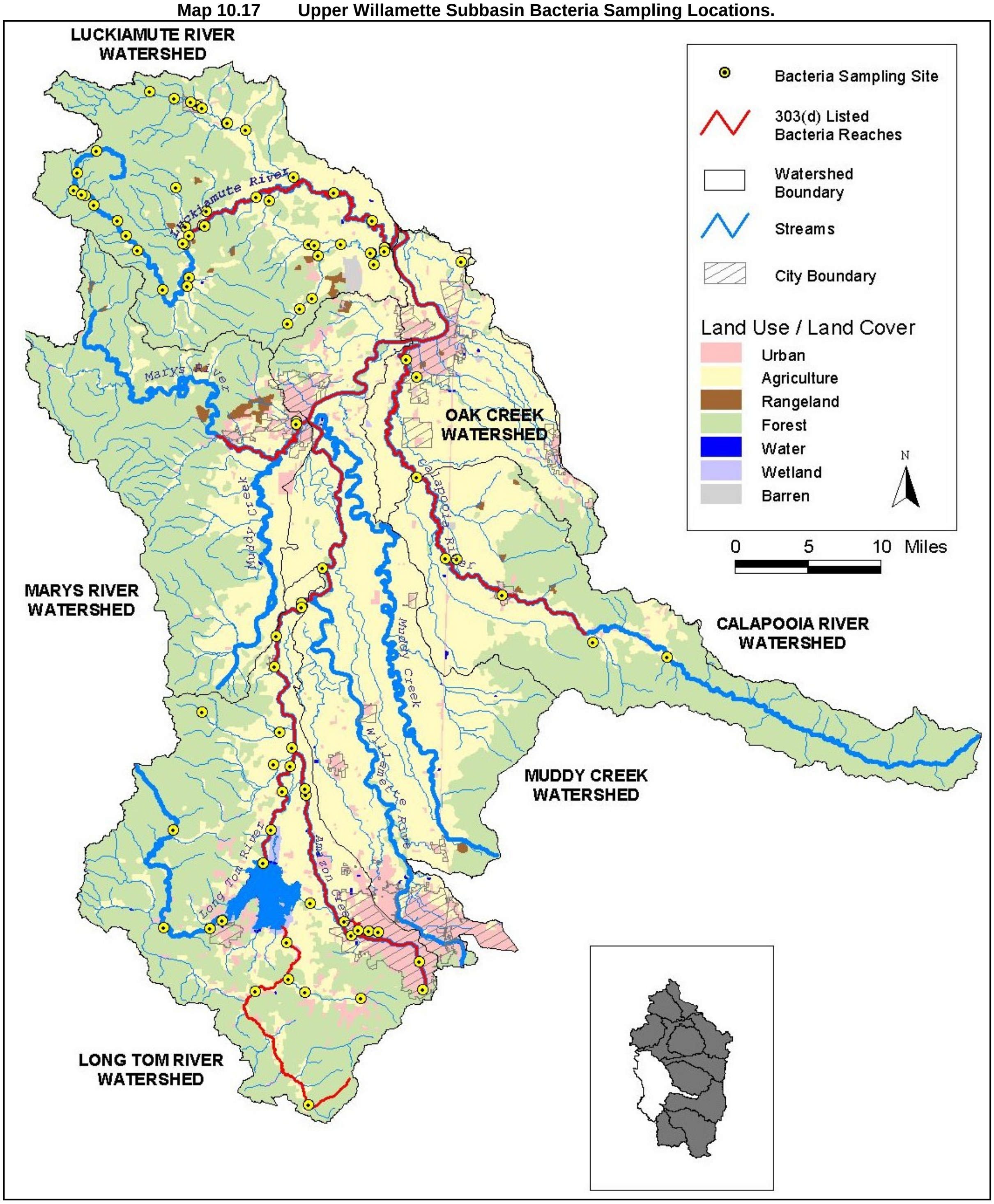
Land-use specific percent reductions were also calculated for the Upper Willamette Subbasin and are applicable to all waterbodies without specific analysis as presented in this TMDL. The land use for each watershed was determined from the USGS land use land cover spatial coverage developed in 1980. Results were generalized by land use for application to other waterbodies of the subbasin where data were limited.

Seasonal Variation

OAR 340-042-0040(4)(j), CWA 303(d)(1)

Seasonal variation in instream bacteria concentrations has been considered in the analysis of current conditions and in developing loading allocations. Box plots and statistical tables are used to describe in-stream bacteria concentrations to determine seasonal variability in the subbasin. Each statistical table identifies the number of samples per site (count), the log mean in units of bacteria count per 100 mL, the maximum bacteria count in units of bacteria count per 100 mL, and the percent reduction needed to achieve the single sample criterion of no exceedance of the 406 counts per 100 mL. Units of the number of bacteria used in all tables and graphs are counts of *E. coli* per 100 mL. Seasonal patterns in *E. coli* concentrations have been assessed for longitudinal variability throughout the year, the summer low flow period from June 1 to October 31, and for the high flow fall-winter-spring period, November 1 to May 31 in each of the watersheds of the Upper Willamette Subbasin. Analysis is based on in-stream bacteria data collected by ODEQ and subbasin watershed councils from 1996 to 2003. Allocations address seasonal fluctuations in bacteria concentrations evident in the data. Map 10.17 identifies the bacteria sampling locations within the Upper Willamette Subbasin.

Map 10.17 Upper Willamette Subbasin Bacteria Sampling Locations.



Long Tom River Watershed

The Long Tom River Watershed is divided into two sections; the Lower Long Tom River and Upper Long Tom River separated by Fern Ridge Reservoir.

Lower Long Tom River

The lower Long Tom River is listed as water quality limited for bacteria from its mouth upstream to the Fern Ridge Reservoir at RM 24.2. Data from fall-winter-spring periods are more plentiful and indicate frequent violations of both the log-mean and single sample exceedance concentration criteria, Table 10.16. See Target Criteria Identification section for an explanation of applicable bacteria water quality criteria. This is a typical pattern associated with run off from the onset of rain events in September through January. Though there are individual samples from summer periods that violate water quality criteria, there are an insufficient sampling number to determine compliance with criteria. Bacteria concentrations during an ODEQ Intensive Survey in December of 2002 were greatest just below Fern Ridge Reservoir and decreased with distance downstream (Figure 10.17). Bacteria concentrations from tributaries were similar to those in the lower reaches of the Long Tom River. This indicates that a site in the lower Long Tom River would best represent the current loading to the lower Long Tom River and its associated tributaries. ODEQ maintains an ambient water quality sampling location on the lower Long Tom River at RM 4.4 at Stow Pit Road (LASAR #11140). This location has been chosen to represent seasonal variation and ultimately percent in-stream bacteria reduction because of the large data set and associated USGS flow gage (Figure 10.18). Bacteria data from the headwaters of Ferguson and Bear Creek, which drain forest land, comply with the log-mean criterion, but occasionally violated the instantaneous maximum water quality criterion.

Table 10. 16 The Lower Long Tom River Bacteria Data Summary

	Lower Long Tom River	Summer				Fall-Winter-Spring			
RM	Station	Count	Log Mean[1]	Maximum	Percent >406	Count	Log Mean[1]	Maximum	Percent >406
1.0	Long Tom River at Old River Rd	1	11	11	0%	12	84	657	17%
4.4	Long Tom River @ Stow Pit Rd.	19	63	270	0%	32	70	1289	13%
6.6	Long Tom River At Monroe	0	0	0	0%	4	149	801	25%
11.0	Ferguson Creek At Territorial Rd (Input)	1	291	291	0%	13	392	2419	54%
13.9	Lower Amazon @ High Pass Rd. (Input)	1	326	326	0%	9	116	479	22%
14.1	Bear Creek At Territorial Hwy (Input)	1	517	517	100%	12	312	2419	42%
15.0	Long Tom River at High Pass Road	0	0	0	0%	3	412	771	67%
17.3	Long Tom River at Hwy 36	1	7	7	0%	13	108	712	23%
23.3	Long Tom River D/S Fern Ridge Dam	0	0	0	0%	5	871	1134	100%

[1] The Log Mean indicated in this table does not represent a 30 day log mean as defined by DEQ water quality standards. Limited data required that the log mean be calculated using all available data for a site.

Figure 10.17 Lower Long Tom River Longitudinal Bacteria Box Plot for December 2002 ODEQ Intensive Survey. (The number above each box plot in parenthesis is the number of samples per river mile, and the five digit number below each box plot is the ODEQ LASAR number.)

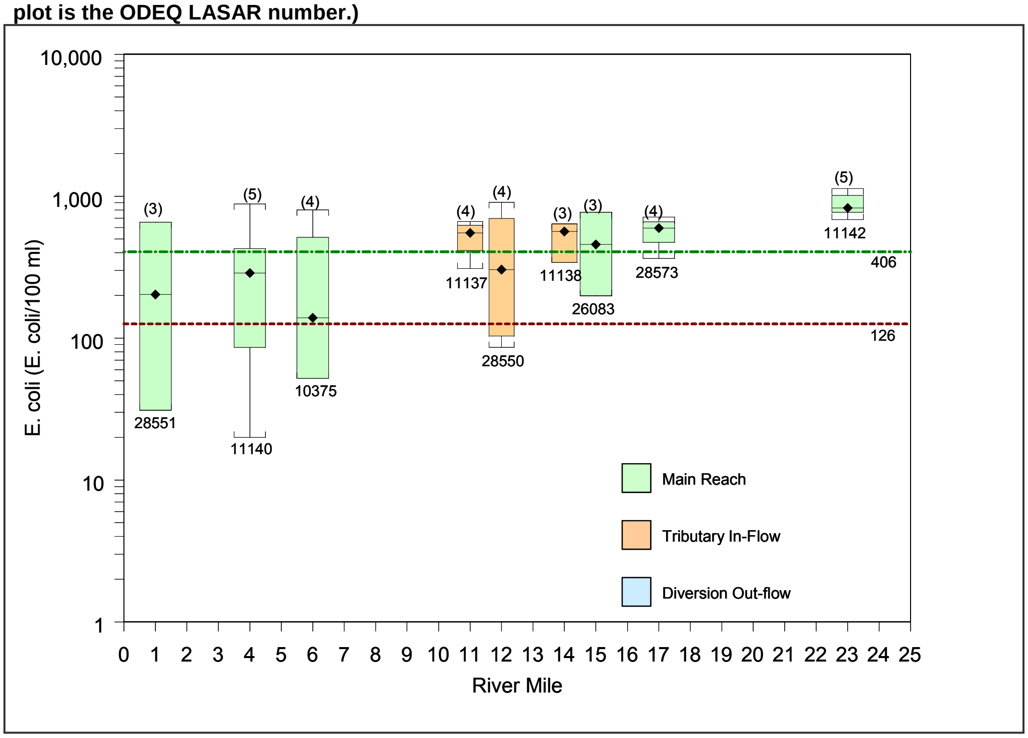
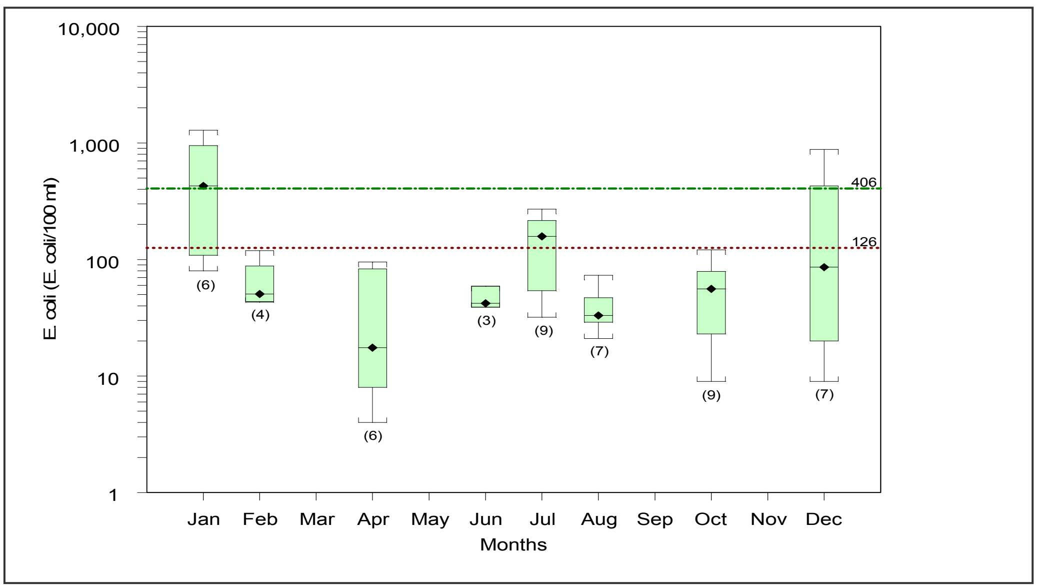


Figure 10.18 ODEQ Long Tom River at Stow Pit Road Ambient Water Quality Site (LASAR #11140) at RM 4.4 Monthly Box Plot. (The number below each box plot in parenthesis is the number of samples taken per month.)



Upper Long Tom River

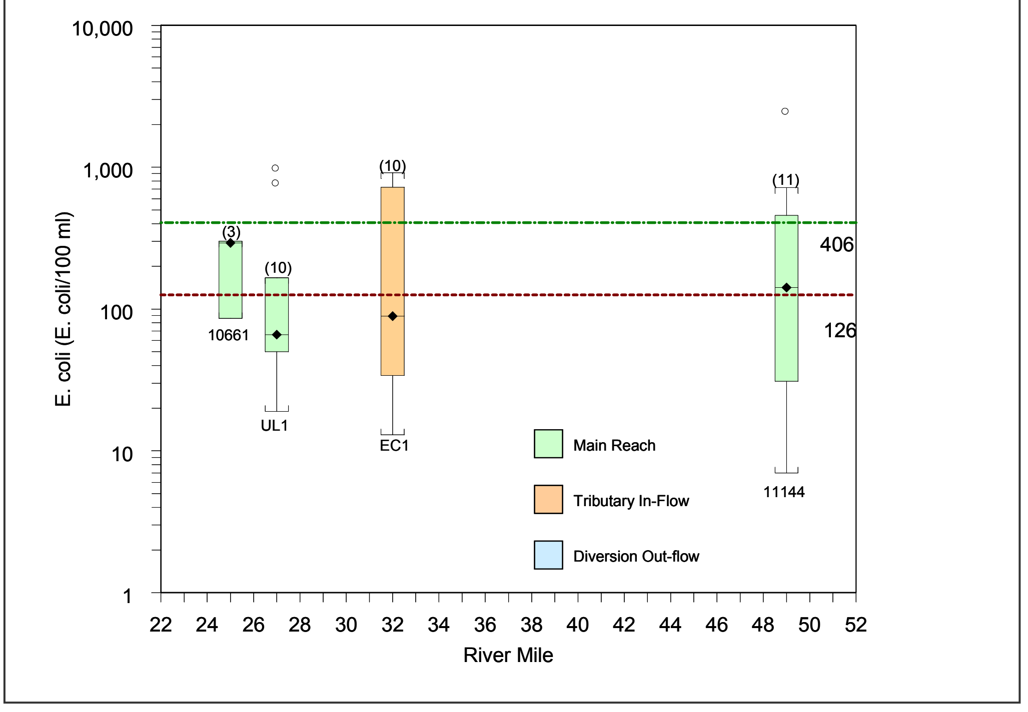
The upper Long Tom River originates on the east side of the Coastal Range and flows into Fern Ridge Reservoir. The upper Long Tom River is not listed as water quality limited, but historical data indicates that water quality violations occurred during the fall-winter-spring period (Table 10.17). This upper reach of the Long Tom River also plays an integral role as a potential source of bacteria loading into Fern Ridge Reservoir. A box plot of the upper Long Tom River, plotting the bacteria data on a year round scale, indicates that bacteria concentrations are exceeding the numeric criteria at the upper most sampling site at RM 49.8, Alderwood Street Park (Figure 10.19).

Table 10. 17 Upper Long Tom River Bacteria Data Summary

	Upper Lower Long Tom River	Summer				Fall-Winter-Spring			
RM	Station	Count	Log Mean[1]	Maximum	Percent >406	Count	Log Mean[1]	Maximum	Percent >406
25.7	Long Tom River At Elmira	0	0	0	0%	3	196	301	0%
27.8	Upper Long Tom I @ Territorial	1	121	121	0%	9	107	961	22%
32.5	Elk Creek @ Noti (Trib. Input)	1	340	340	0%	9	117	914	33%
49.8	Long Tom River At Alderwood St. Park	1	276	276	0%	10	125	2419	30%

[1] The Log Mean indicated in this table does not represent a 30 day log mean as defined by DEQ water quality standards. Limited data required that the log mean be calculated using all available data for a site.

Figure 10.19 Upper Long Tom River Year Round Longitudinal Box Plot of Bacteria Concentrations. (The number above each box plot in parenthesis is the number of samples per river mile, the five digit number below each box plot is the ODEQ LASAR number, UL1 = Upper Long Tom 1 at Territorial, and EC1 = Elk Creek @ Noti.)



Coyote Creek

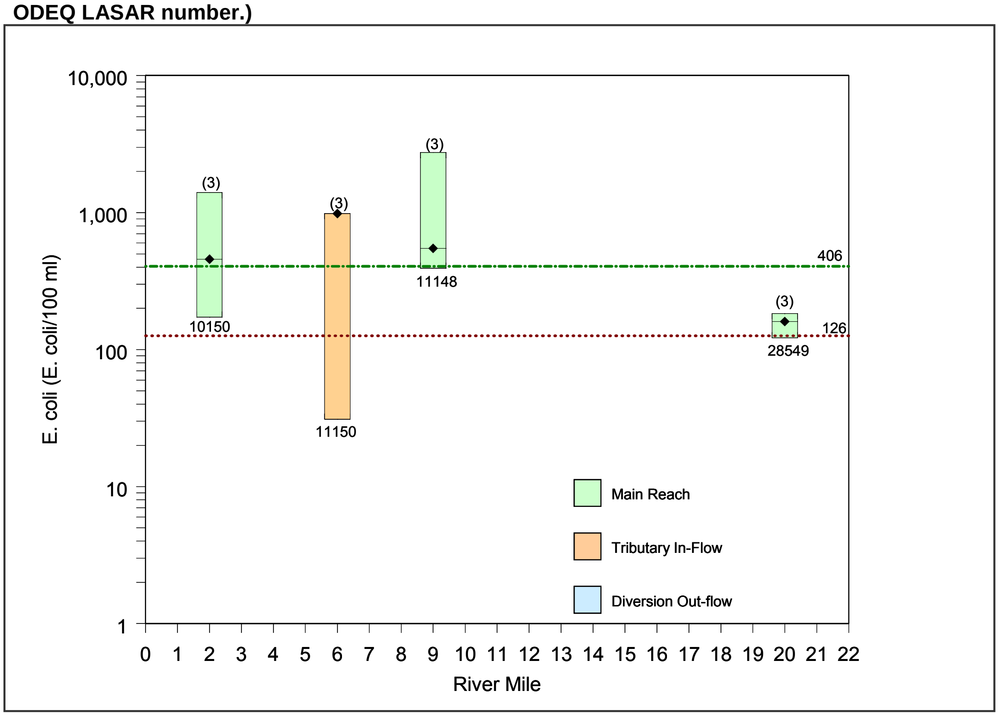
Coyote Creek is listed as water quality limited for bacteria year-round. Instream bacteria samples indicate that the headwaters of Coyote Creek at Hamm Road, RM 20.9, does not exceed water quality criteria; however Coyote Creek does exceed both bacteria criteria starting at RM 16.0, Table 10.18. The Hamm Road site does drain forest land and typically forested land does not have excessive bacteria loading because of the minimal animal and anthropogenic impacts within the forest boundary. Lower reaches draining primarily agricultural lands violated water quality criteria, particularly in fall-winter-spring. Coyote Creek at Powell Road at RM 16.0 exceeded the criteria year round. Data collected during the ODEQ Intensive Survey in December of 2002 indicate elevated concentrations of bacteria in the lower watershed starting at RM 9.5 at Crow Road, Figure 10.20. Coyote Creek flows into Fern Ridge Reservoir and is a potential source contributor of bacteria to the Reservoir.

Table 10. 18 Coyote Creek Bacteria Data Summary

	Coyote Creek	Summer				Fall-Winter-Spring			
RM	Station	Count	Log Mean[1]	Maximum	Percent >406	Count	Log Mean[1]	Maximum	Percent >406
2.7	Coyote Cr. At Cantrell Road	5	19	55	0%	3	480	1401	67%
6.2	Spencer Creek At Mouth (Trib. Input)	0	0	0	0%	3	311	988	67%
6.6	Coyote Creek I @ Petzold Road	1	98	98	0%	9	205	914	22%
9.5	Coyote Creek At Crow	5	111	173	0%	3	840	2755	67%
16.0	Coyote Creek II @ Powell Rd.	7	215	649	14%	9	278	961	44%
20.9	Coyote Cr. at Hamm Rd	1	33	33	0%	12	10	183	0%

[1] The Log Mean indicated in this table does not represent a 30 day log mean as defined by DEQ water quality standards. Limited data required that the log mean be calculated using all available data for a site.

Figure 10.20 Coyote Creek Longitudinal Bacteria data, ODEQ Intensive Survey in December 2002. (The number above each box plot in parenthesis is the number of samples per river mile, and the five digit number below each box plot is the ODEQ LASAR number.)



Upper Amazon Creek

Analysis of the bacteria loads in the Upper Amazon Creek Watershed includes the Amazon Creek Diversion Canel, which diverts a majority of flow from the creek. Exceedances of the bacteria criteria in Amazon Creek and the diversion channel occur year-round in the creek (Table 10.19), although some monitoring stations were characterized with very few samples such as Upper Amazon Creek at Danebo Street (RM 5.2) which only had two samples collected during the summer but 12 samples during the fall-winter-spring period. Fall-winter-spring concentrations were generally higher than summer instream bacteria concentrations. Bacteria concentrations during the summer period were generally below the single sample criterion (Figure 10.21). During the intensive survey in December 2002, bacteria samples were generally well above the criteria (Figure 10.22).

Table 10. 19 Upper Amazon Creek Bacteria Data Summary

	Upper Amazon Creek	Summer				Fall-Winter-Spring			
RM	Station	Count	Log Mean[1]	Maximum	Percent >406	Count	Log Mean[1]	Maximum	Percent >406
1.1	Amazon Cr. Diversion Cannel @ Fir Butte Rd	5	18	575	20%	3	1774	2382	100%
4.2	Amazon Creek at S. Pacific RR Bridge	6	93	517	17%	0	0	0	0%
5.2	Upper Amazon @ Danebo St.	2	671	727	100%	12	735	2602	75%
11.0	Amazon Creek at 29th Street Gaging Station	6	243	649	17%	4	1757	4106	100%
14.3	Amazon Creek at Martin St	0	0	0	0%	1	354	354	0%

[1] The Log Mean indicated in this table does not represent a 30 day log mean as defined by DEQ water quality standards. Limited data required that the log mean be calculated using all available data for a site.

Figure 10.21 Upper Amazon Creek Longitudinal Bacteria Box Plot of Summer Data. (The number above each box plot in parenthesis is the number of samples per river mile, and the five digit number below each box plot is the ODEQ LASAR number.)

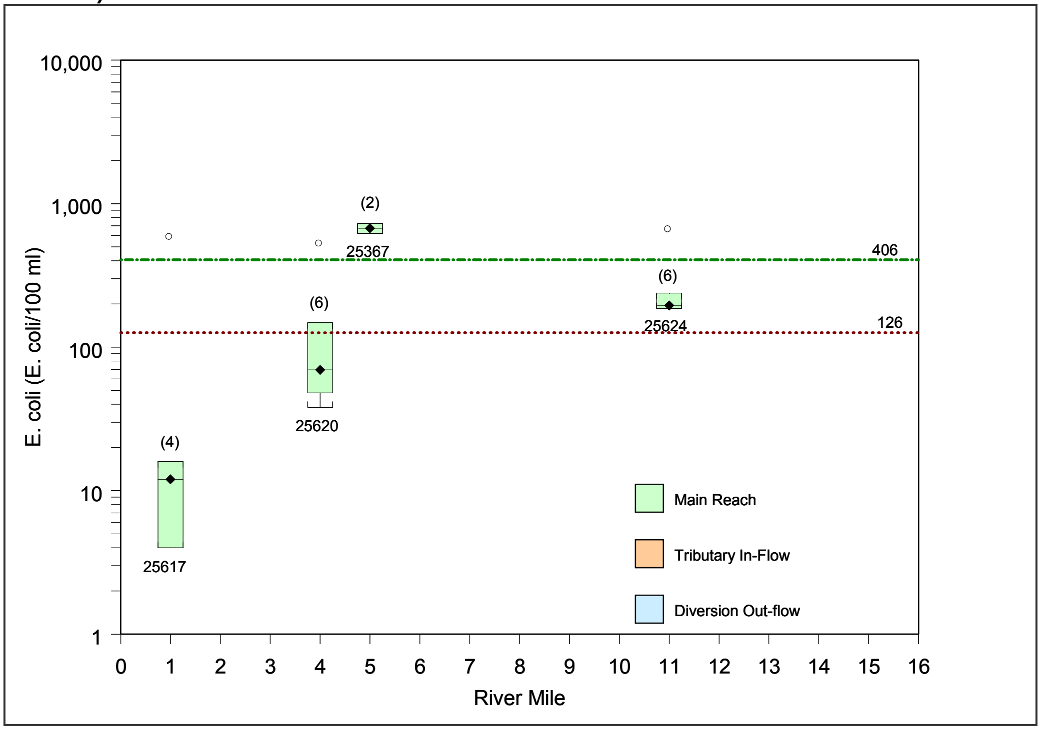
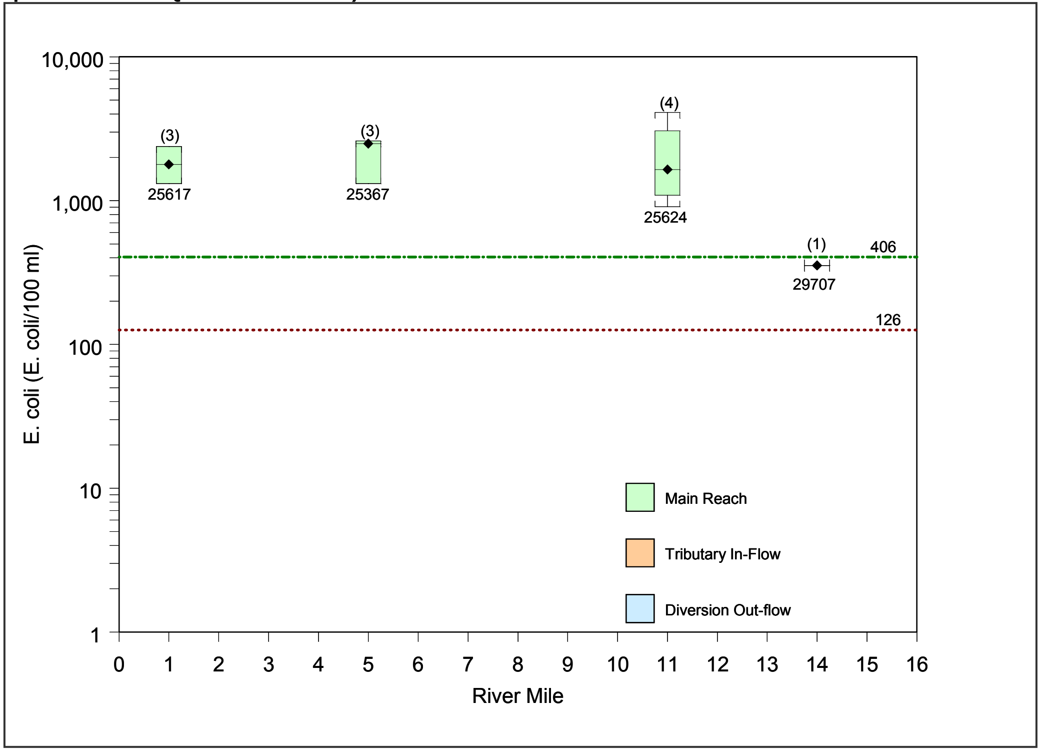


Figure 10.22 Upper Amazon Creek Longitudinal Bacteria box plots, ODEQ Intensive Survey, December 2002. (The number above each box plot in parenthesis is the number of samples per river mile, and the five digit number below each box plot is the ODEQ LASAR number.)



A-3 Drain

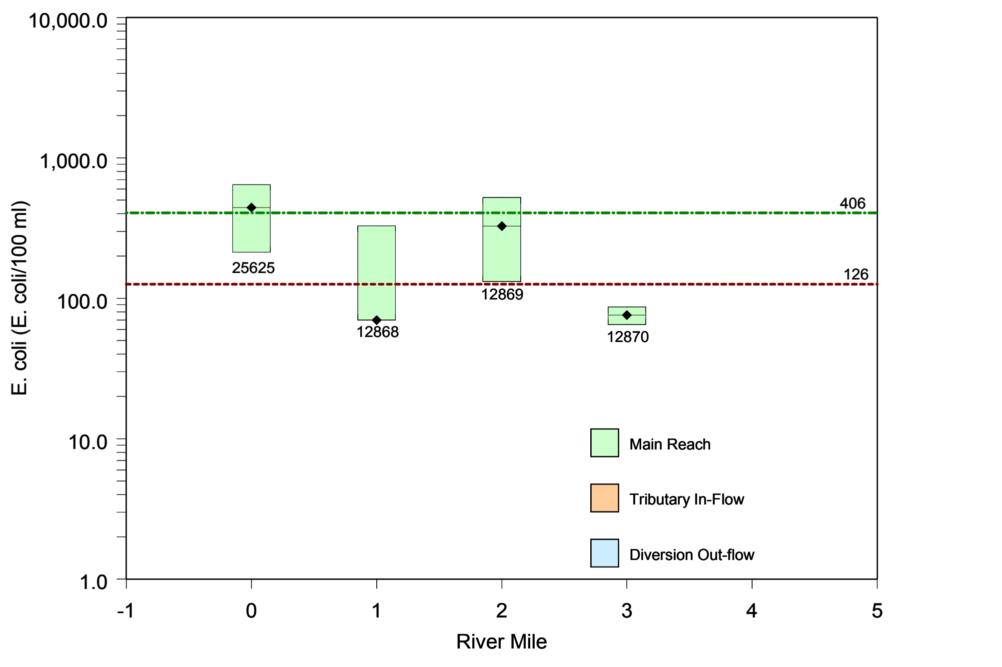
The A-3 Drain is a tributary to the lower Amazon Creek and drains 2.5 square miles of Eugene's urban area. It is listed for exceeding the bacteria criteria year round. Bacteria concentrations varied throughout the reach with the lowest concentrations occurring at the headwaters at RM 2.6 at Wallis Road and at RM 0.5 at North Terry Street, Table 10.20 and Figure 10.23. Instream bacteria data collection only occurred during ODEQ's intensive survey of December 2002. No bacteria instream data is currently available for the summer period.

Table 10. 20 A-3 Drain Bacteria Data Summary

	A-3 Drain	Summer				Fall-Winter-Spring			
RM	Station	Count	Log Mean[1]	Maximum	Percent >406	Count	Log Mean[1]	Maximum	Percent >406
0.5	A 3 Canal at North Terry Street	0	0	0	0%	3	393	644	67%
1.8	A-3 Channel D/S Bertelsen Rd (End Ind.Park)	0	0	0	0%	3	118	329	33%
2.6	A-3 Channel At Wallis Rd (D/S Culvert)	0	0	0	0%	2	262	522	50%
3.2	A-3 Channel At Seneca Rd (D/S Of Culvert)	0	0	0	0%	2	75	87	0%

[1] The Log Mean indicated in this table does not represent a 30 day log mean as defined by DEQ water quality standards. Limited data required that the log mean be calculated using all available data for a site.

Figure 10.23 A-3 Drain Longitudinal Box Plot of Bacteria Concentrations. (Five digit number below each box plot is the site LASAR number.)



Fern Ridge Reservoir

The Fern Ridge Reservoir divides the upper and lower Long Tom River system. The upper Long Tom River, Coyote Creek, and portion of upper Amazon Creek drain into the reservoir and may contribute bacteria loading to the Reservoir. Fern Ridge is listed as water quality limited for bacteria in the fall-winter-spring. Bacteria data has been collected by the Army Corps of Engineers in the late 1990's, but this data was not available to ODEQ at the time of this study, thus fecal coliform data collected in 1983 by the Lane Council of Governments (LCOG) Lakes Study was used. The bacteria data in Table 10.21 are fecal coliform data converted to reflect *E. coli* counts, using the equation, developed by ODEQ (Cude 2001):

$$E.\ coli \text{ count} = 0.53087 * \text{Fecal Coliform count}^{1.05652}$$

This relationship is based on regression analysis of a large data set collected by ODEQ in its ambient monitoring program. This conversion of fecal coliform to *E. coli* data allows for a comparison of the data to the criteria. Summer period bacteria concentrations were below the criteria, however fall-winter-spring bacteria concentrations were exceeded at Perkins Bay, Mid Pool, and East Side Spillway, Table 10.21.

Table 10. 21 Fern Ridge Reservoir Bacteria Data Summary of LCOG Clean Lakes Study 1983.

	Fern Ridge Reservoir	Summer				Fall-Winter-Spring			
RM	Station	Count	Log Mean[1]	Maximum	Percent >406	Count	Log Mean[1]	Maximum	Percent >406
	Amazon Bay	6	9	19	0%	5	17	69	0%
	Coyote Bay	5	5	13	0%	6	40	220	0%
	Perkins Bay	6	5	13	0%	4	112	457	25%
	Long Tom Bay	6	4	13	0%	6	20	69	0%
	Mid Pool	8	5	13	0%	19	68	2188	32%
	East side spillway	0	0	0	0%	3	137	538	33%
	West side spillway	0	0	0	0%	4	17	40	0%

[1] The Log Mean indicated in this table does not represent a 30 day log mean as defined by DEQ water quality standards. Limited data required that the log mean be calculated using all available data for a site.

Luckiamute River Watershed

The Luckiamute River is water quality limited for bacteria from its mouth to the confluence of Pedee Creek. An intensive ODEQ bacteria water quality storm survey occurred in the winter of 2001. Bacteria concentrations during the winter survey did not exceed the criteria upstream of RM 5; however the Luckiamute near its mouth does show exceedances of the criteria (Figure 10.24 and Table 10.22). (Note that the median *E. coli* values increased from upstream to downstream within the mainstem Luckiamute River). Tributary concentrations were generally similar to the associated Luckiamute River sites suggesting that tributaries may be a leading cause of bacteria loading to the Luckiamute River.

Figure 10.24 Luckiamute River Longitudinal Box Plot of Bacteria Concentrations, Winter 2001.

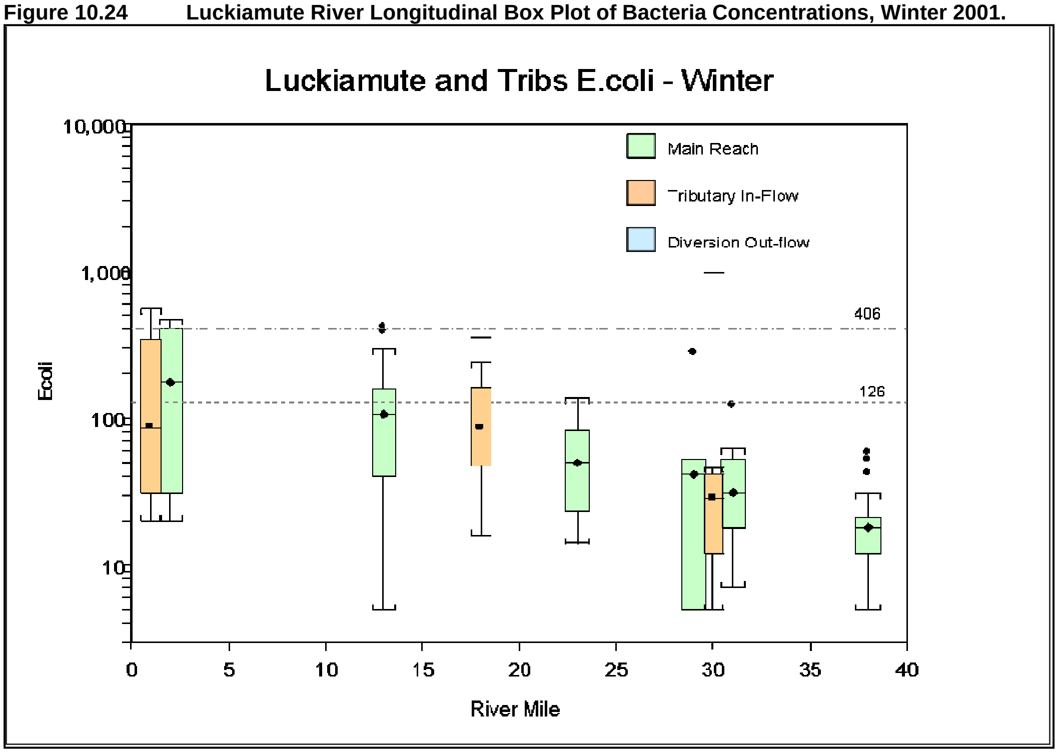


Table 10. 22 Luckiamute River Bacteria Data Summary. (Calculation of the 30-day log mean is for informational purposes and is not used to determine exceedance of the criterion because the data was collected within a 5 day period. A true calculation of the 30-day log mean would occur over a period greater than 5 days.)

LASAR No :	SITE NAME:	Latitude	Longitude	River Mile	Initial Date	Final Date	E.coli Log Mean All Data	E.coli 30-day Log Mean	n All Data	n 30-day Log Mean	E.coli Median All Data	E.coli 90th Percentile All Data	E.coli Max All Data
11111	Luckiamute River at Hoskins	44.6817	-123.46775	38.47	26-Nov	13-Mar	18	26	17	5	18	46	58
25483	Luckiamute River u/s Ritner Creek at Grant Road	44.7281	-123.44109	31.38	21-Feb	13-Mar	38	38	8	8	42	80	121
26734	Luckiamute River u/s Pedee Cr at Ritner Wayside	44.73567	-123.43384	30.5	26-Nov	14-Jan	23	28	10	7	24	39	52
	CONFLUENCE – PEDEE CREEK (to Luckiamute)			30.2									
25481	Pedee Creek at Kings Highway	44.7445	-123.43915	0.56	26-Nov	13-Mar	28	33	16	6	29	45	987
25480	Luckiamute River at Ira Hooker Road	44.7465	-123.41584	29.36	21-Feb	13-Mar	29	29	6	6	41	165	278
28548	RUNOFF- to Luckiamute R RM 29.35 immediately d/s of Ira Hooker Rd	44.7465	-123.4159	29.35	11-Mar	13-Mar	1293	1293	4	4	3515	10836	12997
25477	Luckiamute River at Airlie Road	44.7761	-123.34322	23.61	26-Nov	13-Mar	46	50	16	6	50	94	135
10659	Luckiamute River at Helmick State Park	44.7828	-123.23533	13.57	26-Nov	13-Mar	86	223	18	5	106	325	411
10658	Luckiamute River at Lower Bridge (Buena Vista)	44.7304	-123.1614	2.3	21-Feb	13-Mar	126	242	7	5	175	427	465
	CONFLUENCE – SOAP CREEK			2.29									
11113	Soap Creek at Corvallis Road	44.7249	-123.1808	2.2	21-Feb	13-Mar	95	95	6	6	86	449	556
26733	NF Pedee Creek at Headwaters	44.78293	-123.45436	2	21-Feb	13-Mar	<10	<10	6	6	5	10	10
25481	Pedee Creek at Kings Highway	44.7445	-123.43915	0.56	26-Nov	13-Mar	28	33	16	6	29	45	987
26735	Little Luckiamute River at Fall City Gage	44.87083	-123.46111	13.94	21-Feb	13-Mar	14	14	6	6	8	163	305
28500	POINT SOURCE-Falls City WWTP Final Effuent (to Little Luckiamute R)	44.864	123.4295	12.1	12-Mar	13-Mar	<5	<10	3	3	5	5	5
26736	Little Luckiamute River at Bridgeport Road	44.84786	-123.38791	9.26	11-Mar	13-Mar	26	26	6	6	10	347	389
	CONFLUENCE TEAL CREEK (to Little Luckiamute)			9									
11118	Teal Creek at Gardner Road	44.8479	-123.3868		11-Mar	13-Mar	56	56	3	3	31	237	288
11114	Little Luckiamute River at Elkins Road	44.7972	-123.2915	0.65	26-Nov	13-Mar	77	154	17	5	85	221	350
28519	Soap Creek at South Boundary Road	44.6672	-123.2774	11.744	12-Mar	13-Mar	10	10	2	2	13	19	20
26741	Soap Creek at Beef Barn Road	44.67788	-123.26095	10.59	21-Feb	13-Mar	623	623	4	4	585	6353	8664
26740	Soap Creek at Robison Road	44.72028	-123.25398	7.3	21-Feb	13-Mar	260	260	5	5	246	985	1236
	CONFLUENCE - BERRY CREEK			5.7									
26743	Berry Creek at DeArmond Road (to Soap Cr at about RM 4.65)	44.73084	-123.2679	2.8	21-Feb	13-Mar	178	178	4	4	125	559	743
26739	Soap Creek at Hwy. 99W	44.7323	-123.22346	5.4	21-Feb	13-Mar	109	109	4	4	196	345	388
11113	Soap Creek at Corvallis Road	44.7249	-123.1808	2.2	21-Feb	13-Mar	95	129	6	6	86	449	556
	CONFLUENCE - UNNAMED TRIB TO SOAP CR AT NW IND. HWY			0.4									
26738	Unnamed trib to Soap Cr at NW Ind. Hwy (to Soap Cr at about RM 0.4)	44.71334	-123.17628	1.5	21-Feb	13-Mar	193	193	4	4	566	837	906
26738	Unnamed trib to Soap Cr at NW Independence Hwy (to Soap Cr at about RM 0.4)	44.71334	-123.17628	1.5	21-Feb	13-Mar	193	193	4	4	566	837	906
26743	Berry Creek at DeArmond Road (to Soap Cr at about RM 4.65)	44.73084	-123.2679	2.8	21-Feb	13-Mar	178	178	4	4	125	559	743
11118	Teal Creek at Gardner Road	44.8479	-123.3868		11-Mar	13-Mar	56	56	3	3	31	237	288

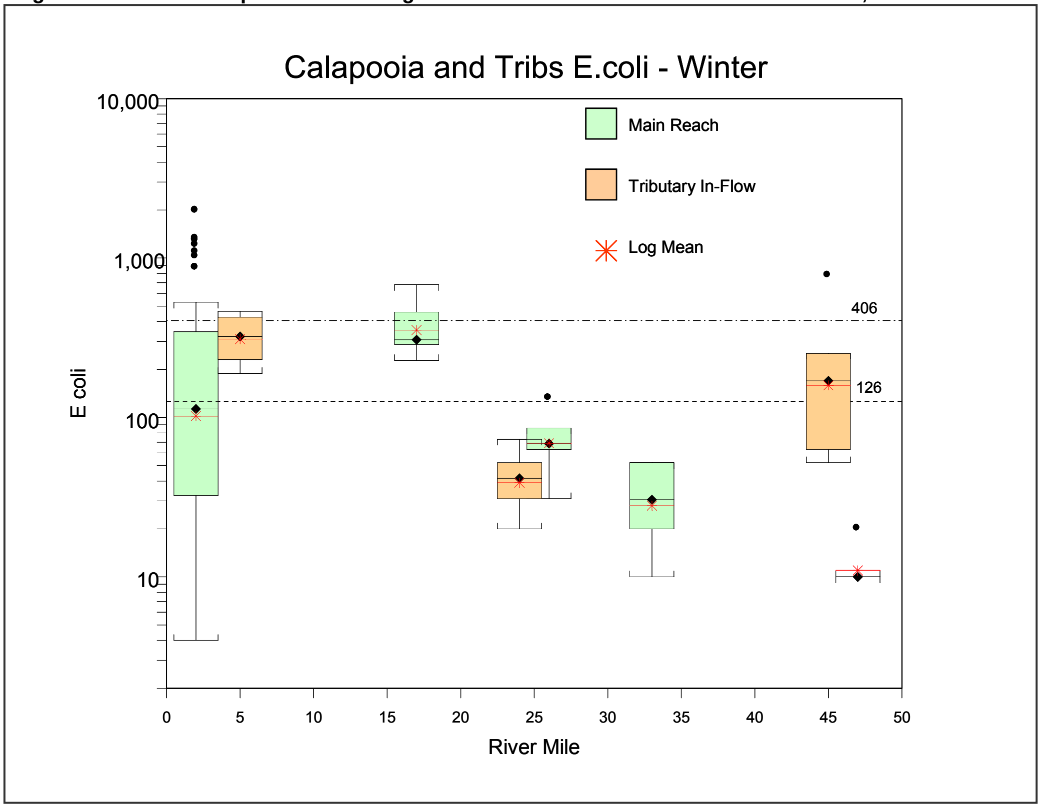
Calapooia River Watershed

Bacteria data collected in the Calapooia River at ODEQ's quarterly ambient monitoring station in the lower watershed at RM 2.6, Calapooia River at Queens Road, were combined with instream bacteria samples collected during a storm survey in 2003 in collaboration with the Calapooia River Watershed Council, Table 10.23. The ODEQ established the Calapooia River at Queen Road site in 1972. Prior to 1996, samples were analyzed for fecal coliform concentrations. The fecal coliform data has been converted to *E. coli* equivalents with an equation developed by ODEQ (Cude 2002). Exceedances of the criteria occur in lower reach of the stream, starting at RM 17.1, and in two of the tributaries, Brush Creek in the upper portion of the watershed and Oak Creek in lower portion (Table 10.23). A box plot of the ODEQ winter 2003 storm survey indicates an increase in bacteria loading in the lower portion of the watershed, Figure 10.25.

Table 10. 23 Calapooia River Bacteria Data Summary

LASAR Number	Site Name	River Mile	Count All data	Geomean all data	Median All Data	90th Percentile All Data	Max All Data	Count 30-day Geomean data	Geomean 30 day
25460	Calapooia River at McClun Wayside	47.9	6	11	10	15	20	6	11
25459	Brush Creek at Courtney Creek Rd.	0.9	6	159	170	515	776	6	159
25457	Calapooia River at Brownsville	33.1	6	28	31	52	52	6	28
25455	Calapooia River at Linn West Rd.	26.5	6	69	69	109	132	6	69
25456	Sodom Ditch at Linn West Rd.	4.2	6	39	42	63	73	6	39
11182	Calapooia River at Hwy 99E	17.1	6	353	307	571	683	6	353
11188	Oak Creek at Hwy 99E (Albany)	1.4	6	310	322	445	464	6	310
11180	Calapooia River at Queen Road	2.6	128	102	393	773	1017	6	383

Figure 10.25 Calapooia River Longitudinal Box Plot of Bacteria Concentrations, Winter 2003.



Marys River Watershed

The Marys River is listed as water quality limited for bacteria from its mouth in Corvallis to RM 13.9. *E. coli* data collected by ODEQ at two stations in Corvallis indicate that single sample criterion has been exceeded 4% during summer and 6% during the fall-winter-spring period at Avery Park, RM 1.2 (Table 10.24).

Table 10. 24 Marys River Bacteria Data Summary.

River Mile	Station	Station ID	Number Samples	Maximum	%>406
Summer					
0.1	Marys River at Hwy 99W, Corvallis	10373	12	278	0
1.2	Marys River at Avery Park., Corvallis		25	>2420	4
Fall-Winter-Spring					
0.1	Marys River at Hwy 99W, Corvallis	10373	28	300	0
1.2	Marys River at Avery Park., Corvallis		51	1414	6

Loading Capacity

OAR 340-042-0040(4)(d), 40CFR 130.2(f)

The loading capacity for the Upper Willamette Subbasin is defined in terms of concentrations of bacteria (*E. coli*) that meet the water quality criteria. The loading capacity is defined as the bacteria water quality criteria as stated in OAR 340-41-0009: a 30-day log mean of 126 *E. coli* counts / 100 mL, based on a minimum of 5 samples, and no 90th percentile calculation exceeding 406 *E. coli* counts / 100 mL. The loading capacity is applied to all the water bodies in the Upper Willamette Subbasin. Application of the loading capacity to the subbasin scale reduces bacteria concentrations in 303(d) listed streams and their tributaries, and protects water contact recreation throughout the Upper Willamette Subbasin. A loading capacity was explicitly calculated for streams modeled with the EMC method, namely the Luckiamute and Calapooia Rivers.

The 30-day log mean of 126 *E. coli* organisms per 100 milliliters criterion was used as the target concentration in the TMDL for determining the loading capacity of a waterbody. This criterion most directly relates to illness rates[2] and potential impacts on the beneficial use of water contact recreation.

The estimate of the current load and the calculated loading capacity were used to calculate a percent reduction to meet the loading capacity and thereby meet the 126 *E. coli* organisms per 100 milliliters criterion. Specific allocations were derived based on an analysis of the contribution of sources relative to the estimate of the current load. Those with similar loads received the calculated percent reduction. Those with minor loadings (e.g. treated waste water) received their current loading, set at the water quality standard.

[2] *From Implementation Guidance for Ambient Water Quality Criteria for Bacteria (USEPA, EPA-823-B-02-003, May 2002 Draft, pg 7): "For the purpose of analysis, the data collected at each of these sites were grouped into one paired data point consisting of an averaged illness rate and a geometric mean of the observed water quality. These data points were plotted to determine the relationships between illness rates and average water quality (expressed as a geometric mean). The resulting linear regression equations were used to calculate recommended geometric mean values at specific levels of protection (e.g., 8 illnesses per thousand). Using a generalized standard deviation of the data collected to develop the relationships and assuming a log normal distribution, various percentiles of the upper ranges of these distributions were calculated and presented as single sample maximum values.*

EPA recognizes that the single sample maximum values in the 1986 criteria document are described as "upper confidence levels," however, the statistical equations used to calculate these values were those used to calculate percentile values. While the resultant maximum values would more appropriately be called 75th percentile values, 82nd percentile values, etc., this document will continue to use the historical term "confidence levels" to describe these values to avoid confusion."

Allocations

40 CFR 130.2(g) & (h)

Allocations are presented for appropriate point source discharges (wasteload allocations) and for nonpoint source discharges (load allocations).

Wasteload Allocations

OAR 340-042-0040(4)(g)

Wasteload allocations are in terms of concentration limits for discharges. In general, the allocations require effluent limits equal to the water quality criteria at the end of the discharge pipe. Point source discharges with a likelihood of discharging bacteria already have limits in their NPDES permits that meet water quality criteria (Table 10.25). Confined animal feeding operations are not allowed to discharge wastes from specific areas covered by the general NPDES permit. CAFOs are allocated zero as an *E. coli* concentration in runoff from regulated portions of the operations.

Table 10. 25 Wasteload Allocations for Wastewater Treatment Plants (WWTP) and Confined Animal Feeding Operations (CAFO) in the Upper Willamette Subbasin. CAFO loads are limited by permit requirements.

Facility	Receiving Water	River Mile	Log Mean Limit MPN/100 ml *E. coli*	Instantaneous Limit MPN/100 ml *E. coli*
Alpine County Service District	Muddy Creek	25.6	126	406
Diamond Hill L.L.C.	Little Muddy Creek	8	126	406
Falls City, City of	Little Luckiamute River	11.9	126	406
Halsey, City of	Muddy Creek	23	126	406
Junction City, City of	Flat Creek	9.15	126	406
Philomath, City of	Marys River	10.2	126	406
Shell Oil Products Company LLC	Courtney Creek	2.7	126	406
Tangent, City of	Calapooia River	10.8	126	406
Veneta, City of	Long Tom River	34.9	126	406
Confined Animal Feeding Operations (CAFO)[a]	Various	NA	0	0

a= CAFOs are allowed zero discharge from confinement, storage, or concentration areas under terms or NPDES permit.

Load Allocations

OAR 340-042-0040(4)(h), 40 CFR 130.2(h)

Load allocations have been developed for both the summer low flow period, June 1 to October 31; and for the high flow fall-winter-spring period, November 1 to May 31. The allocations are calculated to protect the sensitive beneficial use, water contact recreation.

Load allocations are expressed in terms of percent reductions in bacteria loads to streams. For watersheds modeled using the EMC method, Luckiamute River and Calapooia River, load allocations were explicitly derived in terms of total loads of bacteria that may enter the streams. For other streams, load allocations were estimated based on the percent reductions in instream concentrations and loads required to meet criteria. For all streams, the load allocations were translated to required percent reductions in loads from major land use categories. Allocations are determined separately for each 303(d) listed stream watershed; Lower Long Tom, Upper Long Tom, Coyote, Upper Amazon, A-3 Drain, Luckiamute, and Calapooia watersheds and Fern Ridge Reservoir. The percent reductions are determined separately for land use and apply year round. A detailed report of the technical approach used in this bacteria TMDL is available in Appendix A.

An allocation has also been developed for the remainder of the Upper Willamette Subbasin outside of the analyzed watersheds. These overall allocations are land-use specific and are based on the averaging of percent reductions calculated for each land use in each analyzed watershed.

ODEQ chose to calculate the percent reduction necessary to achieve the 126 *E. coli* counts / 100 ml log mean criterion and applied this reduction to nonpoint source (load) allocations. The percent reduction was determined conservatively by using the 90th percentile of the measured samples for Coyote Creek, A-3 Drain, Amazon Creek, Amazon Diversion Channel, and Fern Ridge Reservoir. The calculated log mean of the data set was used to calculate the percent reduction necessary for the Long Tom River. ODEQ believes that this approach will aid in implementation of the TMDL because it sets a tangible and common goal for both point and nonpoint source management practices and programs.

Bacteria load reductions as high as 84% are necessary to achieve compliance with numeric water quality criteria. These load allocations result in compliance with the log mean criterion of 126 counts per 100 ml.

Long Tom Watershed

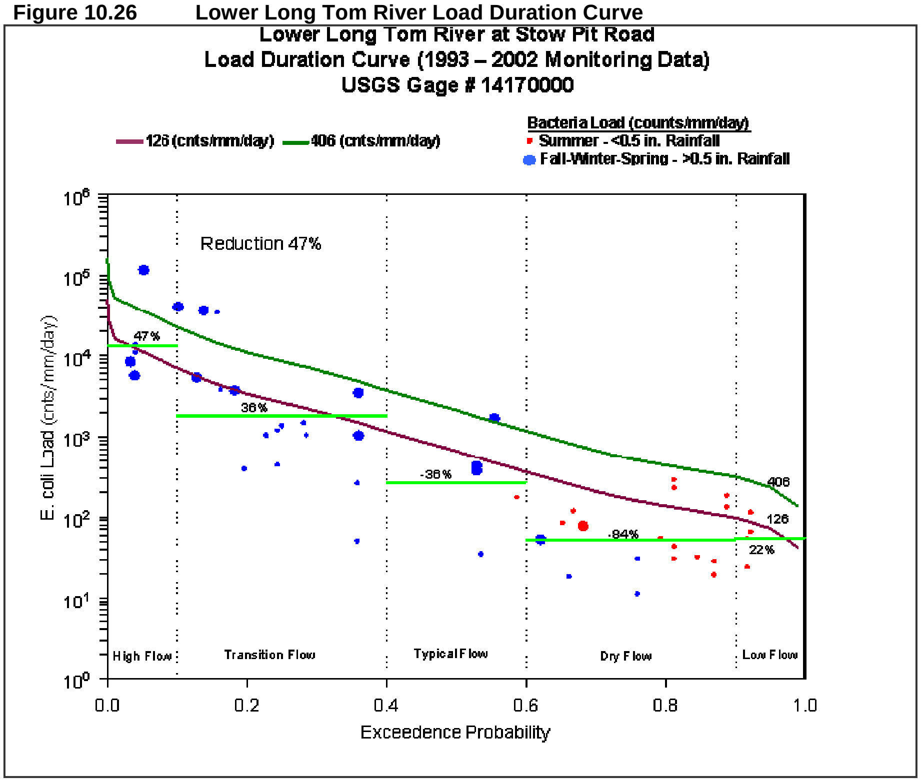
There are two geographic areas within the Long Tom Watershed, upper and lower, separated by Fern Ridge Reservoir. These two geographic areas have been analyzed individually to determine bacteria reductions. The bacteria percent reductions have been assigned to each contributing land use in each watershed.

Lower Long Tom Watershed

ODEQ used the load duration curve approach to develop the bacteria TMDL for the lower Long Tom River. Load duration curves plot the flow exceedence probability in relation to the instream bacteria load. The exceedence probability is the flow rank over the period of record divided by the total flow records. Low exceedence probabilities represent high flows and high exceedence probabilities represent low flow conditions. The load duration curve for lower Long Tom Watershed was developed using water quality data collected by the ODEQ at an ambient monitoring site and flow data from the USGS flow gage (gage# 14170000) near the city of Monroe (Figure 10.26). *E. coli* data used in this analysis were collected during a variety of weather and flow conditions between 1993 and 2002. Data reported as “estimate”, “less than” or “greater than” values were not considered. Violations of the log-mean criterion occur between transitional flow and high flow regimes, while the exceedences of the 406 criteria occur between the typical flow and high flow regimes. As demonstrated by the load duration curve, below, the maximum reduction needed for the system to meet the log-mean criterion is a 47% reduction in current bacteria loading.

The two curves on the plot indicate the maximum loads associated with recreational contact criteria, and represent the loading capacity of the stream. Bacteria loads that are plotted above these curves indicate loads in excess of the criteria. The curve also illustrates the types of flow regimes associated with violations. Violations on the right side of the graph occur during relatively common low flows, not associated with runoff. Those on the left side of the graph occur during uncommon high flows generally associated with rainfall and runoff events. The green horizontal lines represent the log mean of samples of the corresponding flow regime, and the associated numbers are the reductions necessary to meet the log-mean criterion. A negative number represents situations where the waterbody is meeting water quality standards.

Figure 10.26 Lower Long Tom River Load Duration Curve



Primary land use in the valley bottom is agriculture (58%), although urban land use is also represented downstream of agriculture. Water quality bacteria violations occur in and downstream of agriculture. The upland areas of the watershed are forest land (32%) with bacteria concentrations at or below water quality criteria. For this reason a 47% reduction calculated for the lower Long Tom has been assigned to agricultural and urban use (Table 10.26). Range and forest land are both assigned a 0% reduction.

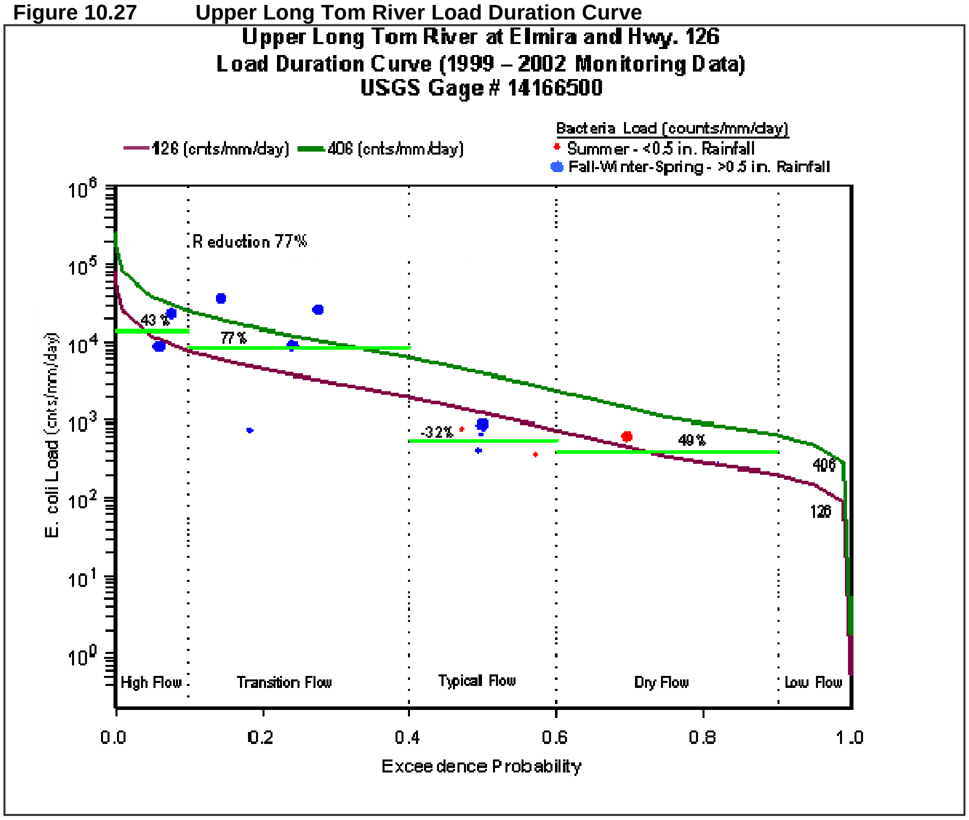
Table 10. 26 Land Use Based Percent Reduction for the Lower Long Tom Watershed

Land Use Category	Percentage of Land Use	Percent Reduction
Urban	8%	47%
Agriculture	58%	47%
Range	0%	0.0%
Forest	32%	0.0%

Upper Long Tom River Watershed

The load duration curve approach was chosen to develop the bacteria analysis for the Upper Long Tom River. The load duration curve for Upper Long Tom Watershed was developed using water quality monitoring data collected by the ODEQ, Long Tom Watershed Council and flow data from the USGS gage at Elmira and Highway 126 (Figure 10.27). ODEQ conducted water quality monitoring during an intensive survey in December 2002 at a site near the city of Elmira. The Council gathered data between 1999 and 2000 at a site located near Highway 126. The USGS stream flow gage at Elmira and Highway 126, near Noti, (gage #14166500) has been operational from 1935 to present. *E. coli* samples considered for this analysis were collected during a variety of weather and flow conditions during 1999 to 2002. Data reported as “estimate”, “less than” or “greater than” values were not considered. Points that plot above the 406 curve (dark green curve) represent deviations from the water quality criterion and the permissible loading function. Those plotting below the curve represent compliance with water quality criteria. The green lines represent the log mean of samples of the corresponding flow regime. Exceedences of the log-mean and maximum criteria occur between transitional flow and high flow regimes. The value in the dry flow regime only contains one sample and was not analyzed further because a log mean cannot be calculated with a single value. The maximum log mean based reduction for the system to meet the log-mean criterion is a 77% percent reduction.

Figure 10.27 Upper Long Tom River Load Duration Curve



Agriculture and urban development are the primary land uses in the valley bottom where a majority of violations occur. The upland areas of the watershed are forest land where bacteria concentrations generally meet the criteria. High bacteria levels at the Alderwood State Park site located near the headwater of the upper Long Tom River may be attributed to pets, wildlife, recreational use, or other sources associated with the state park, and are not representative of typical forest land use. Percent reductions of 77% have been calculated for the upper Long Tom and assigned to agricultural and urban use (Table 10.27).

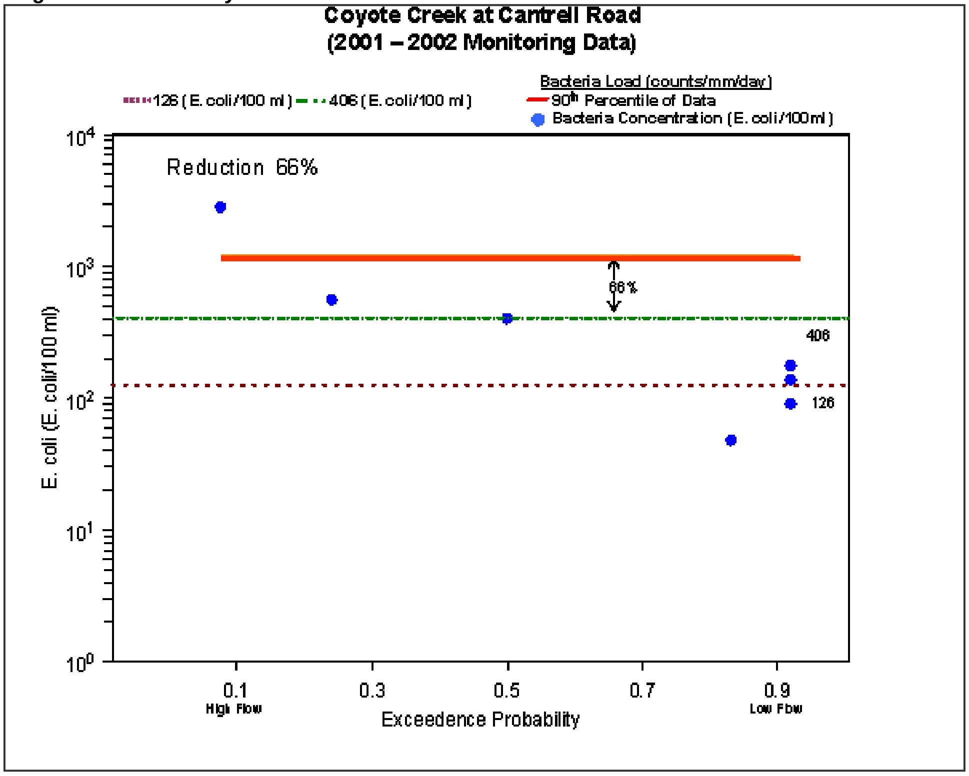
Table 10. 27 Land Use Based Percent Reduction for the Upper Long Tom Watershed

Land Use Categories	Percentage of Land Use	Percent Reduction
Urban	2%	77%
Agriculture	8%	77%
Range	0.0%	0.0%
Forest	89%	0.0%

Coyote Creek Watershed

The load duration curve approach was not appropriate for analysis of the Coyote Creek Watershed because the available bacteria data set did not represent all flow regimes. Therefore, a concentration based reduction was applied to the data at Coyote Creek at Cantrell Road, Figure 10.28. The allocated percent reduction for Coyote Creek is 66%. The data for Coyote Creek at Cantrell Road was collected by ODEQ and the Long Tom Watershed Council during 2001 and 2002. ODEQ conducted water quality monitoring during an intensive survey in December 2002 and the Council gathered data during the summer of 2001. The daily average flows used to develop the load duration curve for Coyote Creek were extrapolated from the USGS flow gage station on Long Tom River at Elmira and Highway 126, near Noti, based on methodology that Bruce Cleland established for the USEPA and America's Clean Water Foundation (www.acwf.org) for relating flow gages among similar watersheds. This modified flow data was used to calculate exceedance probabilities in the load duration curve below. An analysis of the flow data showed the exceedance probabilities to be statistically significant due to the similar characteristics between Long Tom River and Coyote Creek such as flow response, drainage area, and land use. Appendix A: Bacteria Technical Appendix, details the development of this modified flow duration curve. The flow exceedance probabilities were used as a means to graph the bacteria data for the concentration-based reductions in the exceedance probability graph, below, as a source of relating bacteria loads to flow regimes. This graph was developed for informational purposes and not as a means to determine flow based loading percent reductions. Points that plot above the 406 line (green dashed line) represent exceedances of the water quality standard. The red line represents the calculated 90th percentile of the data set. Violations of the single sample criterion occurred at high flows regimes, and concentrations during dry flows were generally below the criterion.

Figure 10.28 Coyote Creek 90th Percentile Concentration Based Percent Reduction



Agriculture is the primary land use, 12% of the land area, in the valley bottom where a majority of violations occur. The upland areas of the watershed are forestland, and bacteria concentrations meet bacteria criteria based on the available data. For this reason reductions calculated at 66% for Coyote Creek have been assigned to only agricultural and urban land uses, Table 10.28.

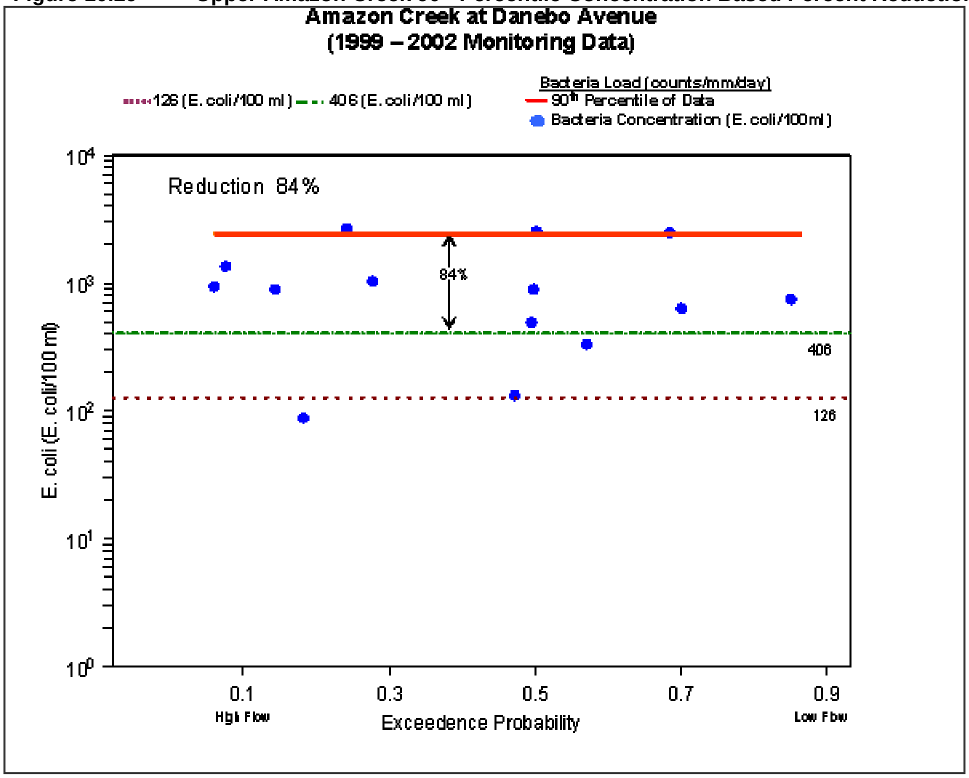
Table 10. 28 Land Use Based Percent Reduction for the Coyote Creek Watershed

Land Use Categories	Percentage of Land Use	Percent Reduction
Urban	3%	66%
Agriculture	12%	66%
Range	0.0%	0.00%
Forest	85%	0.00%

Upper Amazon Creek Watershed

The load duration curve approach was not appropriate for analysis of the Upper Amazon Creek Watershed because the available data set did not represent all flow regimes and flow data for the system was unavailable. Therefore, a concentration based reduction was applied to Upper Amazon Creek at Danebo Avenue, Figure 10.29. The bacteria data for Upper Amazon Creek at Danebo Avenue was analyzed with data collected by ODEQ and the Long Tom Watershed Council. ODEQ conducted water quality monitoring during an intensive survey in December 2002 and the Council collected bacteria data during 1999 and 2000. Analysis showed that an 84% reduction is necessary to meet water quality criteria. The daily average flows used to graph the load duration curve for upper Amazon Creek were the flows recorded for the USGS flow gage station on Long Tom River at Noti. This flow data was used to calculate exceedance probabilities in the load duration curve below. This load duration curve was used as means to graph the bacteria data for the concentration-based reductions in the exceedance probability graph, below. This graph was developed for informational purposes and not as a means to determine flow based loading percent reductions. Concentrations that plot above the single sample criterion (green dashed line) represent exceedances of the single sample criterion. The red line represents the 90th percentile of samples.

Figure 10.29 Upper Amazon Creek 90th Percentile Concentration Based Percent Reduction



Urban (59%) development is the primary land use upstream of the Danebo Avenue sampling site. The upland areas of the watershed are forest land, which are unlikely to be significant sources of bacteria. Upper Amazon Creek bacteria percent reductions of 84% have been assigned to urban land use, Table 10.29. Agricultural land use is downstream of the Danebo Avenue sampling site. The agricultural land use within the Upper Amazon Creek watershed is assigned a 58% reduction in bacteria loading as per the Upper Willamette Subbasin percent reduction calculated specifically for agricultural land use within the subbasin, see Upper Willamette Subbasin sub-section below in the Load Allocations section.

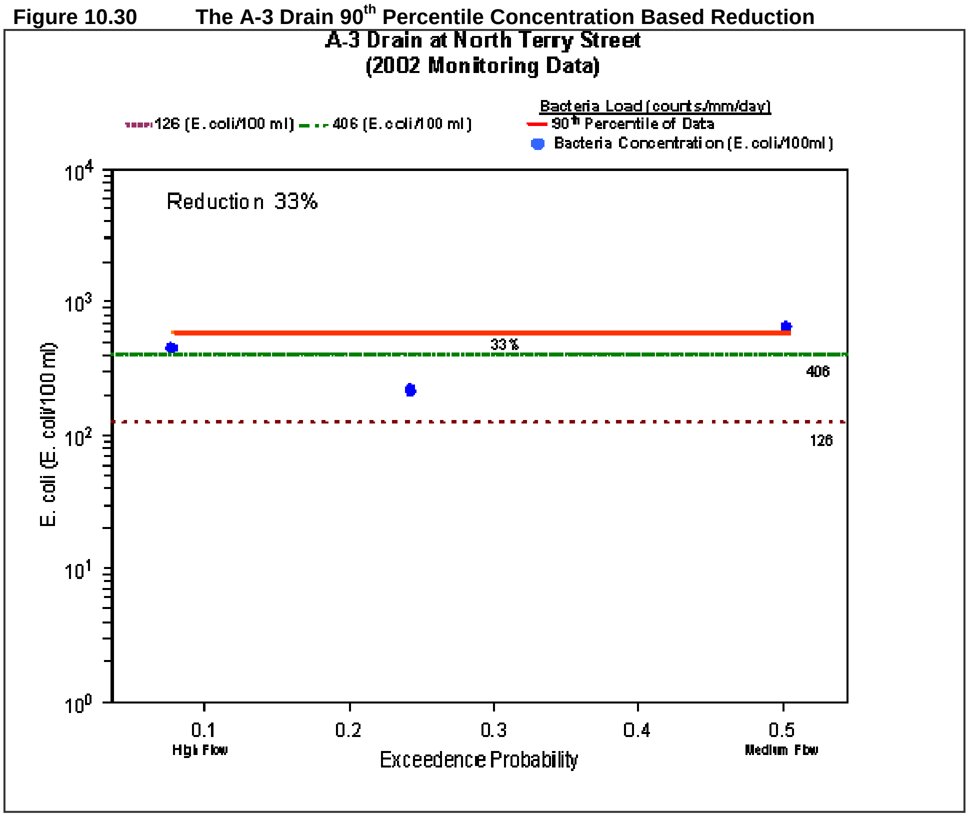
Table 10. 29 Land Use Based Percent Reduction for the Upper Amazon Creek Watershed

Land Use Categories	Percentage of Land Use	Percent Reduction
Urban	59%	84%
Agriculture	13%	58%
Range	0.0%	0.0%
Forest	28%	0.0%

The A-3 Drain Watershed

The load duration curve approach was not appropriate for analysis of the A-3 Drain Watershed because the available bacteria data did not represent all flow regimes and flow data for the system was unavailable. Therefore, a concentration-based reduction was applied to data collected at North Terry Street based on the 90th percentile of the data as it relates to the single sample criterion, Figure 10.30. The allocation for the A-3 Drain at North Terry Street was developed using water quality monitoring data collected by ODEQ during an intensive survey in December 2002. As calculated, bacteria concentrations must be reduced by 33%. The daily average flows used to graph the load duration curve for A-3 Drain were the flows recorded for the USGS flow gage station on Long Tom River at Noti. This flow data was used to calculate exceedance probabilities in the load duration curve below. This load duration curve was used as means to graph the bacteria data for the concentration-based reductions in the exceedance probability graph, below. This graph was developed for informational purposes and not as a means to determine flow based loading percent reductions. Concentrations that plot above the single sample criterion (green dashed line) represent exceedances of the single sample criterion. The red line represents the 90th percentile of samples.

Figure 10.30 The A-3 Drain 90th Percentile Concentration Based Reduction



There are only two land uses in the watershed, agricultural (41%) and urban (59%) development. Both of these land uses are considered contributors to the bacteria load observed. Bacteria percent reductions calculated for A-3 Drain have been assigned to both agricultural and urban land use at 33% (Table 10.30).

Table 10. 30 Land Use Based Percent Reduction for the A-3 Drain Watershed

Land Use Categories	Percentage of Land Use	Percent Reduction
Urban	59%	33%
Agriculture	41%	33%
Range	0.0%	0.0%
Forest	0.0%	0.0%

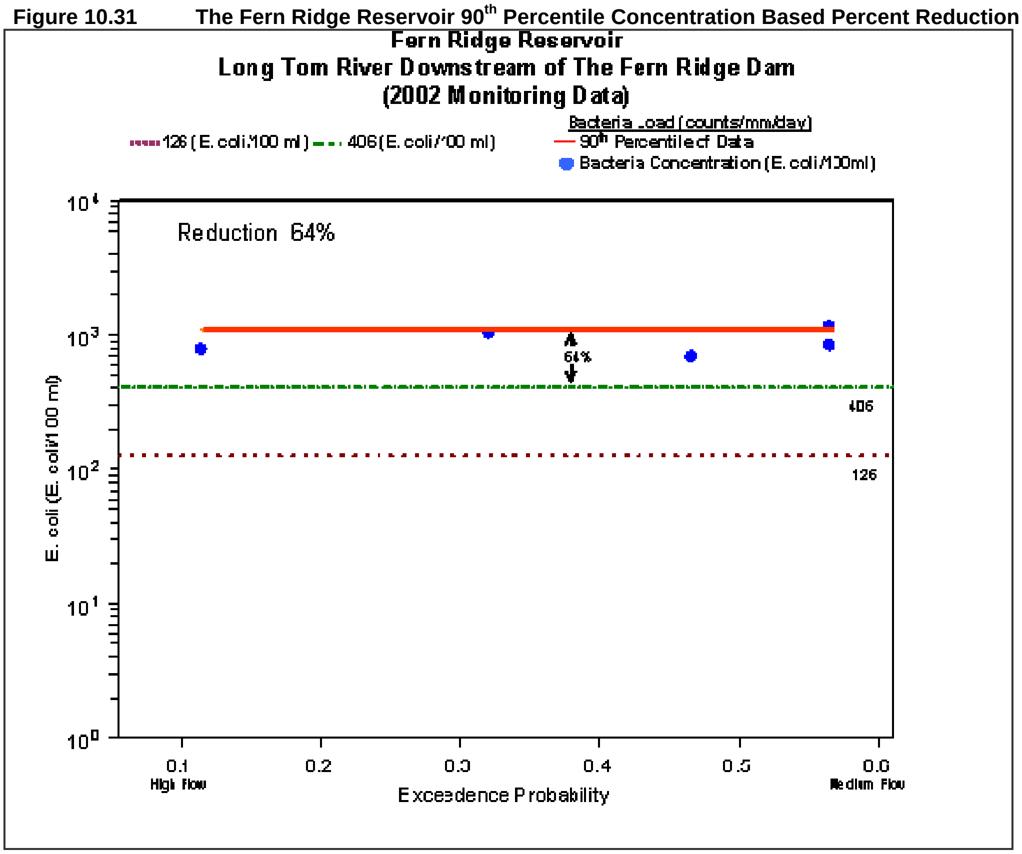
Fern Ridge Reservoir Watershed

The site that best represents bacteria levels in the Reservoir is the Long Tom River immediately down stream of the Fern Ridge Dam. However, the load duration curve approach was not appropriate for analysis of the Fern Ridge Reservoir because available data did not represent all flow regimes. The load duration curve approach requires collection of bacteria samples and stream flow data during multiple stream flow regimes, i.e. from lowest flow to highest flow. Therefore a concentration based reduction analysis was utilized for the Reservoir because subsets of data based on flow were not required. See the load duration analysis description in Appendix A: Bacteria Technical Appendix for detailed information on bacteria analysis.

The Long Tom River site is representative of bacteria concentrations in the Reservoir because the Reservoir discharges just upstream of this location and is the dominate influence at this site. In addition the site is located at the USGS stream flow gage near Alvadore, gage #14169000. The concentration based reduction analysis for Fern Ridge Reservoir was developed using water quality monitoring data collected by the ODEQ during an intensive storm event survey in December 2002. Flow data from the gage was used to calculate the flow exceedance probabilities in the graph below. This x-axis flow exceedence probability was developed as a means to graph the available data points and not as a means to determine flow based reductions as in load duration curve analysis.

Using concentration based reduction analysis the 90th percentile of the bacteria concentrations are calculated. Concentrations that plot above the 406 *E. coli* organisms per 100 milliliter single sample criterion (green dashed line) represent exceedances of the water quality criterion. The red line represents the 90th percentile of samples. A percent reduction is then determined that would lower the 90th percentile to the 406 criterion. Based on the analysis a 64% reduction in bacteria loading is allocated to meet the bacteria criterion in Fern Ridge Reservoir, Figure 10.31.

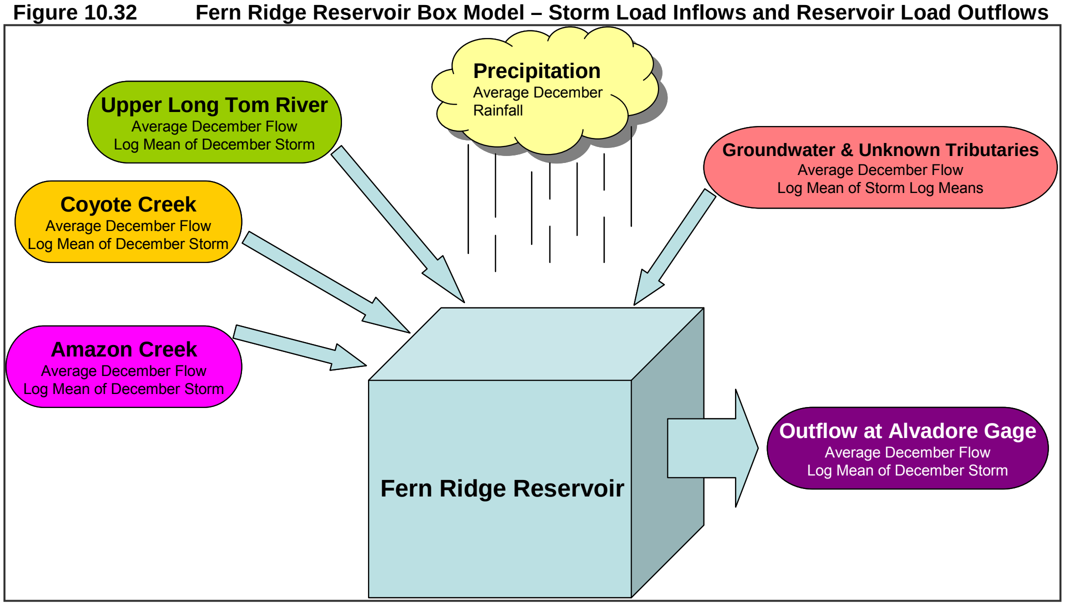
Figure 10.31 The Fern Ridge Reservoir 90th Percentile Concentration Based Percent Reduction



The Fern Ridge Reservoir system is much more complex than the river systems addressed previously in this document. To assess the sources that contribute bacteria leading to criterion exceedances in Fern Ridge Reservoir, a box model was used to represent the flow and bacteria concentrations typical of December conditions. Bacteria loads were calculated for each major tributary and other sources that contribute to the reservoir.

Bacteria data used in these calculations were collected in an ODEQ bacteria survey of the reservoir in December of 2002. The bacteria loads were based on flow calculated from the drainage area, and the average concentration of bacteria observed in the Upper Long Tom River, Upper Amazon Creek, and Coyote Creek. Over land runoff from average December precipitation was also included in the box model. The total bacteria load for the reservoir was estimated and compared to the load measured at the compliance point just below Fern Ridge Dam. Loads from unidentified sources were estimated by determining the difference between input and discharge loads. An illustration of the model assumptions are presented in Figure 10.32. Bacteria die-off was not included in the Box Model.

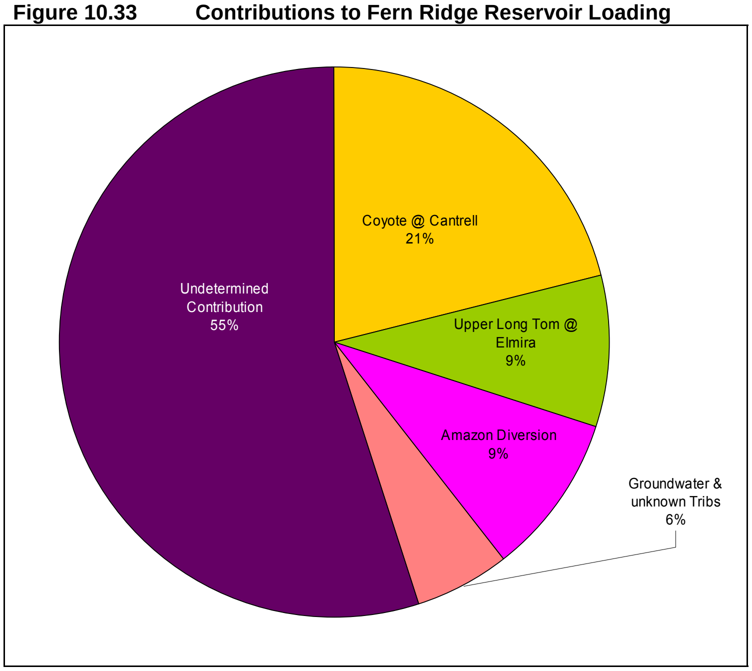
Figure 10.32 Fern Ridge Reservoir Box Model – Storm Load Inflows and Reservoir Load Outflows



Bacteria load analysis established that the load contributed to the Reservoir by the external inputs was less than half of the load at the discharge point of the Reservoir, as measured at the down stream compliance point on the Lower Long Tom River. The analysis suggests that Coyote Creek contributed 21%, Upper Long Tom 9%, Amazon Diversion 9%, groundwater and unknown tributaries contributed 9%, and undetermined contributors contributed 55% of the load discharging from the Reservoir (Figure 10.33).

The undetermined contributor sources can be attributed to direct inputs to the Reservoir. These sources may include wildlife waste originating from the management of the Fern Ridge Wildlife Refuge, pet wastes entering from the Fern Ridge Reservoir State Park through overland runoff, or failing septic systems leaching through soil and groundwater as the Reservoir level is lowered during the winter months. Additional information regarding model development is available in Appendix A: Bacteria Technical Appendix.

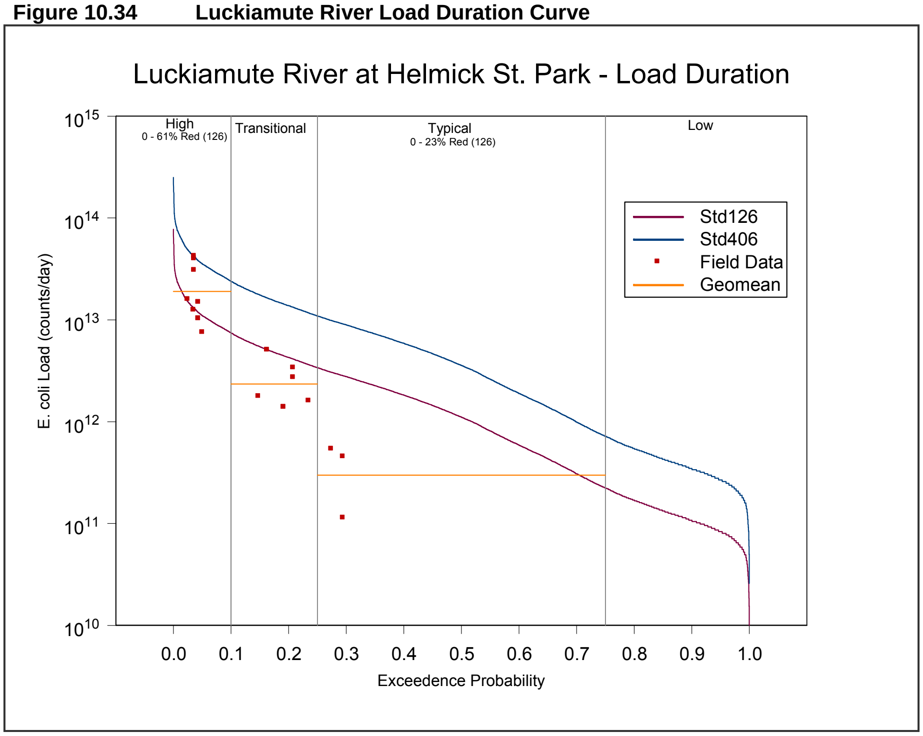
Figure 10.33 Contributions to Fern Ridge Reservoir Loading



Luckiamute River Watershed

The load duration curve methodology was applied to the Luckiamute River. It was not used, however, to determine percent reduction, but rather to describe the flow regimes associated with bacteria loading events and to highlight *E.coli* bacteria criteria curves. ODEQ collected samples at 22 sites over a 3-day storm survey in March 2002. This data was used with the load duration curve for the flow gage in Luckiamute River at Helmick State Park, near Suver (USGS Flow Gage #14190500). The load duration curve indicates concentrations exceeded criteria during high flow events typical of rain events, Figure 10.34.

Figure 10.34 Luckiamute River Load Duration Curve



A GIS-based model was used to evaluate the bacteria loading to the Luckiamute Watershed and determine percent reductions for the Luckiamute River. The model estimates upland runoff volume using the Soil Conservation Service (SCS) method and applies Event Mean Concentrations (EMCs) to estimate relative bacteria loading from the various land uses within the individual watersheds. Watershed composite maximum bacteria loads are then calculated to meet the state water quality criteria concentration.

SSURGO soils (slope and hydrologic soil group), land use (USGS) and watershed delineations were the geographic bases used for this modeling exercise. Each geographic database was overlaid in ArcView to create a composite GIS database that was used to estimate flow volume and bacteria die-off rate as a function of travel time and bacteria load.

Target loads that meet water quality criteria were calculated for urban, agriculture, forest, and range land uses. Load reductions were calculated for each land use with significant contribution to loading, particularly urban, agricultural and range land use area within the watersheds (Table 10.31). Land use delineation and percent within the watershed are as follows: Forest (68%), Agriculture (29%), Range (1%), Urban (1%), and Barren (<1%). Calculated percent reductions ranged from a 61% reduction for urban, 63% for agriculture, and a 5% reduction for forest land use as determined by the model. See Appendix A page 27 for further details regarding EMC model. The greatest load reductions are allocated to agriculture and urban development. These uses are prominent in the lower watershed, while forest land received a relatively small reduction, primarily to account for rural residential uses in the upland areas. As a conservative estimate a 63% reduction applies year round throughout the watershed and for all flow categories (as determined by the load duration curve above).

Table 10. 31 Luckiamute River Watershed Load Allocations

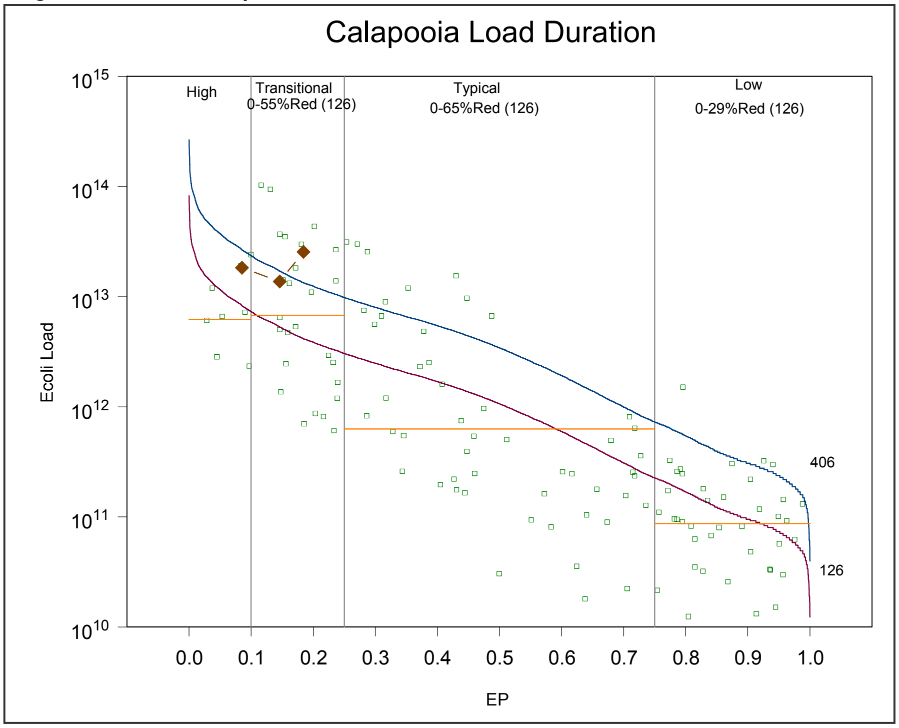
Landuse	Current Load	% Load	Load Allocation For 406 criterion	Percent Reduction For 406 criterion	Load Allocation For 126 criterion	Percent Reduction For 126 criterion
Urban	6.060×10^9	3.0%	5.626×10^9	6.0%	2.363×10^9	61.0%
Agriculture	1.826×10^{11}	95.0%	1.704×10^{11}	7.0%	7.123×10^{10}	63.0%
Range	5.301×10^6	0.0%	5.301×10^6	0.0%	5.301×10^6	0.0%
Forest	4.142×10^9	2.0%	3.954×10^9	5.0%	3.954×10^9	5.0%

Calapooia River Watershed

The EMC model and Load Duration Curve were also used to analyze bacteria loading in the Calapooia River Watershed. The USGS recorded daily flow records for Calapooia River at Albany, OR (USGS Flow Gage #14173500) from 1945 to 1981. In order to determine post 1981 flows on the Calapooia River, a relationship was developed between the Calapooia River at Albany (USGS Flow Gage #14173500) and the Mohawk River near Springfield (USGS Flow Gage #14165000) gages. Exceedence probabilities were compared for the common period of record between the two gages (1945 to 1981) (R^2= 0.96). The Mohawk River near Springfield (USGS Flow Gage #14165000) gage has been operational from 1935 to date. In order to plot bacteria data in the Calapooia River beyond 1981, exceedence probabilities from the Mohawk River near Springfield were used to estimate discharge data for the Calapooia River at the Albany gage. The Calapooia River Watershed Council monitored *E. coli* concentrations at seven stream locations from November 2002 through late April 2003. ODEQ collected samples at eight sites over a 3-day storm during an intensive survey in late January 2003.

The load duration curve for the Calapooia River at Albany indicates violations of the single sample criterion throughout the hydrograph (Figure 10.35). This data identifies a variety of sources that potentially are contributing to bacteria loading during runoff and non-runoff periods, and low and high flow regimes. A 65% reduction over all flow regimes has been calculated to bring the river into compliance with the criteria (orange lines).

Figure 10.35 Calapooia River Load Duration Curve. The connected Diamonds are the bacteria concentrations during a storm event in January 2003.



EP = Exceedance Probability

A GIS-based model was used to evaluate bacteria loading to the Calapooia Watershed. The model estimates upland runoff volume using the SCS method and applies Event Mean Concentrations to estimate relative bacteria loading from the various land uses within the individual watersheds. Watershed composite maximum bacteria loads are then calculated to meet the state water quality criterion concentration.

The calibrated hydrological model predicted loading rates in runoff from the urban, agriculture, and range land uses. Published EMC bacteria concentrations for forest land uses are relatively low (much lower than the instream water quality criteria). ODEQ verified this assumption by collecting data from upland forested drainage areas within the Calapooia Watershed which confirmed this assumption.

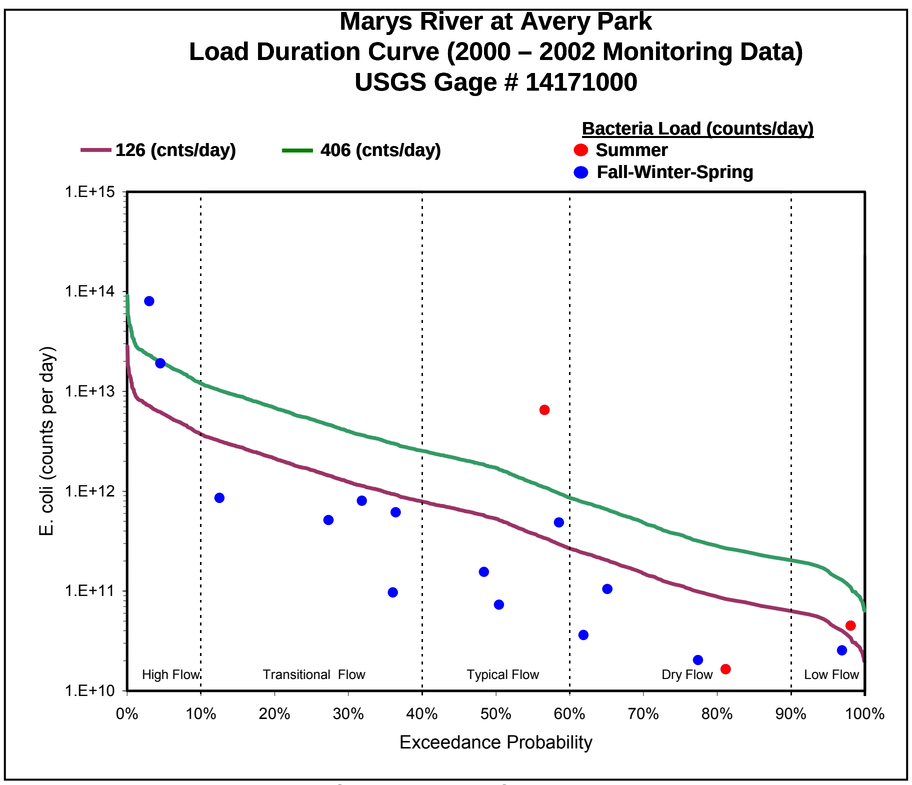
Target loads that meet the water quality maximum criterion were calculated for urban, agriculture, forest, and range land uses. Load reductions were calculated for each landuse with significant contribution to loading; particularly urban, agricultural and range land use area within the watersheds (Table 10.32). Land use delineation and percent within the watershed are as follows: Forest (50%), Agriculture (46%), Range (<1%), Urban (3%), and Barren (<1%). The greatest load reductions are allocated to agriculture, 65% reduction, and urban development, 65% reduction. These uses are prominent in the lower watershed, while forest and range land received a 0% reduction.

Table 10. 32 Calapooia River Watershed Load Allocations

Land use	Current Load	% Load	Load Allocation For 406 criterion	Percent Reduction For 406 criterion	Load Allocation For 126 criterion	Percent Reduction For 126 criterion
Urban	1.023E+10	11.3%	5.346E+09	47.8%	3.582E+09	65.0%
Agriculture	7.973E+10	88.0%	4.166E+10	47.8%	2.791E+10	65.0%
Range	7.214E+05	0.0%	7.214E+05	0.0%	7.214E+5	0.0%
Forest	5.945E+08	0.7%	5.945E+08	0.0%	5.945E+8	0.0%

Marys River Watershed

Figure 10.36 The Marys River Load Duration Curve. EP = Exceedance Probability



ODEQ used the load duration curve approach to analyze bacteria for the Marys River. The load duration curve for Marys River Watershed was developed using water quality data collected by the City of Corvallis at Avery Park in Corvallis. The analysis used flow data from the USGS flow gage (gage# 14171000) near the City of Philomath (Figure 10.36). E. coli data used in this analysis were collected during a variety of weather and flow conditions between 2000 and 2002. Concentrations of E. coli at Avery Park in Corvallis were usually below the 406 single sample water quality criterion with only two violations during the typical flow and high flow regimes. The violations were seen in one summer and one Fall-Winter-Spring sample out of a total of 19 samples analyzed. The one summer sample violating the 406 criterion was collected during an unusually high flow (>90% of summer flows) event and most likely reflects nonpoint source runoff. The Marys River meets the 126 log mean standard, which was adopted for the protection of human health. ODEQ is considering delisting of the Marys River in the 2004 303(d) list based on 30 samples from the ODEQs ambient monitoring site (LASAR 10373) with no violations of the bacteria standards between 1996 and 2003. Therefore an individual percent reduction will not be calculated for the Marys River. Instead, ODEQ will apply the Upper Willamette Subbasin generalized percent reductions calculated in the "Upper Willamette Subbasin Generalized Reductions" to address the criterion violations related to the Willamette mainstem. This ensures that practices are in place that will maintain good water quality in the future.

Reduction Summary

Bacterial Load Reductions calculated for meeting water quality criteria throughout the Upper Willamette Subbasin ranged from 33% in the A-3 Drain designated a mixed urban – agricultural land use watershed, to 84% in the Upper Amazon Creek Watershed an urban watershed (Table 10.33). In general, reductions should be applied on a land use specific basis, and only to the reach specified.

Table 10. 33 Summary of Percent Reductions of Bacteria for the Upper Willamette Subbasin

Reach	Watershed	Major Land Use	Bacteria % Reduction
Lower Long Tom River	Long Tom	Agriculture	47%
Upper Long Tom River	Long Tom	Ag. – Urban Mix	77%
Coyote Creek	Long Tom	Agriculture	66%
Upper Amazon Creek	Long Tom	Urban	84%
A-3 Drain	Long Tom	Ag. – Urban Mix	33%
Fern Ridge Reservoir	Long Tom	N/A	64%
Luckiamute River	Luckiamute	Agriculture	63%
Calapooia River	Calapooia	Agriculture	65%

Upper Willamette Subbasin Generalized Reductions

The Upper Willamette Subbasin generalized percent reductions apply to streams in watersheds not otherwise allocated in the analysis above. The generalized percent reductions for the Upper Willamette Subbasin for agricultural and urban land use were calculated based on an average of the reach specific land use bacteria percent reduction calculated above in this TMDL. The percent reduction calculated for each land use applies to stream reaches not otherwise analyzed in this TMDL on a year round basis. The percent reductions calculated for each land use are as follows: **58%** reduction for agriculture land use (Table 10.34) and **65%** reduction for urban land use (Table 10.35). Note that the percent reductions calculated for A-3 Drain and Upper Long Tom River were used to calculate the subbasin percent reduction for both agriculture and urban land use. This occurred because these reaches represent both land uses.

Table 10. 34 Upper Willamette Subbasin Generalized Agricultural Land Use Percent Reduction

Reach	Watershed	Major Land Use	Bacteria % Reduction
Lower Long Tom River	Long Tom	Agriculture	47%
Upper Long Tom River	Long Tom	Ag. – Urban Mix	77%
Coyote Creek	Long Tom	Agriculture	66%
A-3 Drain	Long Tom	Ag. – Urban Mix	33%
Luckiamute River	Luckiamute	Agriculture	62%
Calapooia River	Calapooia	Agriculture	65%
		Agriculture Percent Reduction Average	**58%**

Table 10. 35 Upper Willamette Subbasin Generalized Urban Land Use Percent Reduction

Reach	Watershed	Major Land Use	Bacteria % Reduction
Upper Long Tom River	Long Tom	Ag. – Urban Mix	77%
Upper Amazon Creek	Long Tom	Urban	84%
A-3 Drain	Long Tom	Ag. – Urban Mix	33%
		Urban Percent Reduction Average	**65%**

Excess Load

OAR 340-042-0040(4)(h)

Since wasteload allocations for point sources were not directly calculated, and a limited number of load allocations were calculated, only for Calapooia and Luckiamute rivers, it is not possible to provide a quantitative estimate of excess load. Qualitatively, in-stream measurements of *E. coli* concentrations are well above the numeric criteria. The use of percent reductions directly addresses the excess loads through the surrogate in-stream concentration. At present, there is no indication that point source discharges are violating the terms of their NPDES permits, which would result in an excess load.

Surrogate Measures

OAR 340-042-0040(5)(b), 40 CFR 130.2(i)

This TMDL allocates "*other appropriate measures*" (or surrogates measures) as provided under USEPA regulations [40 CFR 130.2(i)]. The Upper Willamette Subbasin bacteria TMDL incorporates measures other than "*daily loads*" to fulfill requirements of §303(d). Allocations are in terms of percent reduction in in-stream concentrations needed to achieve the numeric criterion for protection of recreational contact; a log-mean of 126 *E. coli* counts/100 mL. Percent reductions are calculated by land use for each 303(d) bacteria listed stream and for all other streams in the subbasin. The calculated percent reduction at each in-stream analysis point translates load allocations into more applicable measures of performance, a percent reduction of in-stream bacteria counts.

Margins of Safety

OAR 340-042-0040(4)(i), CWA 303(d)(1)

The margin of safety applied to the bacteria TMDL for the Upper Willamette Subbasin is implicit in assumptions made about the surrogate measure, percent reduction. The margin of safety is applied through the conservative calculation of the 90^{th} percentile and log mean to compare to the 126 *E. coli* counts / 100 mL log mean criteria. The 90^{th} percentile values were generally equal to or greater than the log mean values of the same data sets. The use of this "overestimation" of the log mean for purposes of defining percent reductions results in a slight overestimation of the needed reduction, giving an appropriate margin of safety to protect against under estimation of the mean.

Reserve Capacity

OAR 340-042-0040(4)(k)

No reserve capacity is allotted at this time for bacteria in Upper Willamette Subbasin water bodies. Future permitted sources of bacteria will be required to meet the water quality criteria or 126 *E. coli* counts/100 ml as a log mean and no sample greater than 406 *E. coli* counts/100ml, the single sample criterion.

DISSOLVED OXYGEN TMDL: AMAZON DIVERSION CHANNEL AND COYOTE CREEK

Water Quality Summary

Amazon Creek Diversion Channel and Coyote Creek both fail to meet minimum water quality standards for dissolved oxygen. The streams are located in Lane County and provide water for Fern Ridge Reservoir, a popular lake for swimming, fishing, and other recreation. The streams experience low dissolved oxygen levels due to pollutant loads and habitat degradation, high bacteria levels, and excessive loads of suspended solids which contribute to turbidity problems in the lake.

Because of the dissolved oxygen concerns, the streams are included on the 303(d) List of water bodies that do not meet water quality standards for dissolved oxygen. This document describes “total maximum daily loads (TMDLs)” for pollutants which contribute to dissolved oxygen standard violations in the streams, Table 10.36.

Amazon and Coyote Creek Watersheds

The Upper Amazon Creek Watershed drains 31 square miles, much of which is within the city of Eugene (Thieman, 2000). The major land uses are urban and rural residential. The stream channel has been significantly altered from its natural condition. In Eugene, it has been channelized, riprapped, and cemented in many sections, with most of the natural vegetation removed. Downstream of Eugene, most of the stream flow is diverted to Fern Ridge Reservoir through the Amazon Diversion Channel, a manmade channel, to provide a source of water for the lake.

The Coyote Creek Watershed drains 104 square miles of land (Thieman, 2000). Land use in the watershed is a mixture of forestry, agriculture, and rural residential, although most of the watershed is still zoned for forestry. The watershed has many impoundments, many of which are small agricultural impoundments used for livestock watering, fishponds or unspecified domestic use. The watershed has been degraded due to removal of trees from once densely forested riparian areas and, consequently, less shade and large woody debris is available for the streams.

Table 10. 36 Dissolved Oxygen TMDL components

Waterbodies **OAR 340-042-0040(4)(a)**	Amazon Creek Diversion Channel, mouth to headwaters, (HUC 17090003 2146, Segment ID 22E-ACDC0) Amazon Creek, Amazon Diversion Channel diversion to headwaters (HUC 17090003 0051) Coyote Creek, mouth to headwaters (HUC 17090003 0050, Segment ID 22E-COYO0)
Pollutant Identification **OAR 340-042-0040(4)(b)**	<u>Pollutants</u> Pollutants that directly exert an oxygen demand including ammonia, volatile suspended solids, and carbonaceous biochemical oxygen demand (BOD); nutrients that stimulate excessive algal growth including nitrogen and phosphorus; and solar radiation.
Beneficial Uses **OAR 340-042-0040(4)(c)** **OAR 340-041**	Salmonid fish rearing (trout), resident fish and aquatic life, and fishing.
Target Identification **OAR 340-042-0040(4)(c)** **OAR 340-041-0016(1)** **OAR 340-041-0033** ***CWA §303(d)(1)***	OAR 340, Division 41 provides numeric dissolved oxygen criteria: OAR 340-041-0016(1) (IN PART) (b) For water bodies identified by the Department as providing cold-water aquatic life, the dissolved oxygen may not be less than 8.0 mg/l as an absolute minimum. Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 8.0 mg/l, dissolved oxygen may not be less than 90 percent of saturation. At the discretion of the Department, when the Department determines that adequate information exists, the dissolved oxygen may not fall below 8.0 mg/l as a 30-day mean minimum, 6.5 mg/l as a seven-day minimum mean, and may not fall below 6.0 mg/l as an absolute minimum (Table 21); (c) For water bodies identified by the Department as providing cool-water aquatic life, the dissolved oxygen may not be less than 6.5 mg/l as an absolute minimum. At the discretion of the Department, when the Department determines that adequate information exists, the dissolved oxygen may not fall below 6.5 mg/l as a 30-day mean minimum, 5.0 mg/l as a seven-day minimum mean, and may not fall below 4.0 mg/l as an absolute minimum (Table 21). OAR 340, Division 41 also provides criteria relevant to ammonia toxicity: OAR 340-041-033 (IN PART) (2) Levels of toxic substances may not exceed the criteria listed in Table 20 which were based on criteria established by USEPA and published in Quality Criteria for Water (1986), unless otherwise noted.
Existing Sources **OAR 340-042-0040(4)(f)** ***CWA §303(d)(1)***	Multiple point and nonpoint sources during runoff and non-runoff events, including urban storm water discharge and agricultural run-off, and excessive inputs of solar radiation because of the removal or reduction of stream side vegetation.
Seasonal Variation **OAR 340-042-0040(4)(j)** ***CWA §303(d)(1)***	DO standard violations occur from May 1 to October 31. Effective shade targets and load allocations will reduce temperatures and insure that DO standards are met in all seasons.
TMDL **Loading Capacity and Allocations** **OAR 340-042-0040(4)(d)** **OAR 340-042-0040(4)(e)** **OAR 340-042-0040(4)(g)** **OAR 340-042-0040(4)(h)** ***40 CFR 130.2(f)*** ***40 CFR 130.2(g)*** ***40 CFR 130.2(h)***	<u>*Loading Capacity:*</u> For Amazon Creek and Diversion Channel the loading capacity for BOD, nutrients and volatile suspended solids correspond to a 30-40% reduction in oxygen demanding loads. The overall average loading capacity for solar radiation is 421 Ly/day, which corresponds to an overall average effective shade of 33%. For Coyote Creek the loading capacity for ammonia corresponds to an in-stream concentration 0.8 mg/L as N. The loading capacity for other oxygen demanding loads corresponds to current levels. The overall average loading capacity for solar radiation is 248 Ly/day, which corresponds to an overall average effective shade of 63%. <u>*Load Allocations (All Sources):*</u> For Amazon Creek and Diversion Channel load allocations correspond to a 40% reduction in oxygen demanding loads. The overall average load allocation for solar radiation is 421 Ly/day, which corresponds to an overall average effective shade of 33%. For Coyote Creek load allocations for oxygen demanding loads correspond to a 20% reduction in loads and an in-stream concentration of total ammonia of 0.8 mg/L as N. The overall average load allocation for solar radiation is 248 Ly/day, which corresponds to an overall average effective shade of 63%. <u>*Excess Load:*</u> For Amazon Creek and Diversion Channel, the excess load of solar radiation is 115 Ly/day. The excess loads of BOD, nutrients and SOD equal 40% of current levels. For Coyote Creek, the excess load of solar radiation is 157 Ly/day. The excess loads of BOD, nutrients, and SOD range from zero to 20% of current levels.
Surrogate Measures **OAR 340-042-0040(5)(b)** ***40 CFR 130.2(i)***	<u>*Translates Nonpoint Source Load Allocations*</u> Pollutants which contribute to dissolved oxygen violations include BOD, ammonia, nutrients, volatile solids which settle and contribute to SOD, and excess solar radiation (which, by increasing stream temperature reduces DO concentrations). These pollutants are surrogates for DO. However, future determinations regarding compliance with the water quality standard will be based on dissolved oxygen concentrations.

Margins of Safety **OAR 340-042-0040(4)(i)** ***CWA §303(d)(1)***	*Margins of Safety* Amazon Creek and Diversion Channel load allocations provide for margins of safety by: 1. Targeting cool-water rather than warm-water DO standards, 2. Targeting a minimum DO concentration of 5.0 mg/L (rather than 4.0 mg/L), 3. Basing load allocations for BOD, nutrients and volatile suspended solids loads on loads needed to meet standards for a likely (SysPotC) system potential shade condition, and 4. Setting the required load reductions to 40%, which is the upper range of required load reductions based on the loading capacity of the stream. Coyote Creek load allocations provide for margins of safety by: 1. Targeting cold-water rather than cool-water DO standards, 2. Targeting a minimum DO concentration of 6.5 mg/L (rather than 6.0 mg/L). 3. Providing an explicit 20% MOS for ammonia, BOD and other parameters
Reserve Capacity **OAR 340-042-0040(4)(k)**	*Reserve capacity* provides allocations for increases in pollutant loads from future growth and new or expanded sources. No reserve capacity has explicitly been provided for in the TMDL. However, the conservative margins-of-safety applied in establishing load allocations may allow capacity for future loads after the load allocations have been met.
Water Quality Management Plan **OAR 340-042-0040(4)(l)** ***CWA §303(d)(1)***	*The Water Quality Management Plan (WQMP)* provides the framework of management strategies to attain and maintain water quality standards. The framework is designed to work in conjunction with detailed plans and analyses provided in sector-specific or source-specific implementation plans. The WQMP which pertains to this TMDL is the Upper Willamette Subbasin WQMP.
Standard Attainment & Reasonable Assurance **OAR 340-042-0040(4)(l)**	Standard Attainment and Reasonable Assurance is discussed in the WQMP, Chapter 14.

Beneficial Use Identification

Beneficial uses of water in the Upper Willamette Subbasin, designated in OAR 340-041-0340 (Table 340A), include fisheries, aquatic life, drinking water, recreation and irrigation.

The designated fish use for Amazon Creek, Amazon Creek Diversion Channel, and Coyote Creek is "salmon and trout rearing and migration" (including salmon species, steelhead, rainbow, and cutthroat trout) (OAR 340-041, Figure 340A). Neither stream is designated as "core cold-water habitat" or for bull trout. In addition, neither stream has been identified by the Oregon Department of Fish and Wildlife as supporting spring or fall Chinook salmon or winter steelhead populations.

The designated fish use for the Long Tom River below Fern Ridge Reservoir is "cool water species (no salmonid use)" (OAR 340-041, Figure 340A).

"Salmon and steelhead spawning" is not a designated use for the Fern Ridge Reservoir, the Long Tom River below Fern Ridge Reservoir, or associated tributaries including Coyote Creek and Amazon Creek and Diversion Channel
(OAR 340-041, Figure 340B).

Relevant definitions:

> *"Cold-Water Aquatic Life" means aquatic organisms that are physiologically restricted to cold water, including but not limited to native salmon, steelhead, mountain whitefish, char (including bull trout), and trout (340-04l-0002 (9)).*
>
> *"Cool-Water Aquatic Life" means aquatic organisms that are physiologically restricted to cool waters, including but not limited to native sturgeon, pacific lamprey, suckers, chub, sculpins and certain species of cyprinids (minnows) (340-04l-0002 (12)).*
>
> *"Core Cold Water Habitat Use" means waters that are expected to maintain temperatures within the range generally considered optimal for salmon and steelhead rearing, or that are suitable for bull trout migration, foraging and sub-adult rearing that occurs during the summer (340-04l-0002 (12)).*

Applicable Standards for Dissolved Oxygen

Oregon Administrative Rules provide standards for dissolved oxygen, as follows (340-041-0016):

> *(1) Dissolved oxygen (DO): No wastes may be discharged and no activities must be conducted that either alone or in combination with other wastes or activities will cause violation of the following standards: The changes adopted by the Commission on January 11, 1996, become effective July 1, 1996. Until that time, the requirements of this rule that were in effect on January 10, 1996, apply:*
>
> *(a) For water bodies identified as active spawning areas in the places and times indicated on the following Tables and Figures set out in OAR 340-041-0101 to OAR 340-041-0340: Tables 101B, 121B, 180B, 201B and 260B, and Figures 130B, 151B, 160B, 170B, 220B, 230B, 271B, 286B, 300B, 310B, 320B, and 340B, (as well as any active spawning area used by resident trout species), the following criteria apply during the applicable spawning through fry emergence periods set forth in the tables and figures:*
> *(A) The dissolved oxygen may not be less than 11.0 mg/l. However, if the minimum intergravel dissolved oxygen, measured as a spatial median, is 8.0 mg/l or greater, then the DO criterion is 9.0 mg/l;*
> *(B) Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 11.0 mg/l or 9.0 mg/l criteria, dissolved oxygen levels must not be less than 95 percent of saturation;*
> *(C) The spatial median intergravel dissolved oxygen concentration must not fall below 8.0 mg/l.*
>
> *(b) For water bodies identified by the Department as providing cold-water aquatic life, the dissolved oxygen may not be less than 8.0 mg/l as an absolute minimum. Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 8.0 mg/l, dissolved oxygen may not be less than 90 percent of saturation. At the discretion of the Department, when the Department determines that adequate information exists, the dissolved oxygen may not fall below 8.0 mg/l as a 30-day mean minimum, 6.5 mg/l as a seven-day minimum mean, and may not fall below 6.0 mg/l as an absolute minimum (Table 21);*
>
> *(c) For water bodies identified by the Department as providing cool-water aquatic life, the dissolved oxygen may not be less than 6.5 mg/l as an absolute minimum. At the discretion of the Department, when the Department determines that adequate information exists, the dissolved oxygen may not fall below 6.5 mg/l as a 30-day mean minimum, 5.0 mg/l as a seven-day minimum mean, and may not fall below 4.0 mg/l as an absolute minimum (Table 21);*
>
> *(d) For water bodies identified by the Department as providing warm-water aquatic life, the dissolved oxygen may not be less than 5.5 mg/l as an absolute minimum. At the discretion of the Department, when the Department determines that adequate information exists, the dissolved oxygen may not fall below 5.5 mg/l as a 30-day mean minimum, and may not fall below 4.0 mg/l as an absolute minimum (Table 21); (340-041-0016)*

Relevant definitions are as follows (340-04l-0002)

> *(15) "Daily Mean" (dissolved oxygen) means the numeric average of an adequate number of data to describe the variation in dissolved oxygen concentration throughout a day, including daily maximums and minimums. For the purpose of calculating the mean, concentrations in excess of 100 percent of saturation are valued at the saturation concentration.*
>
> *(32) "Minimum" (dissolved oxygen) means the minimum recorded concentration including seasonal and diurnal minimums*
>
> *(33) "Monthly (30-day) Mean Minimum" (dissolved oxygen) means the minimum of the 30 consecutive day floating averages of the calculated daily mean dissolved oxygen concentration.*

(65) "Weekly (seven-day) Mean Minimum" (dissolved oxygen) means the minimum of the seven consecutive day floating average of the calculated daily mean dissolved oxygen concentration.

(66) "Weekly (seven-day) Minimum Mean" (dissolved oxygen) means the minimum of the seven consecutive day floating average of the daily minimum concentration. For purposes of application of the criteria, this value will be used as the reference for diurnal minimums.

OAR 340-041 Table 21 summarizes the dissolved oxygen standards. Portions of Table 21 potentially relevant to Amazon and Coyote Creeks are presented in Table 10.37.

Table 10. 37 OAR Table 21 - Dissolved Oxygen Criteria - relevant portions

Class	Use/Level of Protection			
	30-D	7-Mi	Min	
Cold Water	8.0[6]	6.5	6.0	Principally cold-water aquatic life. Salmon, trout, cold-water invertebrates, and other native cold-water species exist throughout all or most of the year. Juvenile anadromous salmonids may rear throughout the year. No measurable risk level for these communities
Cool Water	6.5	5.0	4.0	Mixed native cool-water aquatic life, such as sculpins, smelt, and lampreys. Waterbodies includes estuaries. Salmonids and other cold-water biota may be present during part or all of the year but do not form a dominant component of the community structure. No measurable risk to cool-water species, slight risk to cold-water species present.
Warm Water	5.5		4.0	Waterbodies whose aquatic life beneficial uses are characterized by introduced, or native, warm-water species

303(d) Listing

The listed dissolved oxygen reaches, Amazon Creek Diversion Channel and Coyote Creek, are shown in Table 10.38, Map 10.18. Shown also are water quality monitoring and major land use categories.

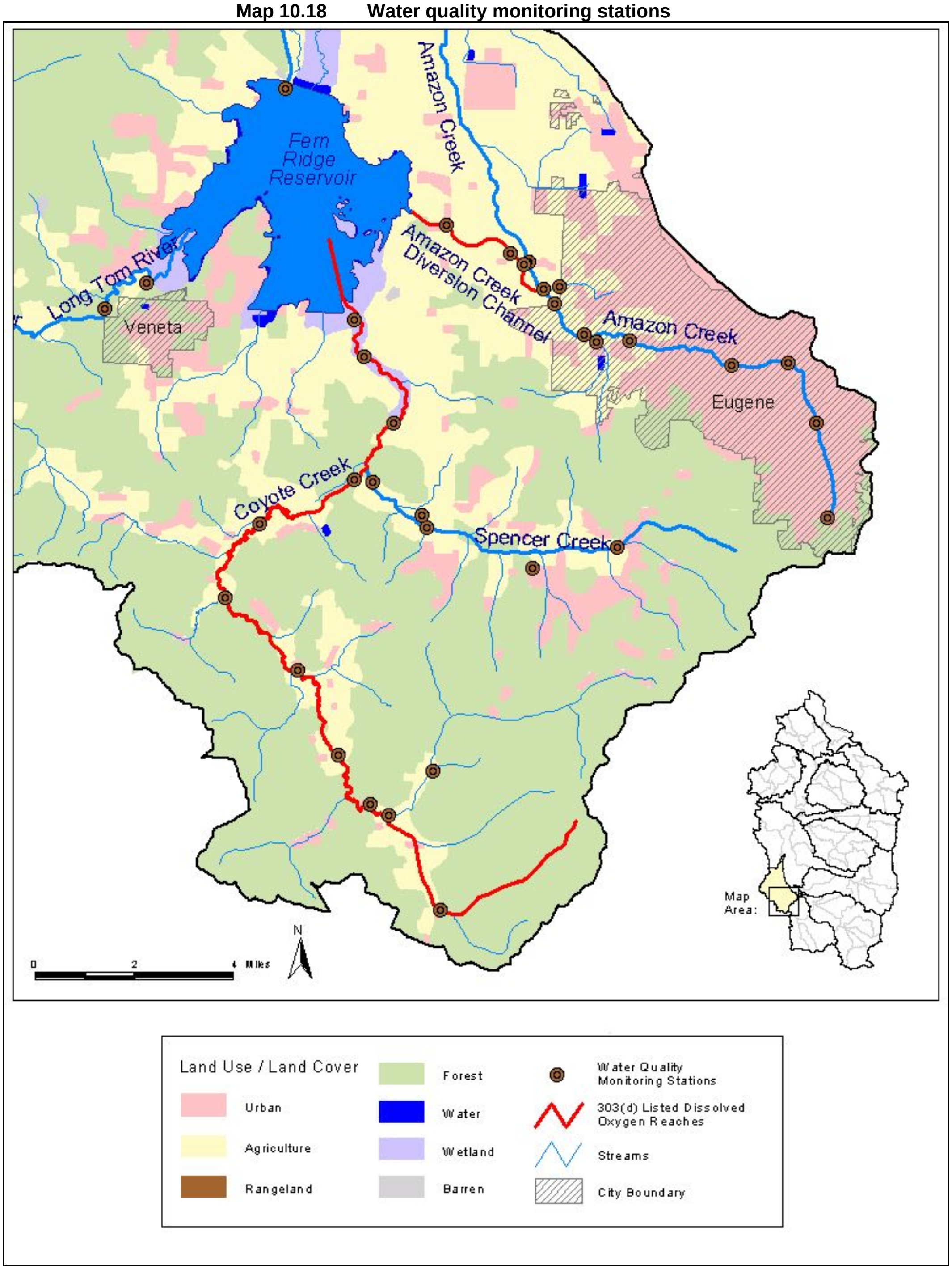
The listings are based on Lane Council of Governments (LCOG) data. All dissolved oxygen listings are based on violation of the cool-water criteria: with 6.5 mg/L as an absolute minimum. The reaches were added to the 303(d) List because greater than 10 percent of the samples did not meet the standard, with at least two exceedances of the standard for the season of interest.

Table 10. 38 Basis for 303(d) listings

Waterbody	303(d) Listed Reach	Season	Supporting Data
Amazon Creek Diversion Channel	Mouth to Headwaters	May 1 - October 31	LCOG Data (Site AM-RO, at Royal Ave, 314LCOG001): 60% (6 of 10) Summer values exceeded dissolved oxygen standard (6.5 mg/l) with a minimum of 3.9 mg/l between 1981 - 1984 (Cool water fishery, annual).
Amazon Creek	RM 12.2 to 21.9	May 1 - October 31	LCOG Data (Upper Amazon Creek at Royal Ave (2.7 miles u/s Lake) and Amazon Creek at Fir Butte Rd (0.8 miles u/s Lake) frequency of exceeding the 6.5 mg/L is 37%.
Coyote Creek	Mouth to Headwaters	May 1 - October 31	LCOG Data (Site CO-CN, at Cantrell Rd, 314LCOG002): 38% (3 of 8) May-October values exceeded dissolved oxygen standard (6.5 mg/l) with a minimum of 3.5 mg/l between 1981 - 1984 (Cool water fishery, annual).

A review of historic data was performed to determine whether the dissolved oxygen (DO) listings are appropriate and whether any additional reaches should also be listed. Historic monitoring stations are shown in Map 10.18.

Map 10.18 Water quality monitoring stations



Review of Historic Data

Amazon Creek and Diversion Channel

The Amazon Creek Diversion Channel is listed (based on Lane Council of Governments data). Amazon Creek, however, is not currently listed.

Data collected by the City of Eugene from 1996 to 1998 for upper Amazon Creek is presented in a report prepared by the Long Tom Watershed Council (Thieman 2000). The station Upper Amazon Creek at 29th Ave is located furthest upstream (10.9 miles upstream from Fern Ridge Reservoir) and receives runoff from residential areas and forest lands of south Eugene (Map 10.18 and Table 10.39). This station did not show DO standard violations.

Table 10. 39 City of Eugene Dissolved Oxygen Data - 1996-1998

Station	N	Range	Mean	Median	Frequency < 6.5 mg/L
Upper Amazon Creek at 29th Ave (10.9 miles above Fern Ridge Reservoir)	16	7 – 12.4	9.4	8.7	0%
Upper Amazon Creek at Royal Ave (2.7 miles u/s Reservoir) and Amazon Creek at Fir Butte Rd (0.8 miles u/s Reservoir) (2 stations,)	99	3.1-13.8	7.7	7.3	37%

Upper Amazon Creek stations at Royal Ave and Fir Butte Rd are located downstream of Eugene (2.7 and 0.8 miles above Fern Ridge Reservoir, respectively) and receive runoff from industrial areas as well as commercial and residential areas. DO concentrations frequently violate the standard at these stations. Note that the data from stations at Royal Avenue and Fir Butte Road was combined in the LTWC report (Thieman, 2000), apparently because the stations are relatively close together. Based on this data, Amazon Creek is violating dissolved oxygen standards with a sufficient frequency to warrant listing. Because of this, load allocations will be developed to address Amazon Creek from headwaters (RM 21.9) to the confluence with the Amazon Creek Diversion Channel (RM 12.2) in addition to Amazon Creek Diversion Channel.

Data for other parameters at Upper Amazon Creek at 29th Avenue and at Royal Ave. and Fir Butte Rd is presented in Table 10.40 and Table 10.41 (Thieman 2000).

Table 10. 40 Additional Data - Amazon Creek at 29th Ave

	Temp (°C)	DO (mg/L)	pH	TP (µg/L)	NO_3N (µg/L)
n	16	16	16	16	16
Range	4.2 – 21.7	7 – 12.4	5.8 – 9.4	20 – 290	75 – 660
Mean	12.9	9.4	7.5	110	330
Median	12.2	8.7	7.7	90	330

Table 10. 41 Additional Parameters of Concern - Amazon Creek at Royal Ave./ Fir Butte Rd

	Temp (°C)	DO (mg/L)	pH	TP (µg/L)	NO_3N (µg/L)
n	98	99	99	69	35
Range	3.2 – 27.4	3.1 – 13.8	6.2 – 8.4	20 – 780	20 – 1,300
Mean	15.7	7.7	7.35	140	370
Median	15.2	7.3	7.4	120	300

The data indicate that temperature is also a problem. 19% of the temperature measurements at 29th Ave and 42% at Royal Ave./ Fir Butte Rd exceeded 17.8°C. The high temperatures in Amazon Creek probably contribute to the suppressed dissolved oxygen levels in the stream. Note that Amazon Creek is not included on the 303(d) list for temperature. Based on the City of Eugene data, consideration should be given to listing it for temperature, in addition to dissolved oxygen, if salmonid fish species are found to be present. Note, however, that salmonids do not appear to be present in either Amazon Creek or Amazon Creek Diversion Channel.

pH is also a parameter of concern, although the streams are not included on the 303(d) list for pH standards violations. For pH, the OAR specifies that fresh water pH values shall not fall outside the range 6.5 - 8.5. Occasional pH values outside of the allowable range have been observed in Amazon Creek.

Coyote Creek

Data collected by the U.S. Army Corps of Engineers (USACE) shows continuing standard violations (Table 10.42; Thieman, 2000). This data indicates that the 303(d) listing for dissolved oxygen is appropriate.

Table 10. 42 USACE DO Data - 1996-1998 (Thieman 2000)

Station	N	Range	Mean	Median	Frequency < 6.5 mg/L

Coyote Creek at Petzold Road (5.3 mi. u/s Fern Ridge Lake)	59	3.4 - 13.5	8.6	8.4	20%
Coyote Creek at Cantrell Road (1.5 mi. u/s Fern Ridge Lake)	59	3.7 – 14	8.5	8.0	20%

Other USACE data relevant to dissolved oxygen is presented in Table 10.43 and Table 10.44. As shown, temperature is also a problem for Coyote Creek. 25% of the temperature measurements at Petzold Road and 34% at Cantrell Road exceeded 17.8°C. The high temperatures in Coyote Creek probably contribute to the suppressed dissolved oxygen levels in the stream. Note that Coyote Creek is not included on the 303(d) list for temperature. Based on the USACE data, consideration should be given to listing it for temperature, in addition to dissolved oxygen.

Table 10. 43 Other parameters of interest at Coyote Creek at Petzold Road

	Temp (°C)	DO (mg/L)	pH	TP (μg/L)
n	59	59	59	22
Range	5 – 22.8	3.4 - 13.5	6.9 – 8.0	0 – 170
Mean	13.6	8.6	7.4	80
Median	12.6	8.4	7.5	80

Table 10. 44 Other parameters of interest at Coyote Creek at Cantrell Road

	Temp (°C)	DO (mg/L)	pH	TP (μg/L)
n	59	47	46	16
Range	4 – 26.9	5.5 – 14.1	6.9 – 8.3	0 – 220
Mean	12.5	9.5	7.5	90
Median	11.5	9.7	7.5	60

No pH values outside of the allowable range have been observed in Coyote Creek.

Dissolved Oxygen Targets

The dissolved oxygen standards are complex relative to other standards and require that the applicable class of the water body (cold water, cool water, etc.) be established to determine the applicable set of standards.

Amazon Creek Targets

Amazon Creek and the Amazon Diversion Channel appear to contain few, if any, cold-water species, even though the designated fish use for Amazon Creek and the Diversion Channel is "salmon and trout rearing and migration" (including salmon species, steelhead, rainbow, and cutthroat trout) (OAR 340-041, Figure 340A). Salmonids and other cold-water biota may be present during part of the year, but do not form a dominant component of the community structure. Currently, because of severe dissolved oxygen and temperature standard violations, the water bodies appear to be able to support little more than carp, and other warm-water species, at least during the summer. Because it is unlikely that cold-water aquatic life would ever form a dominant component of the community structure, the cold-water class standards are not appropriate for Amazon Creek and the Amazon Diversion Channel. The appropriate class is either cool-water or warm-water. In order to provide for a margin of safety, cool-water class standards have been selected as the applicable targets.

The cool-water standards specify that, when ODEQ determines that adequate information exists, the DO target may be set to 6.5 mg/L as a 30-day average, rather than as an absolute minimum. ODEQ performed continuous dissolved oxygen and temperature monitoring during a critical summer period and used this data to develop a calibrated dynamic water quality model of the streams. Because this model allows daily average and minimum concentrations to be calculated, sufficient information exists to set the DO targets to 6.5 mg/l as a 30-day mean minimum, 5.0 mg/l as a 7-day minimum mean, and 4.0 mg/l as an absolute minimum.

Coyote Creek Targets

Coyote Creek appears to be more likely to support cold-water species than Amazon, since it is a natural stream channel with significantly higher flow rates than Amazon Creek. Like Amazon Creek, the designated fish use for Coyote Creek is "salmon and trout rearing and migration" (including salmon species, steelhead, rainbow, and cutthroat trout) (OAR 340-041, Figure 340A). No active spawning areas have been identified in the stream, however. In addition, it is unclear whether salmon, trout, cold-water invertebrates, and other native cold-water species could exist throughout all or most of the year, even in the absence of non-dam related anthropogenic influences. The appropriate class for the stream appears to be either cold-water or cool-water. In order to provide for a margin of safety, cold-water class standards have been selected as the applicable targets.

The cold-water standards specify that, when ODEQ determines that adequate information exists, the DO target may be set to 8.0 mg/L as a 30-day average, rather than as an absolute minimum. ODEQ performed continuous dissolved oxygen and temperature monitoring during a critical summer period and used this data to develop a calibrated water quality model of the stream. Because this model allows daily average and minimum concentrations to be calculated, sufficient information exists to set the DO targets to 8.0 mg/l as a 30-day mean minimum, 6.5 mg/l as a 7-day minimum mean, and 6.0 mg/l as an absolute minimum.

Data Review

Impact of Algae on Water Quality

Amazon Creek, Amazon Diversion Channel, and Coyote Creek experience excessive algal growth due to excessive solar radiation levels, high temperatures, high nutrient concentrations, and low flows. Excessive growth of algae and other autotrophs in natural waters can result in significant diel fluctuations in dissolved oxygen and pH which may adversely impact aquatic life. Autotrophs are organisms that obtain energy from sunlight and their materials from non-living sources (Allan, 1995). In streams, autotrophs include periphyton, phytoplankton, and macrophytes. Periphyton include algae and other small autotrophs that are attached to substrate, such as submerged rocks and vegetation. They consist of complex assemblages of diatoms, green algae, and cyanobacteria (blue-green algae) and, to a lessor degree, yellow-brown algae, euglenoids and red algae. Phytoplankton are algae and other small autotrophs which are suspended in the water column. While they can dominate slow moving rivers and backwaters, they generally are not present in significant quantities in fast flowing streams since their reproduction rates are low relative to retention times. Macrophytes include large vascular plants and bryophytes (mosses and liverworts). Some large members of periphyton, such as long filaments of the green alga Cladophora, may also be classified as Macrophytes.

Algae and other autotrophs impact pH and dissolved oxygen levels as they grow and respire. During the day, when algae perform photosynthesis and grow, carbon dioxide is consumed and oxygen produced. At night respiration dominates. Respiration, which occurs at a relatively constant rate both day and night, has the opposite effect of consuming oxygen and producing carbon dioxide. The net result is that during the day photosynthesis dominates and increases water column concentrations of oxygen while decreasing carbon dioxide concentrations. At night respiration dominates, which decreases oxygen concentrations and increases carbon dioxide concentrations.

Carbon dioxide, when introduced into an aqueous solution, combines with water to form carbonic acid (Chapra, 1997),

$$CO_2 + H_2O \leftrightarrow H_2CO_3$$

The carbonic acid, in turn, dissociates into ionic form,

$$H_2CO_3 \leftrightarrow HCO_3^- + H^+$$

This increases the hydrogen ion concentration, and consequently lowers the pH. Therefore, during the day algae consume carbon dioxide and pH increases, while at night algae produce carbon dioxide and pH declines. Through this process algae can cause large diurnal fluctuations in dissolved oxygen and pH which may result in water quality standards violations. Low oxygen levels can suffocate aquatic organisms, while excessively high or low pH levels can cause toxic effects ranging from growth and reproduction limitations to death.

The extent to which benthic carbon dioxide and oxygen fluxes impact water column pH and dissolved oxygen depends not only on the magnitude of the fluxes, but also on the water depth and the reaeration rate. Water depth controls the mass of water influenced by the fluxes. Reaeration controls the rate that carbon dioxide and oxygen is transferred between the water column and atmosphere. Therefore, for a given set of flux rates, pH and dissolved oxygen fluctuations will be greater in shallow streams with poor aeration than in deep streams with good aeration.

Flow Patterns in Amazon and Coyote Creeks

Coyote Creek has a drainage area about four times as large as the portion of the Amazon Creek Watershed that is diverted to Fern Ridge Reservoir. Accordingly, flows are higher in Coyote Creek, except during the summer when irrigation diversions can result in Coyote Creek flow rates even lower than in Amazon Creek (Table 10.45).

Table 10. 45 Monthly mean stream flow rates

	Monthly Mean Stream Flow Rates (cfs)			Ratios		
Month	USGS 14169500 AMAZON CREEK NEAR EUGENE	USGS 14166500 LONG TOM RIVER NEAR NOTI	USGS 14167000 COYOTE CREEK NEAR CROW	Coyote to Long Tom	Amazon to Long Tom	Amazon to Coyote
Jan	71.7	584	505	86%	12%	14%
Feb	57.5	556	441	79%	10%	13%
Mar	48.3	409	303	74%	12%	16%
Apr	21.7	248	151	61%	9%	14%
May	11.8	127	62	49%	9%	19%
Jun	2.38	65.8	16.6	25%	4%	14%
Jul	1.11	30.6	3.7	12%	4%	30%
Aug	0.81	16.8	0.84	5%	5%	96%
Sep	1.66	17.4	1.14	7%	10%	146%
Oct	4.6	39.5	18.9	48%	12%	24%
Nov	28.2	204	163	80%	14%	17%
Dec	85.9	471	459	97%	18%	19%

Meteorological Conditions During Summer 2001 Study

Studies were performed on Amazon and Coyote Creeks during a warm, mostly sunny week in July, 2001. Meteorological data is available from University of Oregon Solar Radiation Monitoring Laboratory (SRML) in Eugene for air and dew point temperature (Figure 10.37); wind speed (Figure 10.38); daytime cloud cover (Figure 10.39), with 0 indicating no cloud cover and 10 complete cloud cover; and solar radiation (Figure 10.40) in watts per square meter). Model calibration for the streams focused on July 10 and 11, which are days for which 24 hours of continuous temperature and DO data are available from all stations. As shown, both days high temperatures were 30°C (86°C). July 10 was occasionally cloudy, while July 11 was mostly sunny.

Figure 10.37 Air and dew point temperature

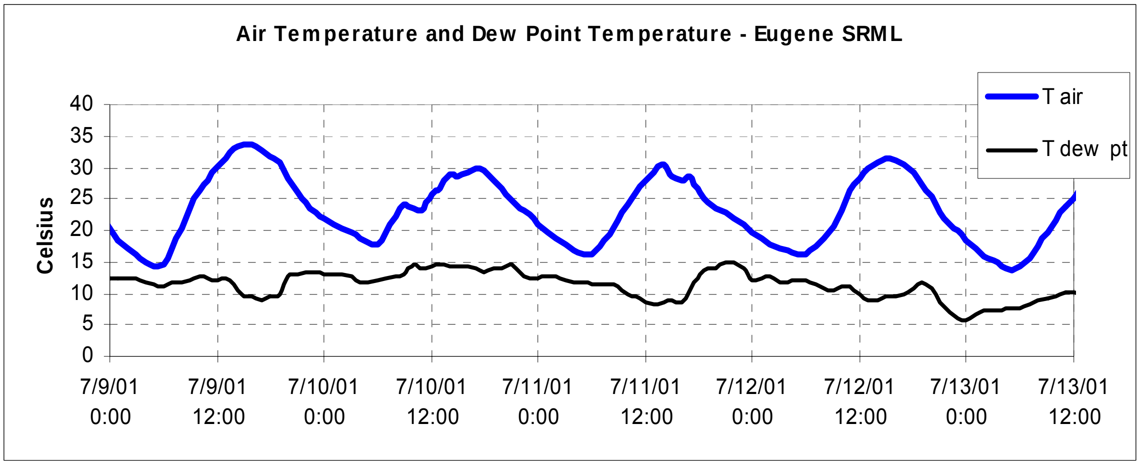


Figure 10.38 Wind speed - Eugene SRML

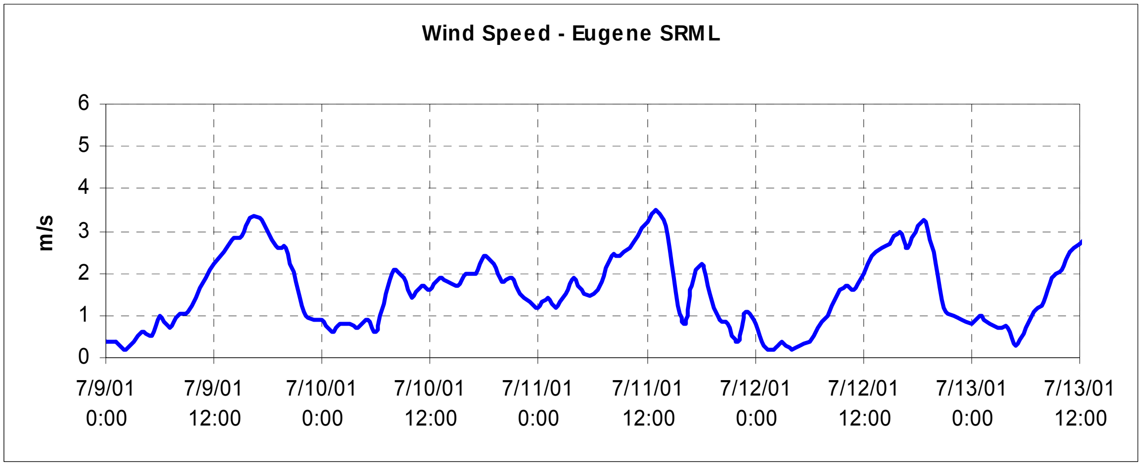


Figure 10.39 **Daytime cloud cover estimates based on solar radiation**

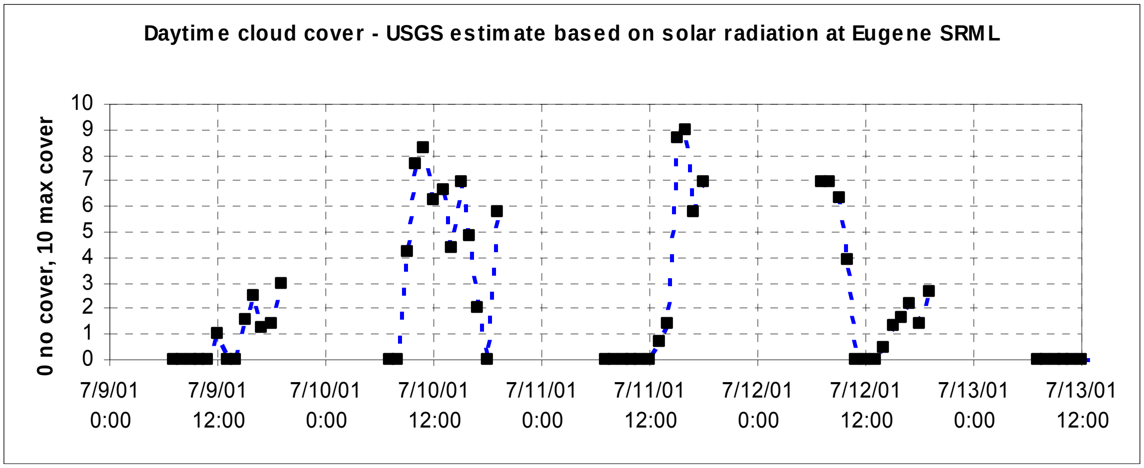
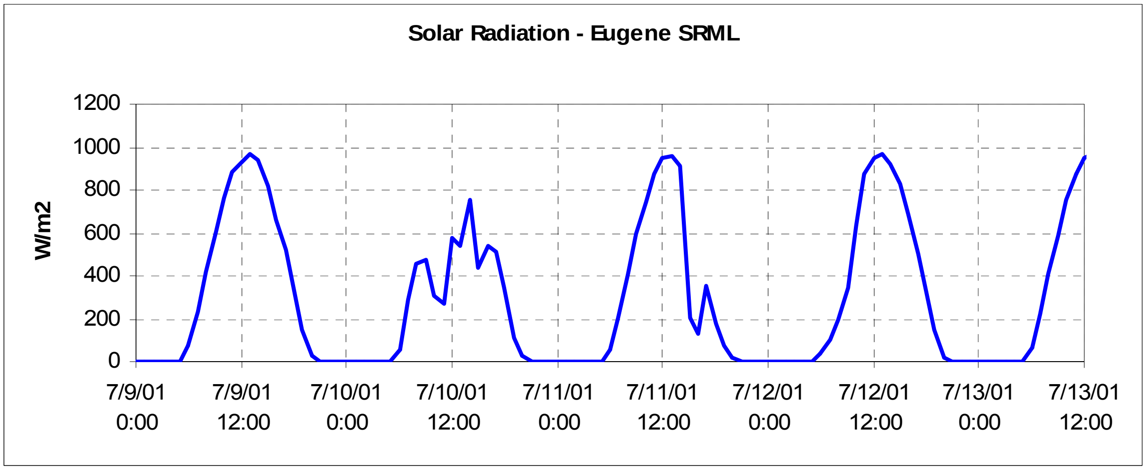


Figure 10.40 **Solar radiation**



Amazon Creek Summer 2001 Data

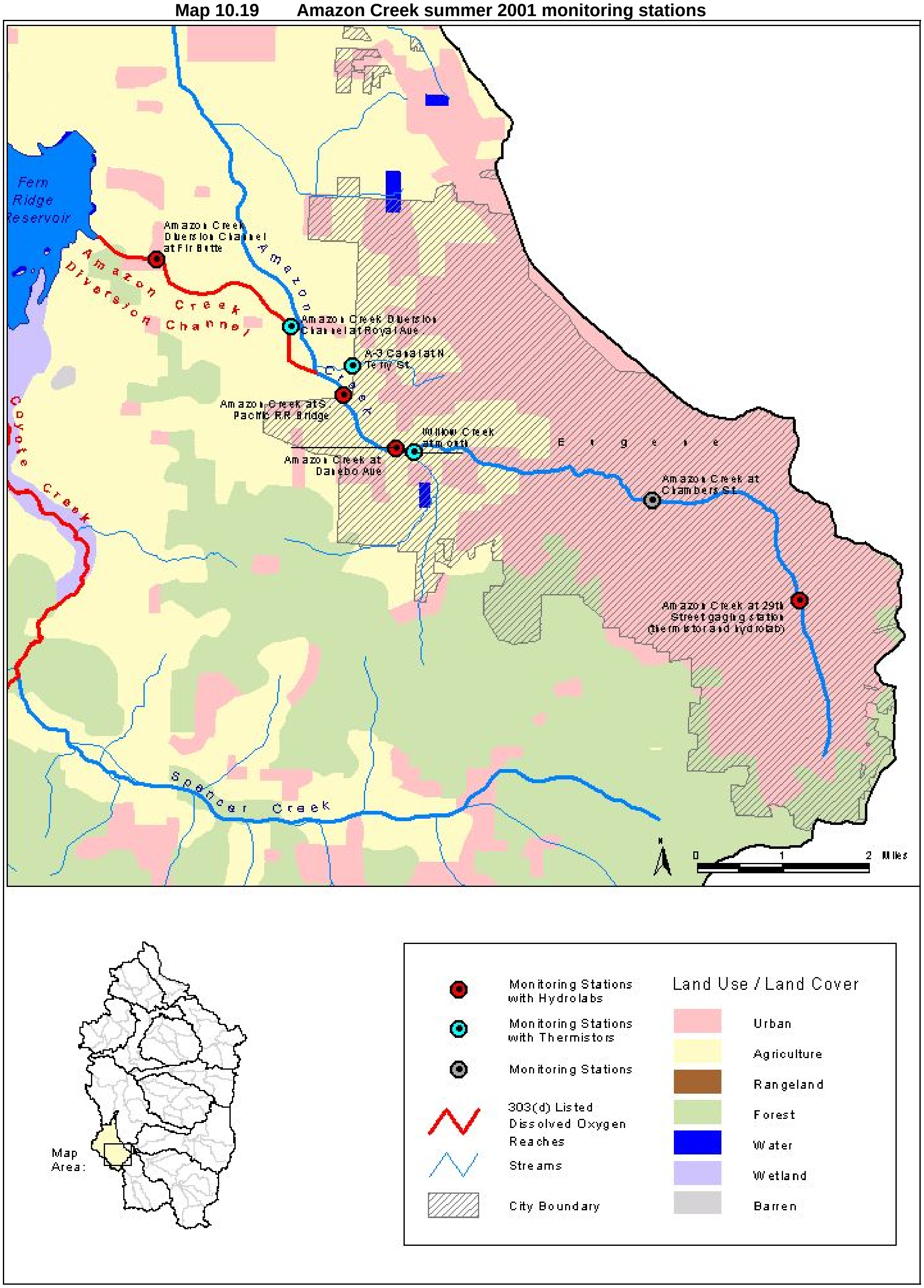
A joint survey was conducted by ODEQ and the City of Eugene during a warm, mostly sunny week in July, 2001. Hydrolab brand or similar multi-parameter datasondes which continuously record stream temperature and dissolved oxygen were deployed at 4 locations (see Table 10.46 and Map 10.19; also see section ***Photographs of Stations*** below for photos).

Data from the datasondes is presented below. The most upstream diel monitoring station, Amazon Creek at 29th Ave (LASAR No. 25624), is located 10.9 miles upstream from the confluence of Amazon Creek Diversion Channel with Fern Ridge Reservoir (mile point 10.9). The most downstream station, Amazon Creek Diversion Channel at Fir Butte Road (LASAR No. 25617), is located 0.8 miles upstream of Fern Ridge Reservoir (MP 0.8).

Table 10. 46 Amazon monitoring stations - July, 2001

LASAR No	Station Description	Miles above lake weir (MP) (via GIS)	Lat	Long	2001 DO Study WQ Sampling Station	2001 DO Study Field WQ Station	2001 DO Study Hydrolab Station	2001 DO Study Thermistor Station	2001 DO Study Flow Station	2001 Hydrolab Agency
25624	Amazon Creek at 29th Street gaging station	10.9	44.02615	-123.08306	X	X	X	X	X	Eugene
25623	Amazon Creek at Chambers St.	8.3	44.04231	-123.11797		X				
25367	Amazon Creek at Danebo Ave	4.9	44.049722	-123.177778	X	X	X	X	X	Eugene
25620	Amazon Creek at S. Pacific RR Bridge	3.9	44.05837	-123.19026	X	X	X		X	DEQ
10149	Amazon Creek Diversion Channel at Royal Ave.	2.7	44.069722	-123.203056		X		X	X	
25617	Amazon Creek Diversion Channel at Fir Butte Rd.	0.8	44.08033	-123.23469	X	X	X			DEQ
25625	A-3 Canal at N. Terry St.		44.0635	-123.18838	X	X		X	X	
25937	Willow Creek at Mouth		44.04915	-123.1735				X		

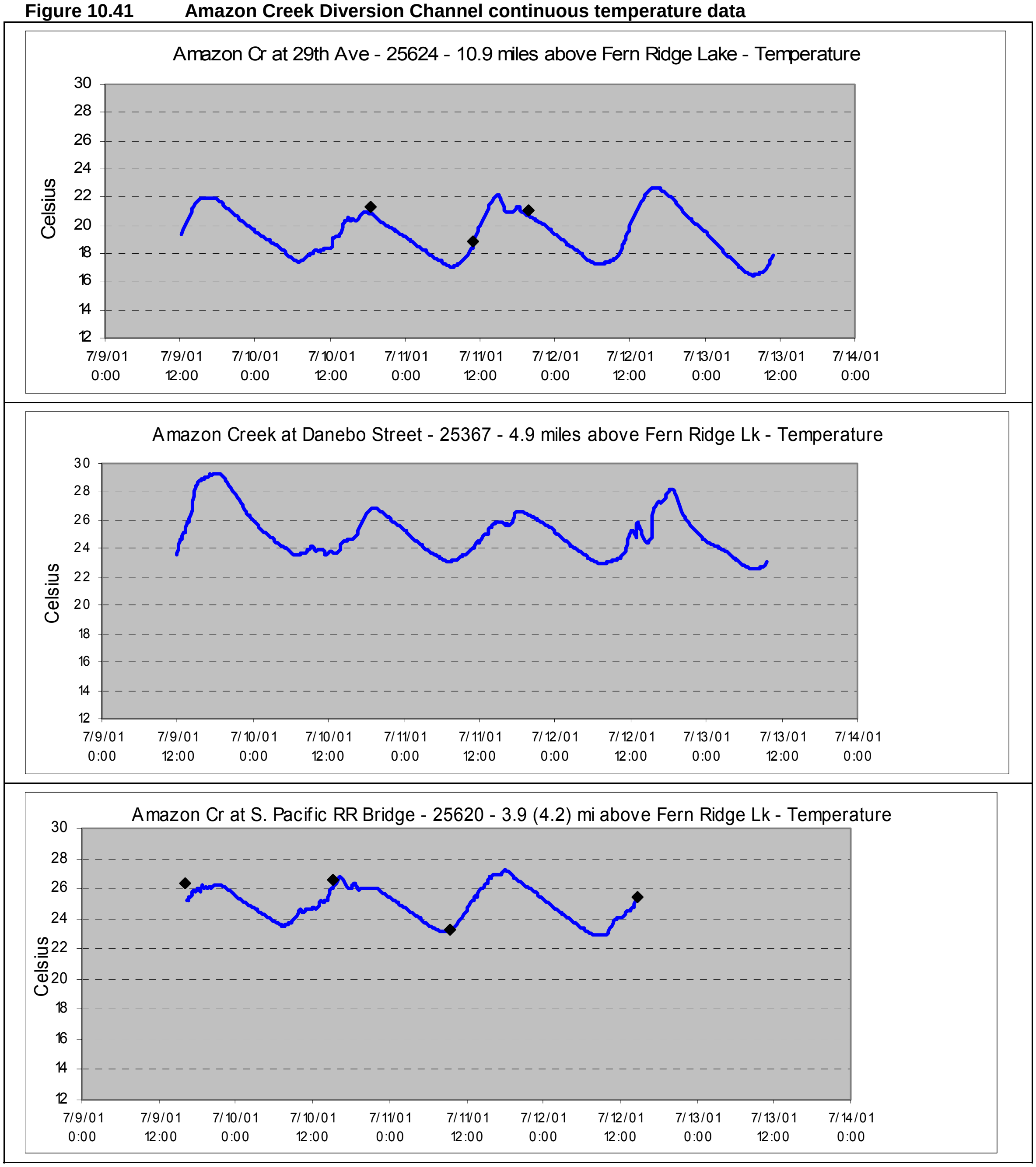
Map 10.19 Amazon Creek summer 2001 monitoring stations

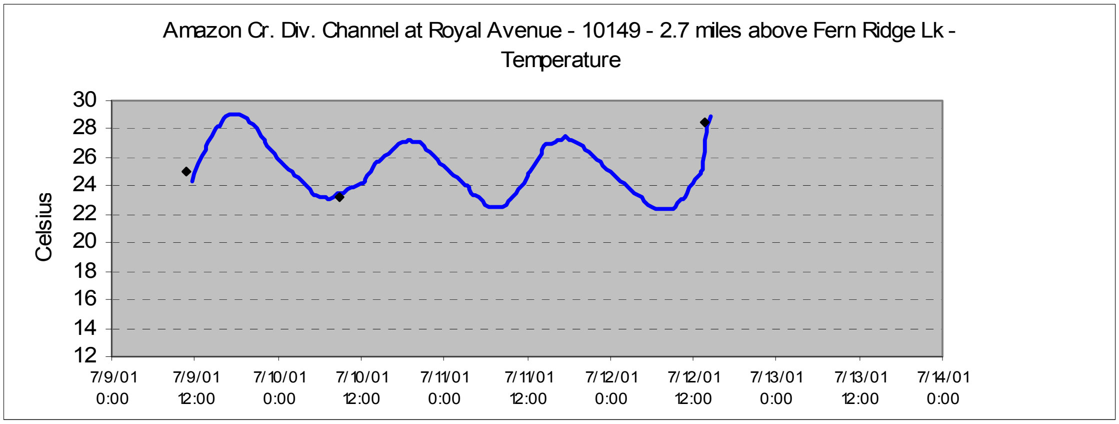


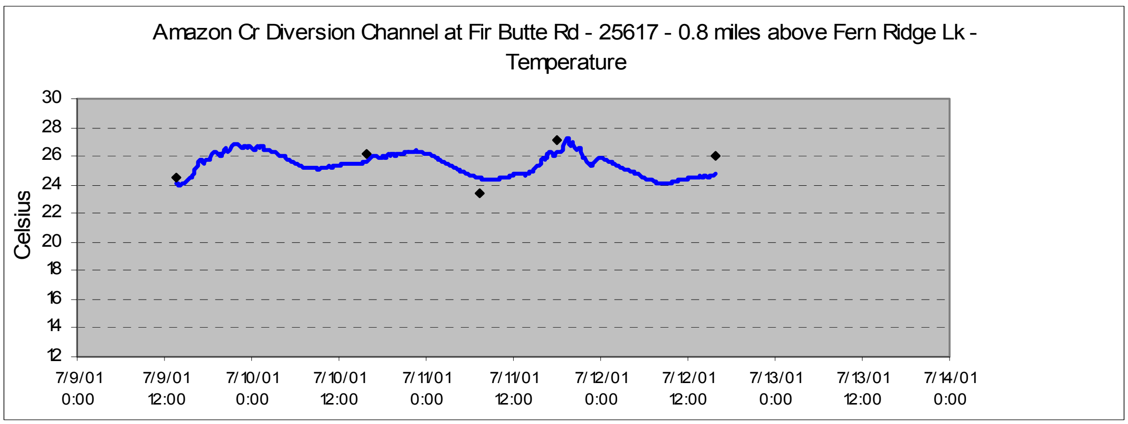
Amazon Creek Diel Temperature

Amazon Creek and Amazon Creek Diversion Channel are poorly shaded and heat relatively quickly. At MP 10.9 stream temperatures average 19.4°C and fluctuate from less than 18°C to about 22°C (Figure 10.41). Six miles downstream at RM 4.9 stream temperatures average 25.0°C and fluctuate from about 23°C to as high as 29°C. No further increases in daily average temperature occur downstream from RM 4.9, in spite of poor shading, which indicates that temperatures have reached dynamic equilibrium conditions by RM 4.9.

Figure 10.41 Amazon Creek Diversion Channel continuous temperature data







Amazon Creek Diel Dissolved Oxygen

Oxygen solubility in water declines as temperature increases. Therefore, the high Amazon Creek and Diversion Channel temperatures contribute to dissolved oxygen (DO) violations.

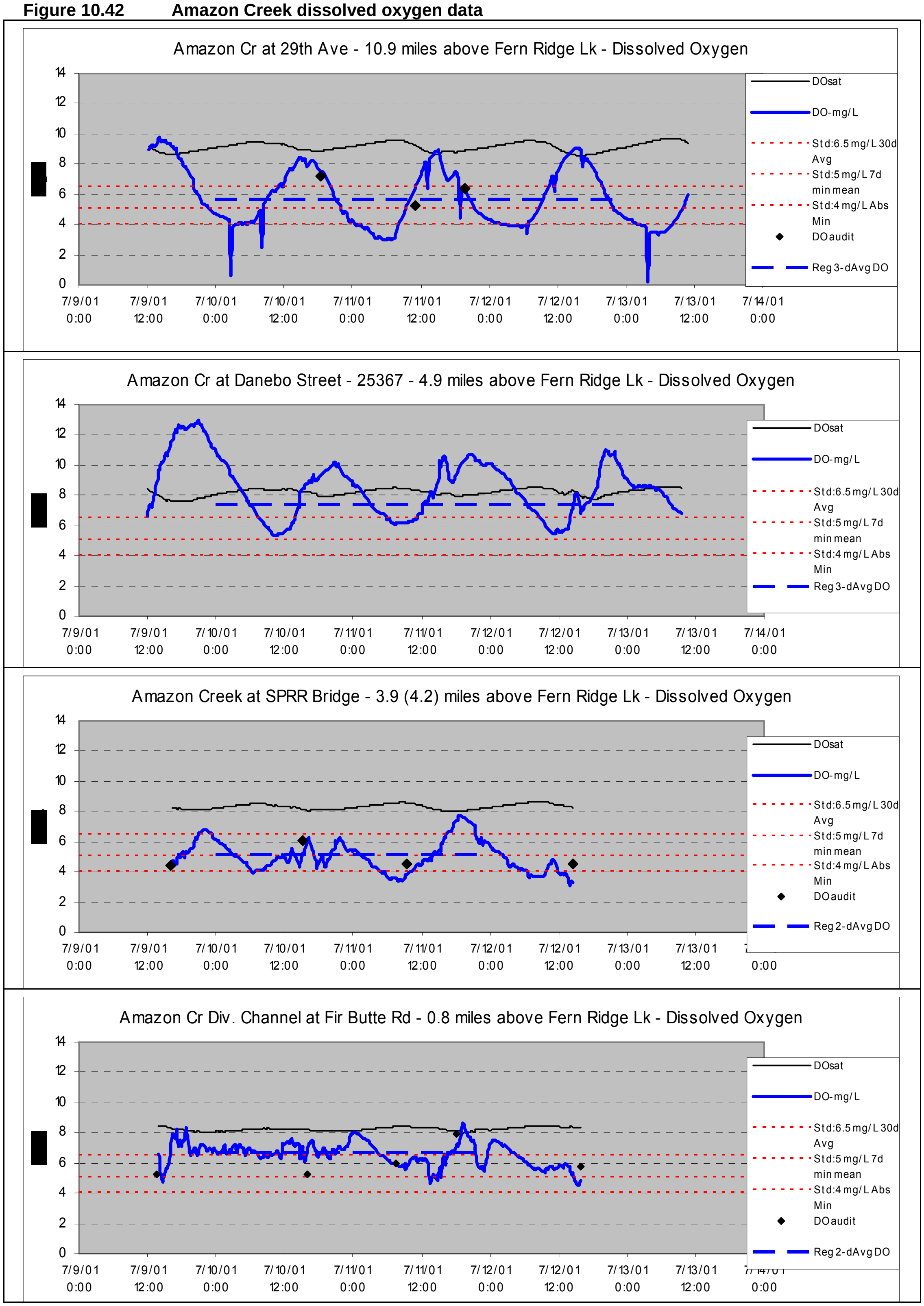
The DO in streams typically fluctuates due to stream temperature induced fluctuations in oxygen solubility and the production and consumption of oxygen by algae and other aquatic plants. At the most upstream DO monitoring station, RM 10.9, large diel dissolved oxygen fluctuations occur (Figure 10.42). In streams with minimal algal activity, maximum DO concentrations occur before sunrise when temperatures are lowest. However, in Amazon Creek and Diversion Channel maximum DO concentrations occur during the day roughly at the same time as maximum temperatures. This production of oxygen is consistent with significant daytime algal photosynthetic activity. At night, when algae respire, oxygen is consumed and oxygen concentrations decline.

DO standards were violated during the survey at RM 10.9 (Figure 10.42). The regulatory average DO concentration over the 3 full days monitored at RM 10.9 was 5.7 mg/L. This was calculated by setting DO concentrations greater than saturation equal to saturation in accordance with methodologies described in OAR 340-041-0002 (see definition for “daily mean” DO presented previously). It is useful to compare this to the 6.5 mg/L 30-day regulatory average DO standard. While a full 30 days of data is needed to compare directly to the standard, it does appear that the 30-day average standard is being violated.

The daily minimum standard was also violated. The average of the daily minimum DO concentrations for the 3 days was 3.3 mg/L. While not a full 7 days of data, this does imply that the 7-d minimum mean standard of 5.0 mg/L is being violated. The 4.0 mg/L daily minimum was also violated during 2 out of 4 nights. At night, DO levels routinely decline to 40% of saturation. It is generally preferable that DO be no less than 90% of saturation.

DO standards may also have been violated at RM 3.9 and RM 0.8. At RM 3.9 the regulatory average DO was less than the 6.5 mg/L standard and the absolute minimum DO was less than the 4.0 mg/L standard. At RM 0.8 the regulatory average was only slightly above the 6.5 mg/L standard.

Figure 10.42 Amazon Creek dissolved oxygen data



Coyote Creek Summer 2001 Data

During July 2001, studies were also performed on Coyote Creek. Hydrolab brand or similar datasondes, which continuously record stream temperature, dissolved oxygen, pH and conductivity, were deployed at 2 locations, while thermistors which monitored temperature were deployed at 3 additional locations (see Table 10.47 and Map 10.20; also see section ***Photographs of Stations*** below for photos). A thermistor was also deployed on Spencer Creek, although little or no flow was observed entering Coyote Creek from Spencer Creek during the study.

In addition to continuous monitoring data, grab samples were collected and analyzed for water quality parameters. Parameters analyzed included biochemical and chemical oxygen demand (BOD and COD), nitrogen (total Kjeldahl, nitrate/nitrite, and ammonia), phosphorus (total and orthophosphate), algae (chlorophyll a), turbidity, pH, and DO.

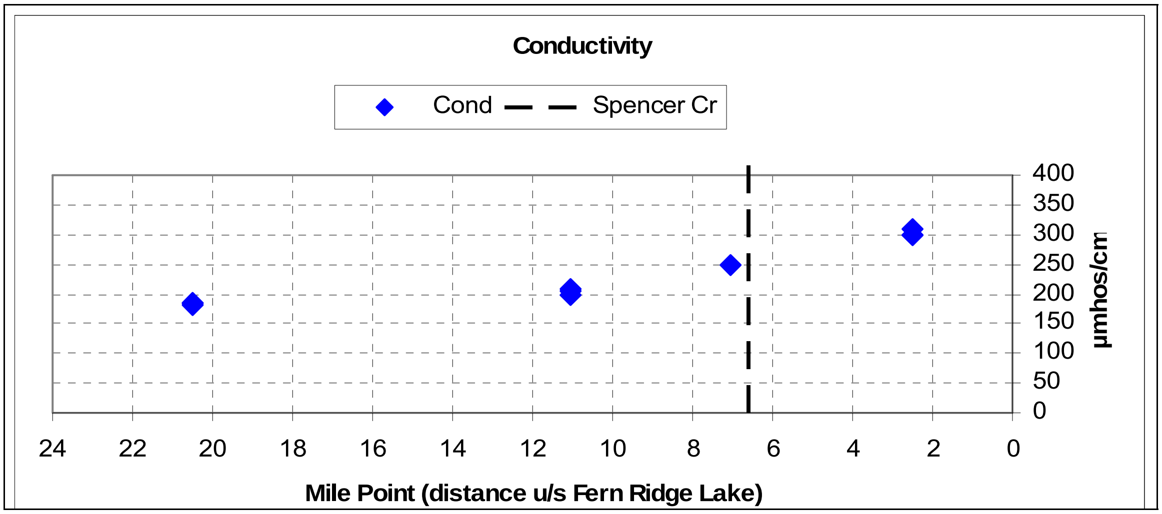
Table 10. 47 Coyote monitoring stations – July 2001

LASAR No.	DESCRIPTION	HS RM above Lake (mi)	LAT	LONG	2001 DO Study WQ Sampling Station	Other WQ Sampling Station	2001 DO Study "Hydrolab" Station	2001 DO Study Thermistor Station
25627	Coyote Cr at Gillespie Corners	22.9	43.908100	-123.250450				X
25626	Coyote Cr at Powell Road	20.5	43.925030	-123.271260	X		X	
11148	Coyote Cr at Crow Road	11.1	43.991750	-123.306083	X			X
10151	Coyote Cr at Petzold Road	7.0	44.005278	-123.268611		X		X
10150	Coyote Cr at Cantrell Rd.	2.5	44.041111	-123.266111	X		X	
12290	Fox Hollow Cr At Rm 1.3 (Trib to Coyote at RM 23.1)	1.3	43.921361	-123.233250		X		
25828	Spencer Cr at Pinegrove	1.9	43.992000	-123.238900		X		
25806	Spencer Cr at Pine Grove Rd	1.8	43.995800	-123.240680	X			
11150	Spencer Creek at Mouth - Crow Rd	0.3	44.005000	-123.261389				X

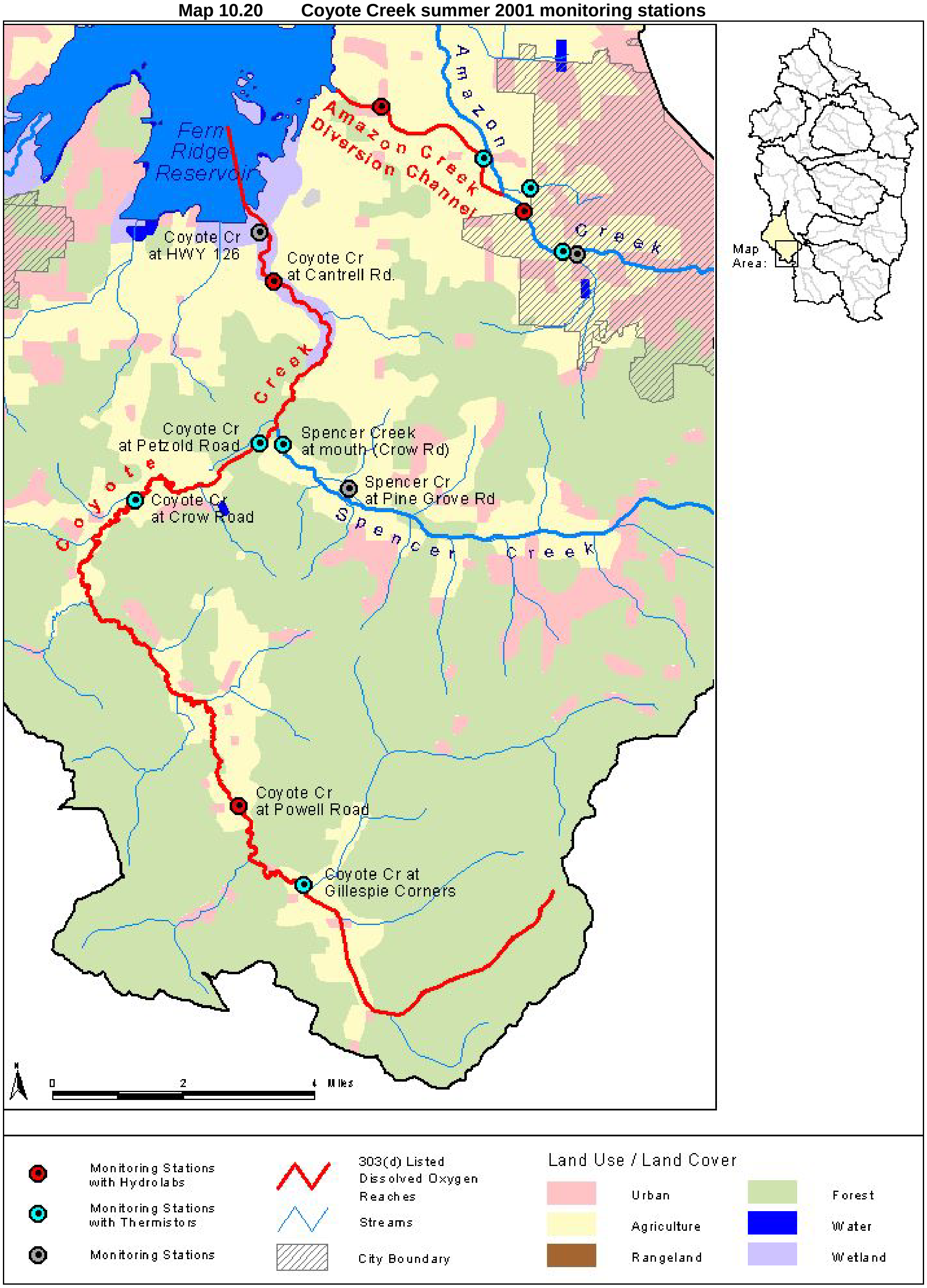
Coyote Creek Water Quality Grab Samples

During the study, pollutant concentrations were found to be higher in more downstream reaches (see Figure 10.43 - Figure 10.46).

Figure 10.43 Coyote Creek Conductivity - July 2001


Conductivity
Cond
Spencer Cr
400
350
300
250
200
150
100
50
0
µmhos/cm
24
22
20
18
16
14
12
10
8
6
4
2
0
Mile Point (distance u/s Fern Ridge Lake)

Map 10.20 Coyote Creek summer 2001 monitoring stations



Concentrations of oxygen demanding pollutants below Spencer Creek are almost twice as high as above (Figure 10.44 and 10.45). Concentrations of ammonia, which may contribute to oxygen demand and be a component of measured BOD, are several times higher (Figure 10.46 and 10.47). The source of the oxygen demanding pollutants is unclear. Spencer Creek flow rates were quite low during the study, which implies that it is not the only source of oxygen demanding pollutants.

Figure 10.44 Coyote Creek COD - July 2001

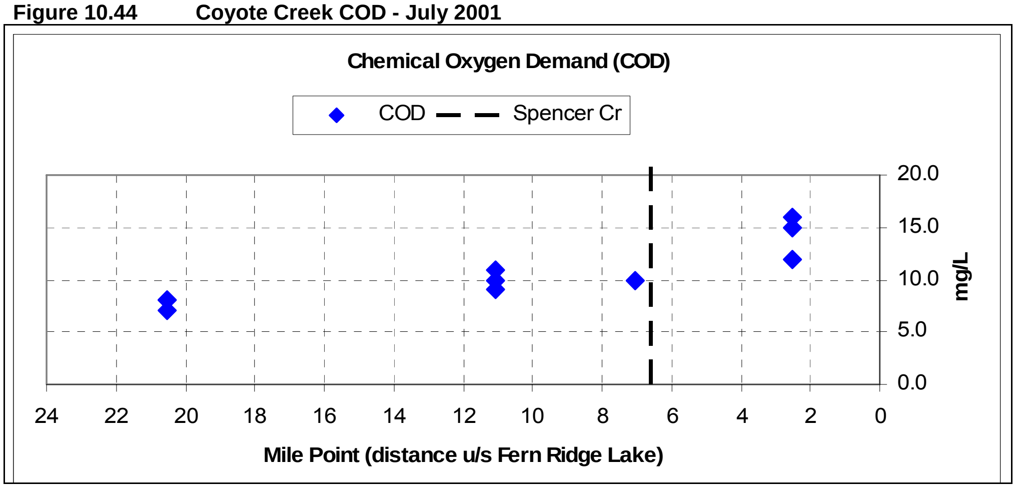


Figure 10.45 Coyote Creek BOD - July 2001

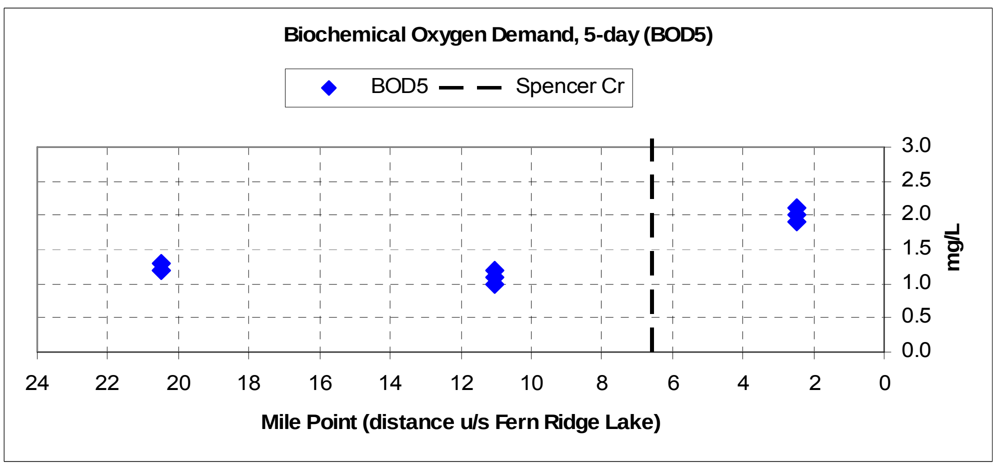
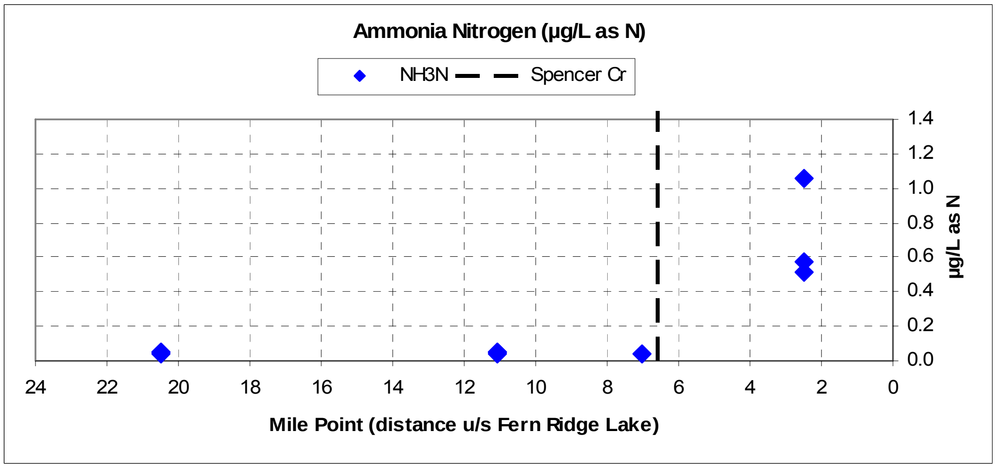
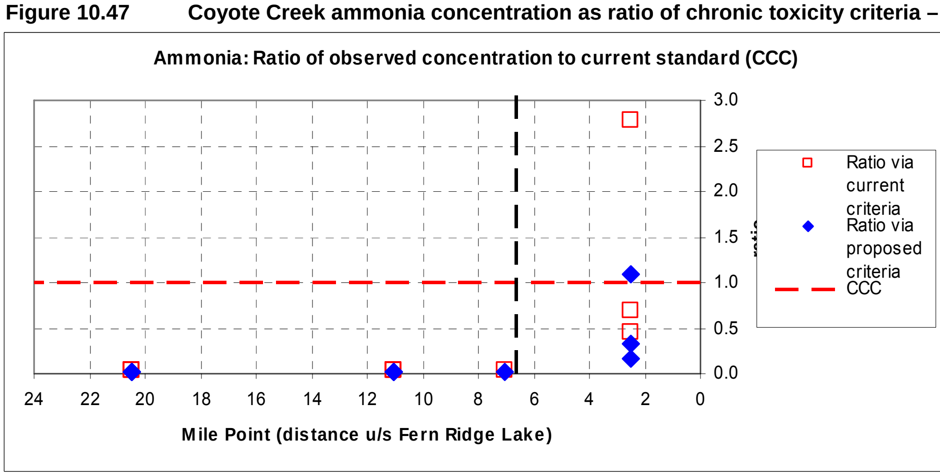


Figure 10.46 Coyote Creek Ammonia Nitrogen (ug/L as N) – July 2001



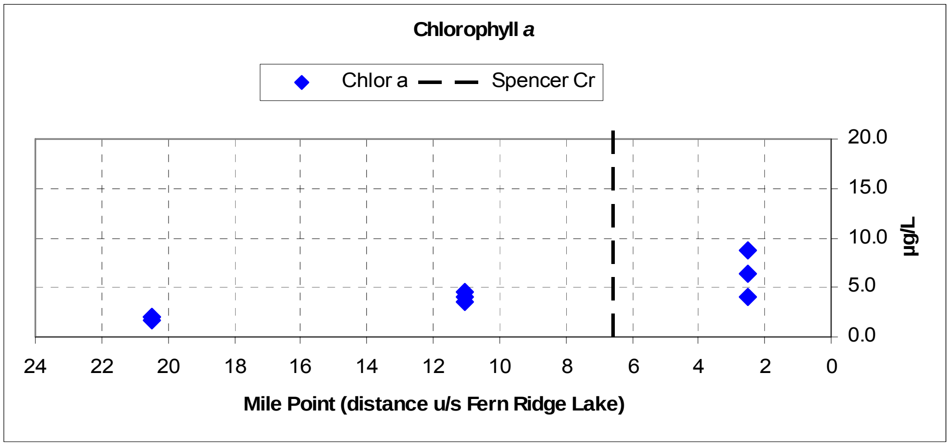
Ammonia toxicity is also a concern. The toxicity of ammonia is a function of pH and temperature, mainly because the percentage of ammonia in the toxic un-ionized phase increases with increased temperature and pH. Figure 10.47 compares observed ammonia concentrations to two water quality standards for chronic ammonia toxicity: the current State standard (OAR 340-041-0033) and the proposed State standard (DEQ 2004a). As shown, above Spencer Creek the standard is easily met. Below Spencer Creek, the standard is at times exceeded. Note that while the proposed standard is less stringent than the existing standard, it still may occasionally be exceeded.

Figure 10.47 Coyote Creek ammonia concentration as ratio of chronic toxicity criteria – July 2001



Algae consist of suspended algae (phytoplankton) and attached algae assemblages (periphyton). Phytoplankton concentrations were quantified by measuring chlorophyll a (Figure 10.48). As shown, phytoplankton concentrations increase in a downstream direction. Periphyton concentrations were not measured during the study, but rather, were quantified by modeling.

Figure 10.48 Coyote Creek chlorophyll a concentration – July 2001



The ratio of nitrogen to phosphorus is also of interest because it provides insight into which nutrient is limiting algal growth, if any. Algal growth is limited by the nutrient in lowest supply relative to algal cell needs. Under nutrient saturated conditions, algal stoichiometry is generally well represented by the Redfield ratios:

106C:16N:1P (atomic basis)

This results in a mass basis ratio of N/P of 7. Therefore, the half-saturation constant for nitrogen is 7 times the phosphorus half-saturation constant. Since the ratio of nitrogen to phosphorus in algal cells is about 7 to 1 on a mass basis, if the ratio of water column nitrogen to water column phosphorus is much less than 7, nitrogen is likely to be limiting. However if the N/P ratio is much greater than 7, phosphorus is likely to be limiting. Note that if both nutrients are present in concentrations well in excess of algal needs, then neither would be limiting. Therefore, N/P ratios must be considered in tandem with in-stream concentrations of phosphorus and nitrogen. Since algal cell stoichiometry is somewhat variable, in practice, if the N/P ratio is less than 5, nitrogen is considered the limiting nutrient. If greater than 20, phosphorus is the limiting nutrient.

During the study the ratio of dissolved inorganic nitrogen (DIN, which includes ammonia, nitrite and nitrate nitrogen) to soluble reactive phosphorus (SRP, which consists of orthophosphate phosphorus) in Coyote Creek ranged from 4 to 6 in the reaches upstream from Spencer Creek, which indicates that nitrogen may be limiting (Figures 10.49 to 10.51). Below Spencer, nitrogen is available in excess and the N/P ratio is much greater than 20, indicating that phosphorus is the nutrient that potentially limits growth (Figure 10.51).

Figure 10.49 Coyote Creek dissolved inorganic nitrogen concentration – July 2001

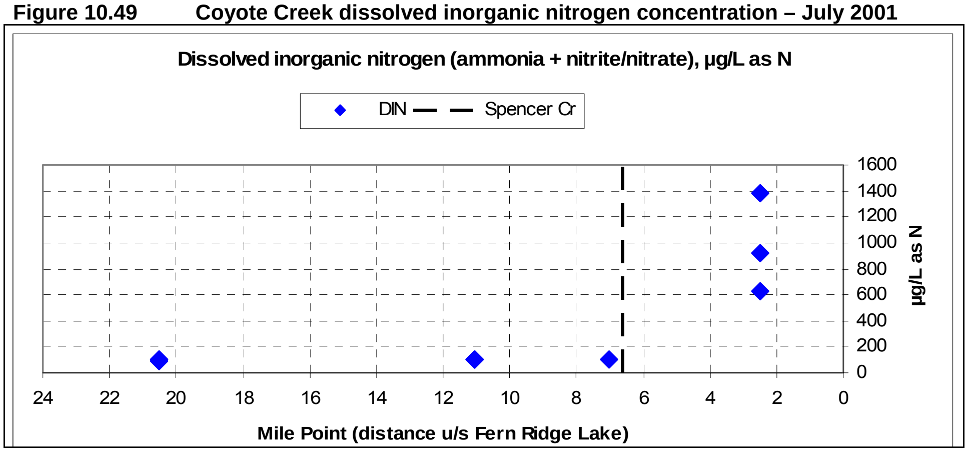


Figure 10.50 Coyote Creek dissolved orthophosphate concentration – July 2001

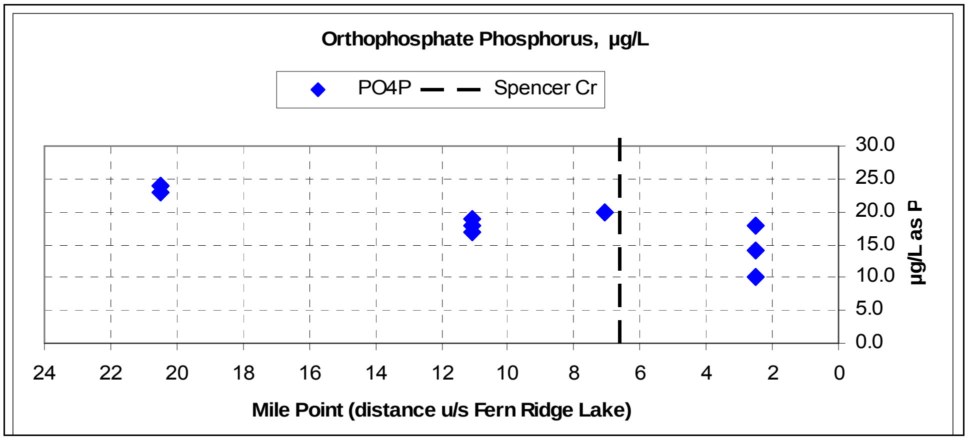
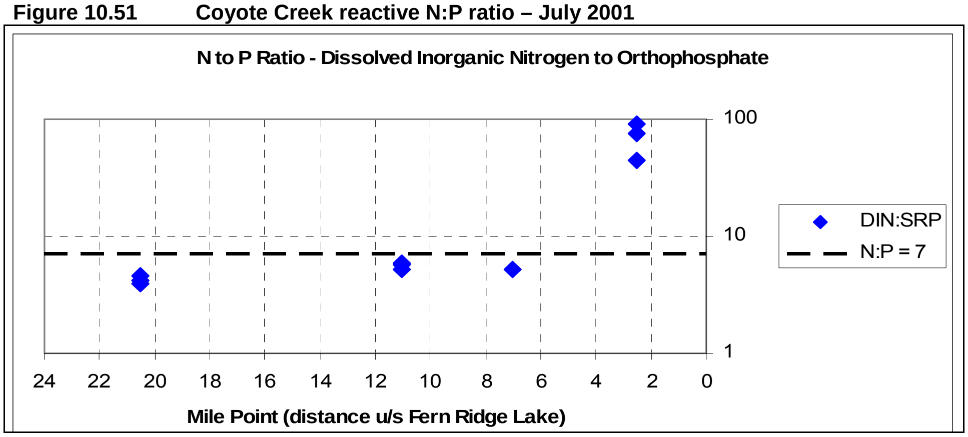


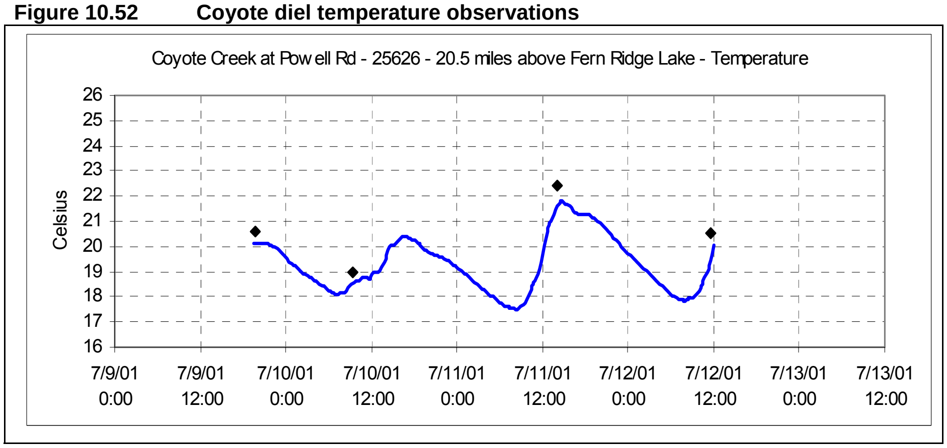
Figure 10.51 **Coyote Creek reactive N:P ratio – July 2001**

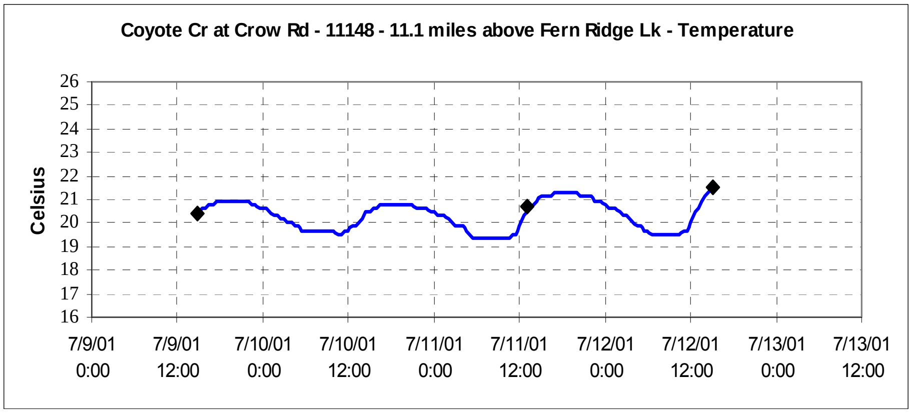


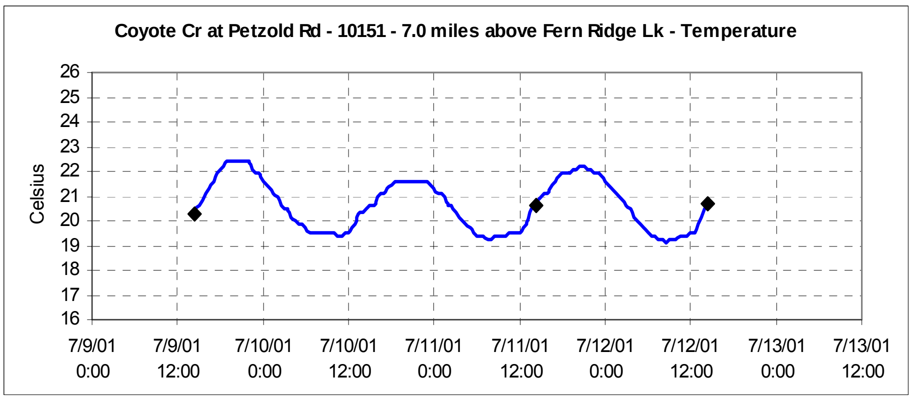
Coyote Creek Diel Temperature

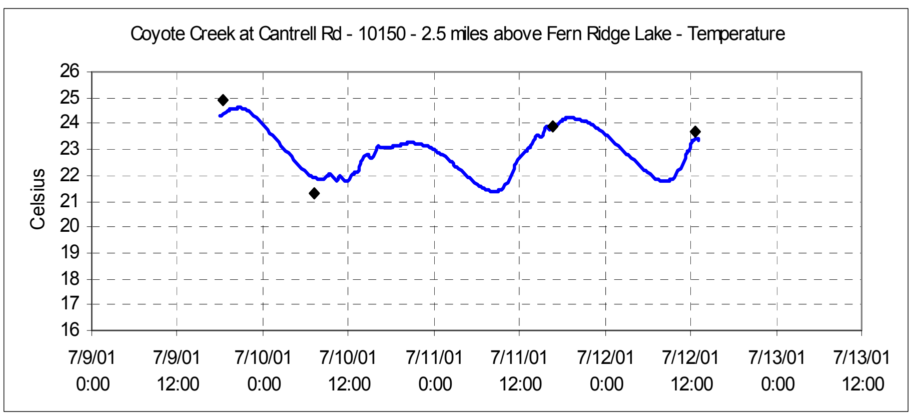
Temperatures are quite warm throughout Coyote Creek (Figure 10.52). Daily maximum temperatures at RM 20.5 approach 22^{o}C, with large diel fluctuations. Near the mouth, temperatures approach 25^{o}C.

Figure 10.52 **Coyote diel temperature observations**









Coyote Creek Diel DO and pH

Diel DO and pH fluctuations are significantly more pronounced in lower reaches due to the high nutrient and algae concentrations (Figures 10.53 and 10.54).

At RM 20.5, 48 hour DO concentrations average 7.7 mg/L, which is slightly less than the water quality standard. At this station, little diel DO and pH fluctuation occurs and DO rarely exceeds saturation, which indicates that algal activity is relatively minor in this area.

At RM 2.5, DO concentrations are much higher and frequently exceed saturation. 48 hour DO concentrations (July 10 0000 hrs to July 12 0000 hrs) average 9.7 mg/L. 48 hour "regulatory average" concentrations (for comparison to the 8.0 mg/L 30-day average DO standard) equal 8.4 mg/L. The large diel DO and pH fluctuations at this station indicate that algal activity is significant in this area.

While DO standards were met at RM 2.5 during the July 2001 study, the large diel fluctuations in DO are of concern. It is quite likely that on many days consumption of DO by respiring and decaying algae results in DO concentrations below standards. This may be why historic data shows frequent DO standard violations in the stream.

Figure 10.53 Coyote Creek diel dissolved oxygen

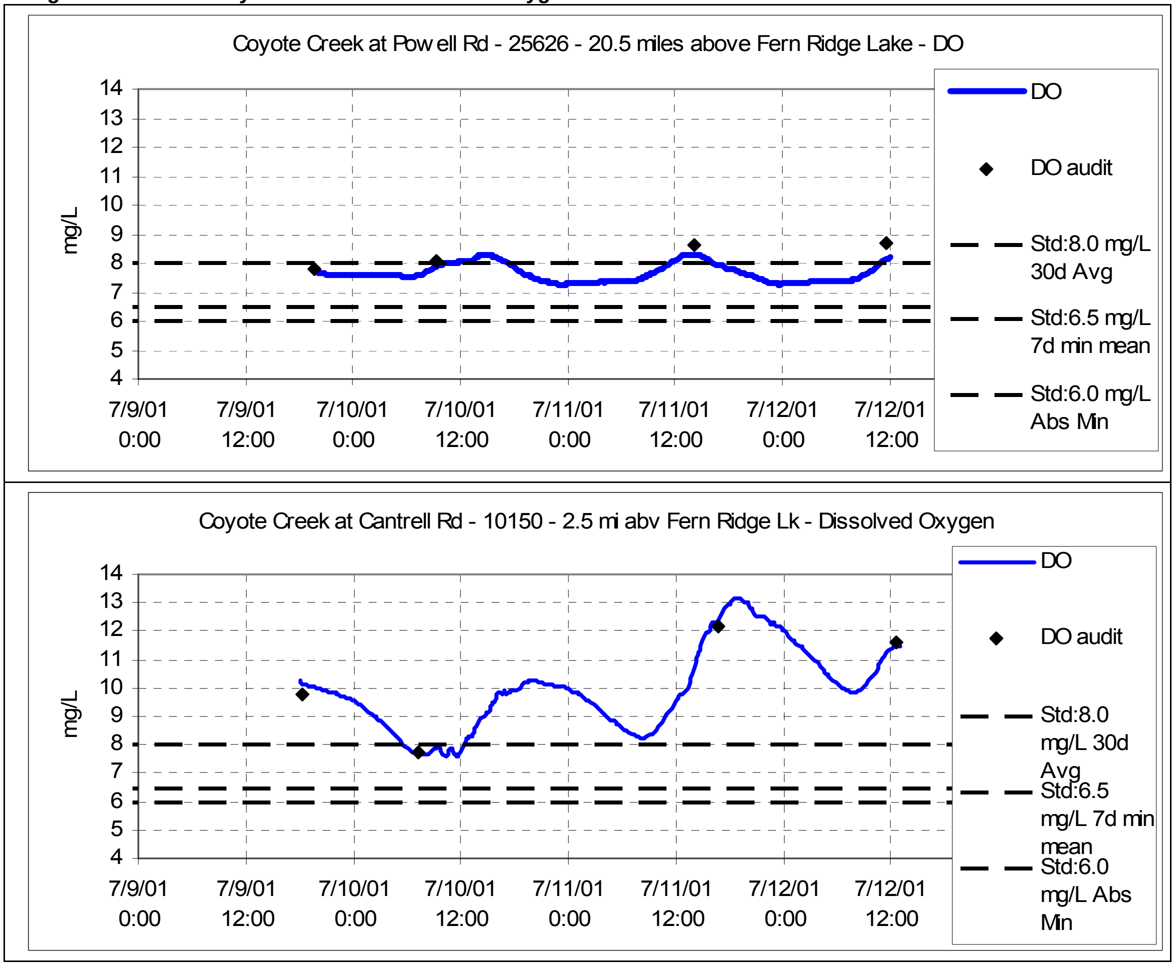
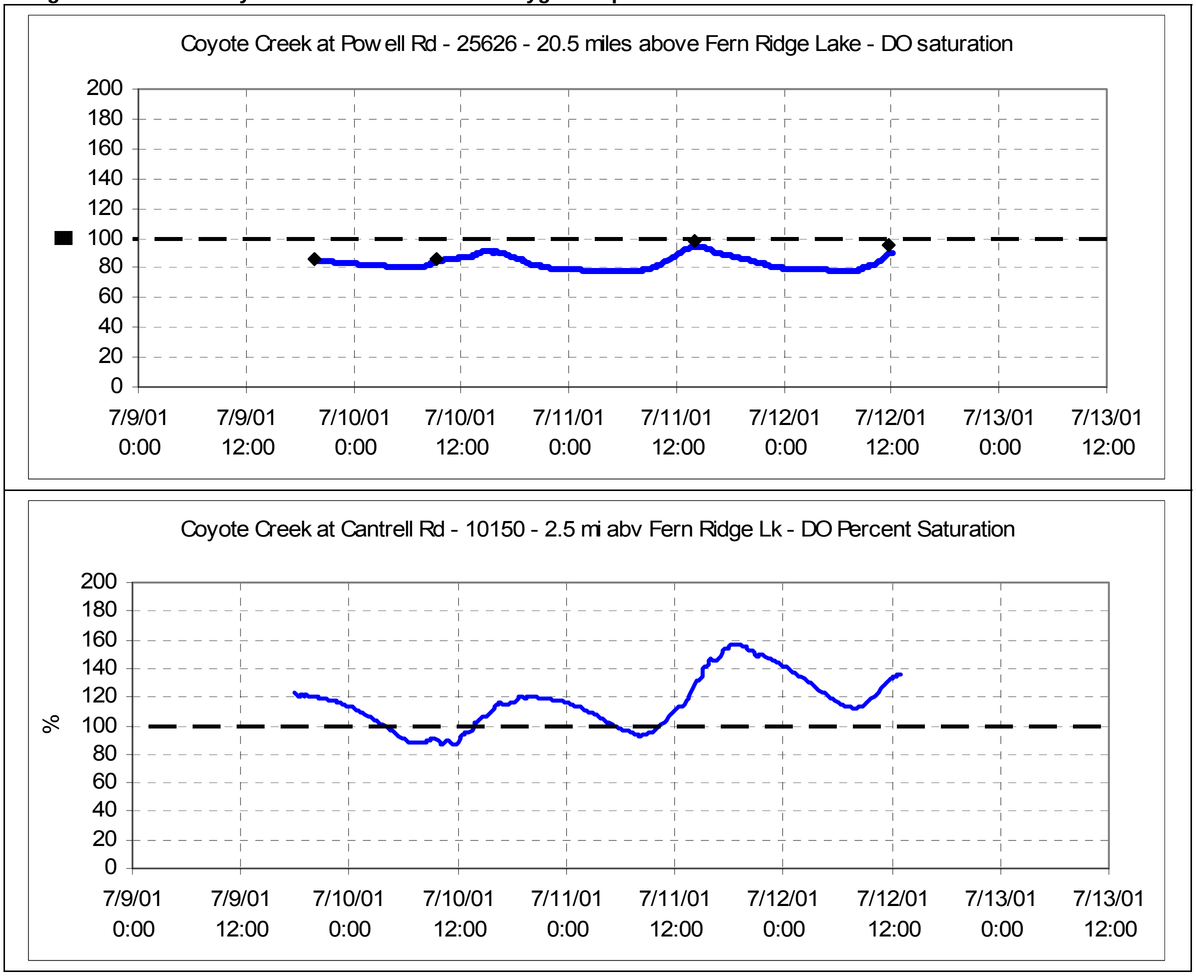


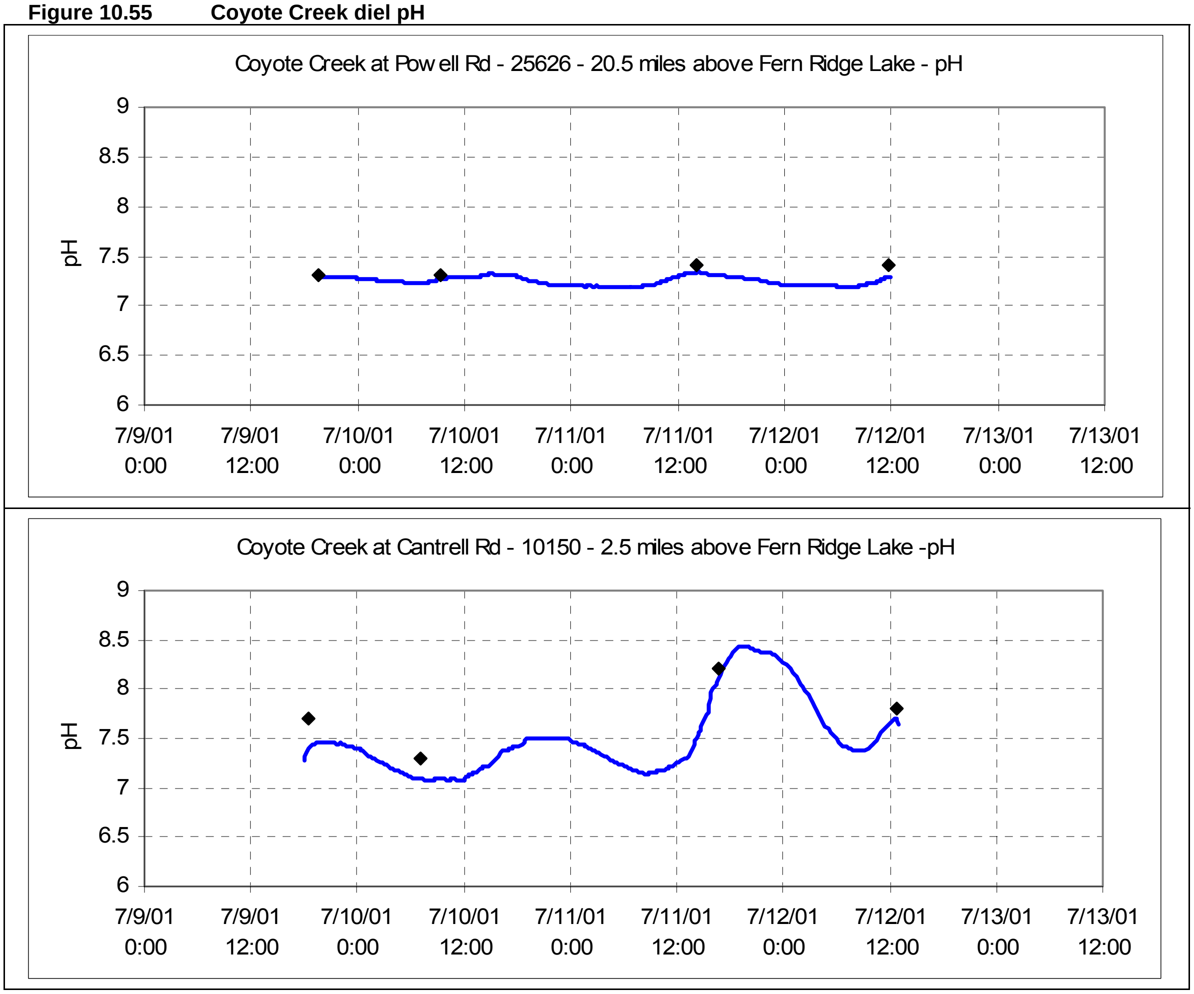
Figure 10.54 Coyote Creek diel dissolved oxygen as percent of saturation



Coyote Creek Diel pH

On July 11, pH levels climbed dramatically at RM 2.5 and approached the maximum pH standard (Figure 10.55). This high pH is of particular concern because of the presence of large concentrations of ammonia in the system. At high pH levels (low hydrogen ion levels) a large fraction of ammonia present is in the toxic, un-ionized form, which may result in aquatic life toxicity.

Figure 10.55 Coyote Creek diel pH



Spencer Creek Water Quality Grab Samples

Spencer Creek is a significant tributary to Coyote Creek which enters 6.6 miles upstream of Fern Ridge Reservoir (Map 10.20). The only recent data available for the stream is from 2001 and 2002. At two stations near the mouth, ODEQ collected nutrients and DO data in July, 2001 and bacteria data in December, 2002. Additional data was collected in 2001 and 2002 by the Long Tom Watershed Council. Combined DO related data from all stations for summer (July-September) and fall-winter-spring (October-June) periods is summarized in Table 10.48. As shown, DO concentrations during the summer averaged 4.95 mg/L, which is less than the 8.0 mg/L applicable standard.

Table 10. 48 Spencer Creek grab sample data

	BOD_5 (mg/L)	Ammonia as Nitrogen (mg/L)	Nitrate Nitrite as N (mg/L)	Total Phosphate as P (mg/L)	Dissolved Ortho-phosphate as P (mg/L)	Chloro-phyll a (µg/L)	DO (mg/L)	Percent Saturation DO (%)	Field Temp (°C)
Summer n	**2**	**3**	**6**	**6**	**6**	**2**	**8**	**2**	**8**
Summer Mean:	2.05	0.017	0.011	0.042	0.011	13.6	4.80	55	17.90
Summer Median:	2.05	0.020	0.011	0.030	0.011	13.6	4.95	55	18.35
Summer Std.Dev:		0.006	0.010	0.039	0.010		1.48		2.16
F-W-S n:	**0**	**0**	**4**	**4**	**4**	**0**	**5**	**0**	**7**
F-W-S Mean:			0.065	0.138	0.020		7.56		8.39
F-W-S Median:			0.045	0.130	0.020		6.29		7.80
F-W-S Std.Dev:			0.059	0.056	0.000		2.59		1.84

Existing Sources

NPDES Permitted Facilities

The federal Clean Water Act requires that all point sources that discharge wastewater to surface waters must obtain a National Pollutant Discharge Elimination System (NPDES) permit. By point sources, USEPA means discrete conveyances such as pipes or man-made ditches. In Oregon, facilities are either covered by general or individual permits. General permits are issued by ODEQ to cover categories of minor discharges when an individual permit is not necessary to adequately protect water quality. ODEQ may issue a general permit when there are several minor sources or activities involved in similar operations that are discharging similar types of waste. New sources apply to be "assigned" to the general permit that has been issued by ODEQ. Some of the sources covered by general NPDES permits include fish hatcheries, log ponds, seafood processing, petroleum hydrocarbons cleanup, and vehicle wash water. Sources not eligible for a general permit must apply for an individual permit.

Sources which discharge waste into a sewerage system do not have to obtain an NPDES permit, provided that the owner of the sewerage system has a valid permit. However, these sources may be subject to municipal pretreatment requirements.

Some industrial activities are required to obtain an individual or general permit for storm water discharges that leave the site and drain to surface waters.

Active ODEQ NPDES permitted facilities are present on Amazon Creek and Amazon Creek Diversion Channel (Map 10.21), some of which are authorized to discharge to Amazon Creek. There are no active ODEQ NPDES permitted facilities on the modeled reaches of Coyote Creek.

All of the facilities are classified as Minor facilities (DEQCLASS). Most have only WQ Category STM stormwater permits, which permit only the discharge of stormwater runoff (see Table 10.49). These facilities may contribute loads of oxygen demanding pollutants during rainfall events, but otherwise they are not permitted to discharge to the stream. Except for stormwater runoff, none of the point sources appear likely to discharge significant quantities of nutrients, ammonia, or oxygen demanding organic matter to the stream during the summer period of concern.

In addition to those permitted only for stormwater, facilities with NPDES permits are as follows:

- Forrest Paint Co. has a GEN01 permit which allows the discharge of industrial cooling water discharge to surface water.
- Georgia-Pacific Resins, Inc., Eugene Resin Plant has an NPDES-IW-N permit, No. 101474, which allows discharge of stormwater runoff via Outfall 001 and boiler blowdown, cooler water, and stormwater via Outfall 002 to an unnamed tributary to Amazon Creek. Outfall 001 may not discharge form June 1 to Oct 31, the time period for which Amazon Diversion Channel is listed for DO. Outfall 002, however, may discharge year-round.
- Madill Corporation and Army Forces Reserve Maintenance Shop have GEN17A permits. These are permitted to discharge industrial washwater to surface water.
- Conard Snow has a GEN51b permit which allows the operation of an onsite sand filter for domestic wastewater treatment.

In addition, there are a number of permitted facilities on A-3 Drain, which flows into the Amazon Creek natural channel downstream of the Amazon Diversion Channel diversion. During low flow periods, water from A-3 Drain appears to be released by the diversion dam and flow down the natural Amazon Creek channel rather than through the Amazon Diversion Channel. During high flow periods, this water could back flow and impact Amazon Diversion Channel.

Several NPDES facilities have potential for heating the stream. Point sources with potential to heat the stream are addressed in the Upper Willamette Temperature TMDL.

Map 10.21 NPDES permitted facilities - Amazon Creek

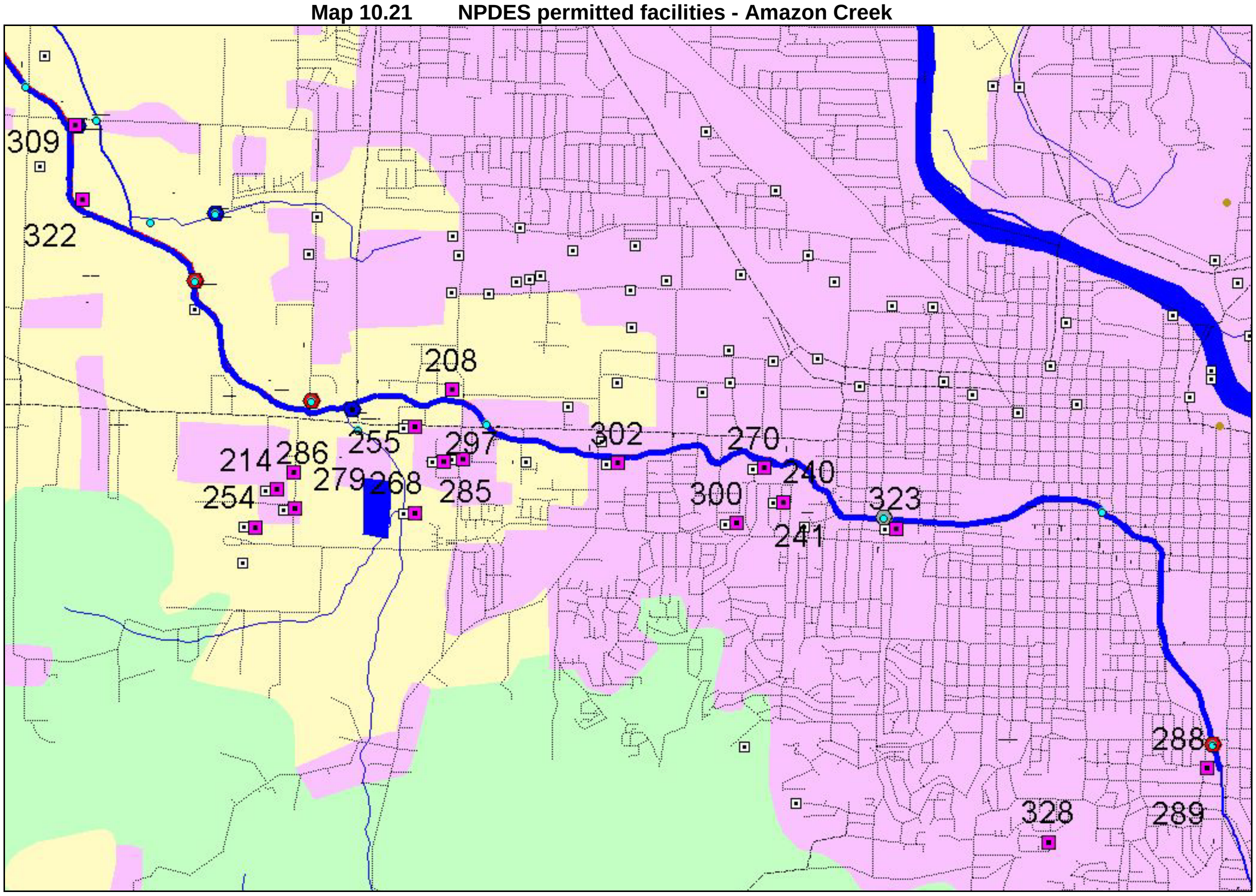


Table 10. 49 NPDES permitted facilities - Amazon Creek

ID	Common Name	City	Permit Type	Permit No.	WQ File No.	USEPA No.	WQ Category	Pmt Desc	Lat	Long	Type
208	AL'S SHEET METAL	EUGENE	GEN12Z	14846	108843	ORR202046	STM	1200-Z	44.050900	-123.163200	general
214	BULK HANDLING SYSTEMS, INC.	EUGENE	GEN12Z	12378	104795	ORR111993	STM	1200-Z	44.043000	-123.181100	general
240	FORREST PAINT CO.	EUGENE	GEN01	11192	100684	ORG253508	IND	100-J	44.043300	-123.128400	general
241	FORREST PAINT CO.	EUGENE	GEN12Z	11190	100684	ORR231018	STM	1200-Z	44.043300	-123.128400	general
245	G P EUGENE RESIN PLANT	EUGENE	NPDES-IW-N	101474	32864	OR0002101	IND	* (See Below)	44.101400	-123.272300	individual
254	HYNIX SEMICONDUCTOR	EUGENE	GEN12Z	15095	109089	ORR112114	STM	1200-Z	44.040100	-123.183200	general
255	INDUSTRIAL ADHESIVES, INC.	EUGENE	GEN12Z	14806	108805	ORR112036	STM	1200-Z	44.048000	-123.167000	general
268	LAURENCE-DAVID INC.	EUGENE	GEN12Z	11116	100471	ORR231408	STM	1200-Z	44.041600	-123.166700	general
270	MADILL CORPORATION	EUGENE	GEN17A	17590	109638	ORG753514	IND	1700-A	44.045800	-123.130600	general
279	MOLECULAR PROBES, INC.	EUGENE	GEN12Z	11324	102076	ORR231424	STM	1200-Z	44.041600	-123.179200	general
285	OBIE CONSTRUCTION, INC.	EUGENE	GEN12Z	14794	108794	ORR202030	STM	1200-Z	44.045500	-123.163900	general
286	OREGON COACHWAYS, INC.	EUGENE	GEN12Z	14791	108792	ORR802027	STM	1200-Z	44.044300	-123.179400	general
288	ARMED FORCES RESERVE MAINT. SHOP	EUGENE	GEN12Z	17298	111771	ORR114146	STM	1200-Z	44.024400	-123.083600	general
289	ARMED FORCES RESERVE MAINT. SHOP	EUGENE	GEN17A	17297	111771	ORG754109	IND	1700-A	44.024400	-123.083600	general
297	PRECISION MACHINE & MFG	EUGENE	GEN12Z	12798	106612	ORR111216	STM	1200-Z	44.045700	-123.161900	general
300	QUALITY METAL FINISHING	EUGENE	GEN12Z	15518	109557	ORR208015	STM	1200-Z	44.041600	-123.133300	general
302	REXIUS FOREST	EUGENE	GEN12Z	12998	106920	ORR221322	STM	1200-Z	44.045800	-123.145800	general
309	SNOW, CONARD	EUGENE	GEN51b	15098	109092		DOM	5102	44.069800	-123.203200	general
322	USACOE - AMAZON CREEK WETLAND RESTORATION	EUGENE	GEN12C	16397	110568	ORR103716	STM	1200-C	44.064200	-123.202200	general
323	USF REDDAWAY INC.	EUGENE	GEN12Z	13568	107628	ORR801659	STM	1200-Z	44.041600	-123.116700	general
328	WESTERN PATCH & MFG, INC.	EUGENE	GEN12Z	16572	110782	ORR603750	STM	1200-Z	44.018500	-123.099800	general
* Facilities not elsewhere classified which disposal of process wastewater											

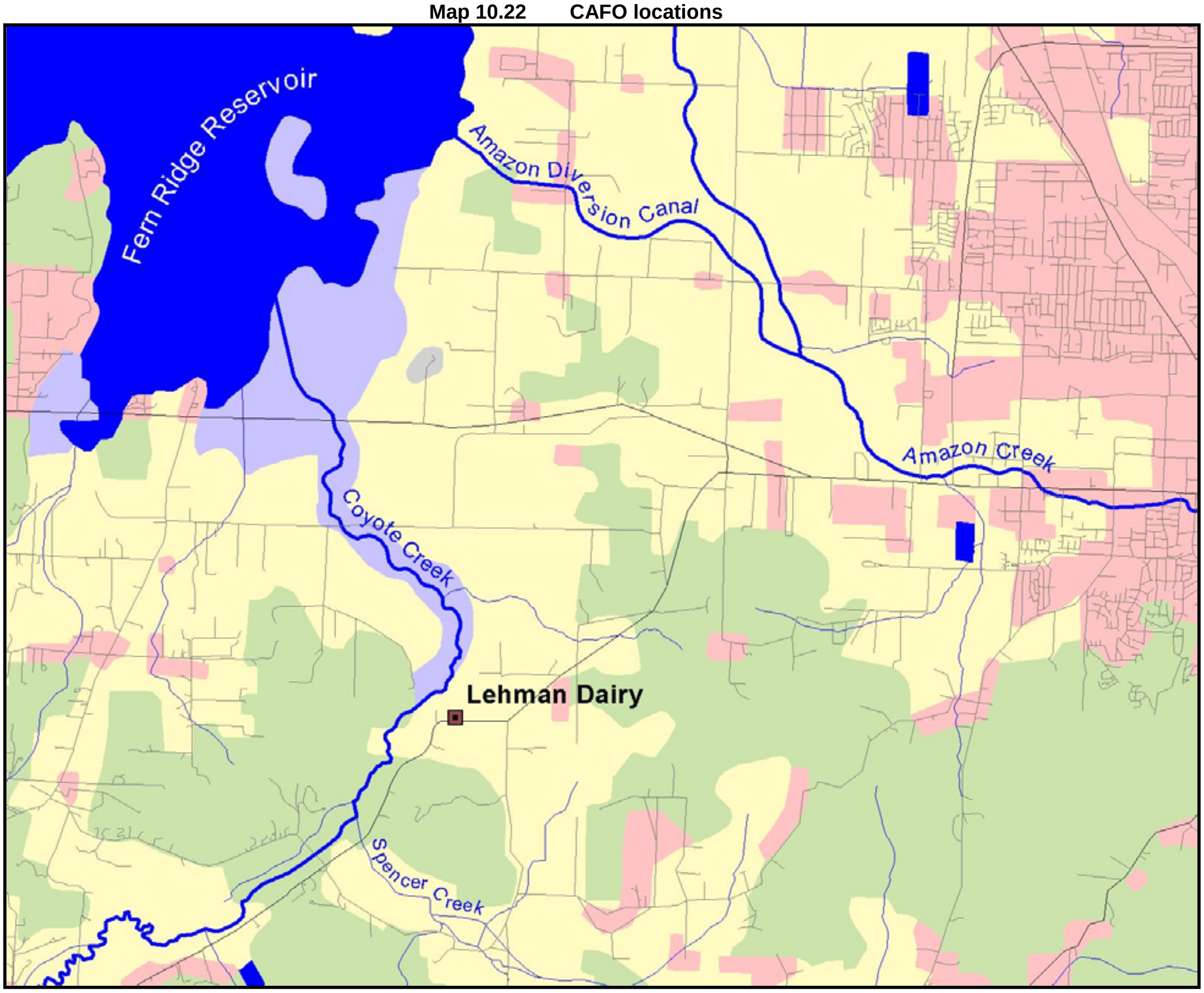
Confined Animal Feeding Operations (CAFOs)
Confined Animal Feeding Operations (CAFOs) have significant potential to discharge large quantities of nutrients, ammonia, and oxygen demanding pollutants to streams. CAFOs are generally operations in which animals are concentrated in buildings or surface prepared pens or lots, or which hold and treat animal waste products, such as manure lagoons. CAFO wastes include, but are not limited to, manure, silage pit drainage, wash down waters, contaminated runoff, milk wastewater, and bulk tank wastewater.

The CAFO permit program is administered by the Oregon Department of Agriculture (ODA). Since the early 1980s CAFOs have been registered to a general Water Pollution Control Facility (WPCF) permit. The 2001 Oregon legislature directed ODA to convert the program to an NPDES permit program.

For more information on CAFO permits, see the ODA website: http://www.oda.state.or.us/

One CAFO has been identified near Coyote Creek (Map 10.22). The CAFO, Lehman Dairy (License No. 143657), is located downstream of Spencer Creek in the vicinity of significant algae and dissolved oxygen concerns.

Map 10.22 CAFO locations



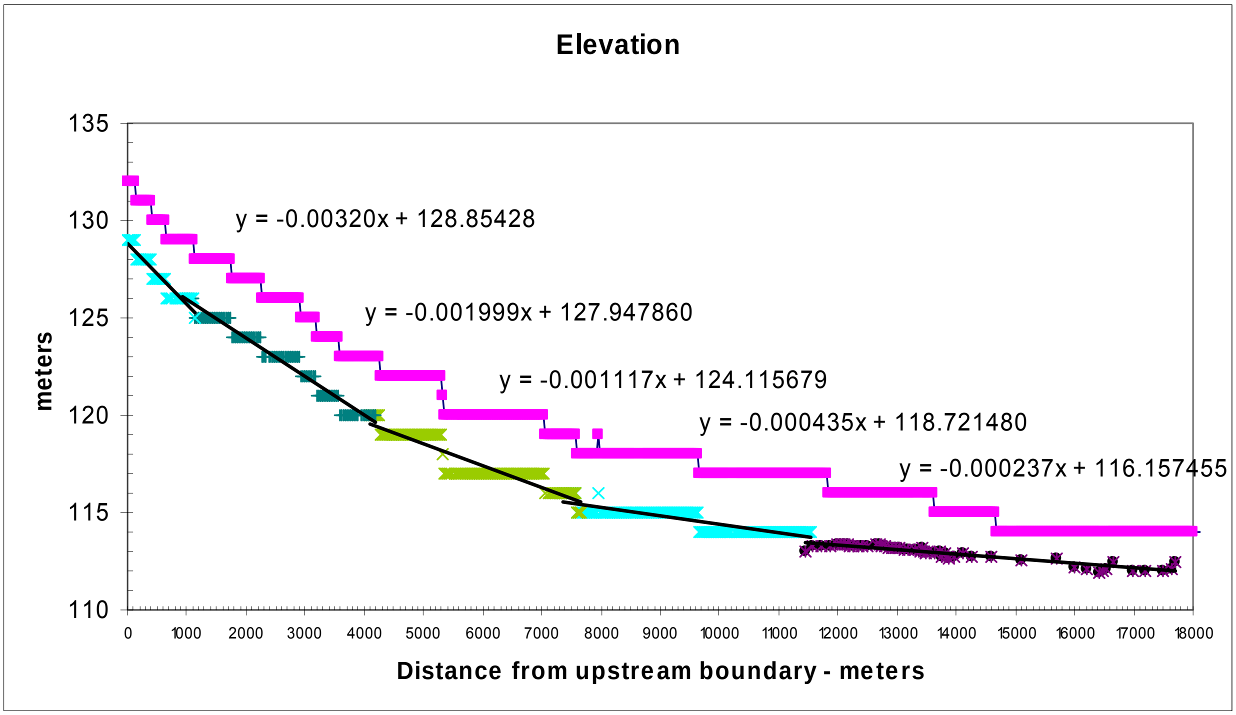
Amazon Creek Model

A model of Amazon Creek and Diversion Channel was developed using the modeling framework CE-QUAL-W2 (W2). W2 is a two-dimensional, laterally averaged hydrodynamic and water quality model developed by the U.S. Army Corps of Engineers, Waterways Experiment Station (Cole and Wells, 2002). The model calculates hydrodynamics, including water surface elevations and velocities; thermodynamics, including temperature; and water quality, including dissolved oxygen, nutrients, and attached and suspended algae concentrations.

Model Segmentation, Geometry and Flow

The model extends from Amazon Creek at Martin Street, model river mile (RM) 12.7 to a weir which defines the confluence of Amazon Creek Diversion Channel with Fern Ridge Reservoir (RM 0.0). It includes 178 segments with lengths ranging from 61 m in upper higher slope reaches to 305 m in lower reaches. The model is divided into five reaches (referred to as “branches” by CE-QUAL-W2) and two “waterbodies”. The upper water body (WB 1) consists of free flowing reaches with depth defined by channel roughness. The lower water body (WB 2) consists mostly of impounded reaches with depth mostly defined by weir elevations. Slopes of each branch are defined by regressions through Digital Elevation Model elevations (see Figure 10.56).

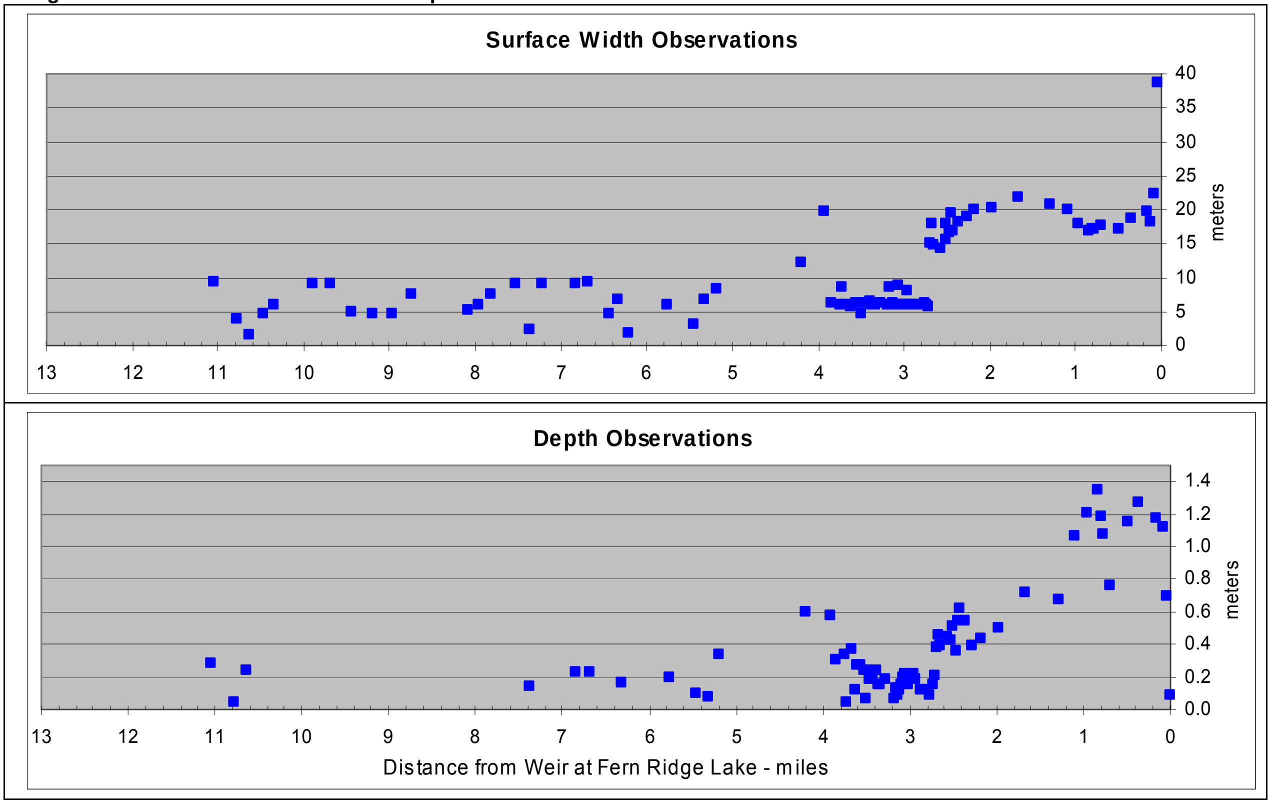
Figure 10.56 W2 model branch slopes



Data used to derive stream width and depth includes (Figure 10.57):

1. A HEC-RAS model developed by the U.S. Army Corps of Engineers of Amazon Creek and Diversion Channel. The model included measured channel and floodplain elevations at 26 cross-sections from Amazon Creek at SPRR Bridge (RM 3.9) to Amazon Diversion Channel (RM 2.7).
2. Data collected by the City of Eugene from Amazon Diversion Channel at Royal Avenue (RM 2.7) to a weir at the confluence of Amazon Diversion Channel with Fern Ridge Reservoir (RM 0.0). This included channel and bank elevations and defined edge of water locations and elevations.
3. Data collected by ODEQ during a July 2001 stream walk from Fern Ridge Reservoir to Amazon Creek at 29th Street (RM 10.9). Data was collected at 76 locations. Estimated stream widths were collected and, where wadeable, depths were measured.

Figure 10.57 Amazon width and depth observations



Each segment is divided into 5 vertical layers, which allows wetted width to vary with flow and depth (Table 10.50).

Table 10. 50 W2 Model Geometry

Waterbody:	1	1	1	1	2	2
Branch:	**1**	**2**	**3**	**4**	**5 (upper)**	**5 (lower)**
Layer Thickness - top layer (meters):	0.4	0.4	0.4	0.4	0.6	0.6
Layer Thickness - remaining layers:	0.2	0.2	0.2	0.2	0.3	0.3
Layer 1 – Virtual:	NA	NA	NA	NA	NA	NA
Layer 2 - Top layer width (meters):	7.2	9.2	12.4	12.4	16.4	20.7
Layer 3 – Width:	6.4	8.4	10.9	10.9	12.3	19.0
Layer 4 – Width:	5.6	7.6	9.9	9.9	9.6	18.0
Layer 5 – Width:	4.8	6.8	8.9	8.9	6.9	16.9
Layer 6 - Bottom layer width:	4.0	6.0	7.9	7.9	4.2	15.8
Layer 7 – Virtual:	NA	NA	NA	NA	NA	NA
Slope (m/m):	0.003195	0.001999	0.001117	0.000435	0.000237	0.000237
Bottom elevation of final segment (ELBOT) (m):	125.72	119.44	115.22	113.53		111.98

Stream flow rates were based on limited flow measurements taken during the July, 2001 survey. Measured flow rates ranged from 1.0 to 2.3 cfs.

At model mile point 3.5 (3.5 miles u/s of weir at lake), stream flow is split between the Amazon Creek natural channel and Amazon Creek Diversion Channel. An undetermined amount of flow is released through a hole in the diversion dam in order to prevent complete dewatering of the natural channel. Some of this flow appears to consist of flow from A-3 Canal. Amazon Creek flow not released through the diversion dam is transported via Amazon Creek Diversion Channel to Fern Ridge Reservoir. During low flow periods, evaporation and irrigation diversions may reduce the discharge to Fern Ridge Reservoir to zero. This may have been the case during the July, 2001 survey, as no flow was observed over the weir/sediment trap at the confluence with Fern Ridge Reservoir.

Shade Inputs – Heat Source Model

A vegetation assessment was performed in order to derive shade inputs for the CE-QUAL-W2 model. Digital orthophoto quadrangle (DOQ) images were used in conjunction with orthorectified color aerial photographs and field data to digitize vegetation polygons. Vegetation characteristics of height, density, and overhang were assigned to each vegetation type. The TTools vegetation analysis programs (Boyd and Kasper, 2002) and the modeling framework Heat Source (Boyd and Kasper, 2004) were then used to calculate daily average effective shade for every 100 ft. Heat Source model segment.

Example vegetation polygons at the uppermost station, Amazon Creek at 29th Ave (25624, RM 10.9), are shown in Figure 10.58 along with corresponding upstream and downstream photos in Figure 10.59. As shown, existing vegetative shade is limited in the vicinity of this station.

Figure 10.58 Digitized vegetation polygons in vicinity of Station 25624

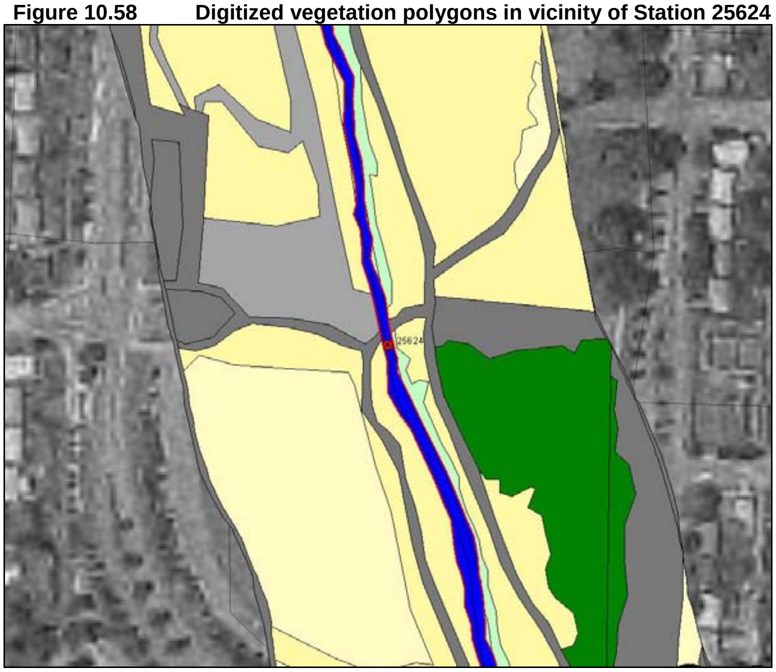
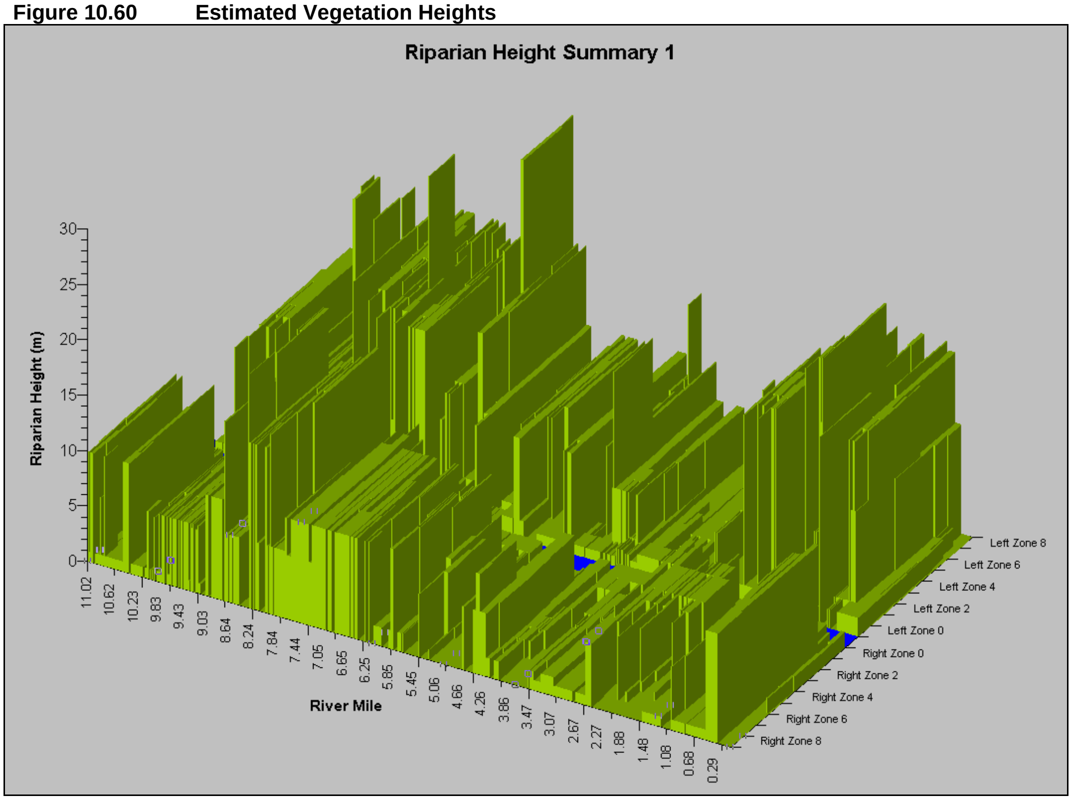


Figure 10.59 Amazon Creek at 29th St – LASAR 25624 – RM 10.9 (u/s Lake) - view u/s left panel, d/s right panel

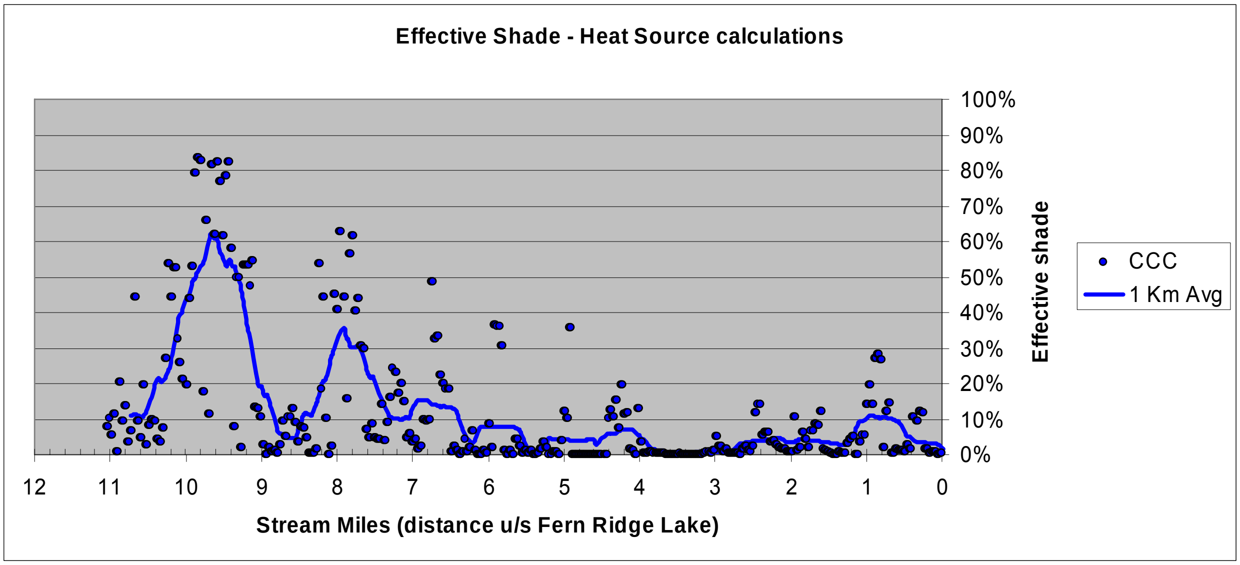
Vegetation heights calculated by TTools for Amazon Creek for a 40 m buffer on each side of the stream are presented graphically in Figure 10.60. As shown, much of the system is poorly shaded.

Figure 10.60 Estimated Vegetation Heights



Daily average effective shade as calculated by Heat Source (v.6.5.1) is presented in Figure 10.61. As shown, as vegetative heights decline, so does effective shade. While some of the upper reaches are shaded reasonably well, shade for lower reaches is quite poor.

Figure 10.61 Heat Source estimated effective shade (calibrated current condition, CCC)

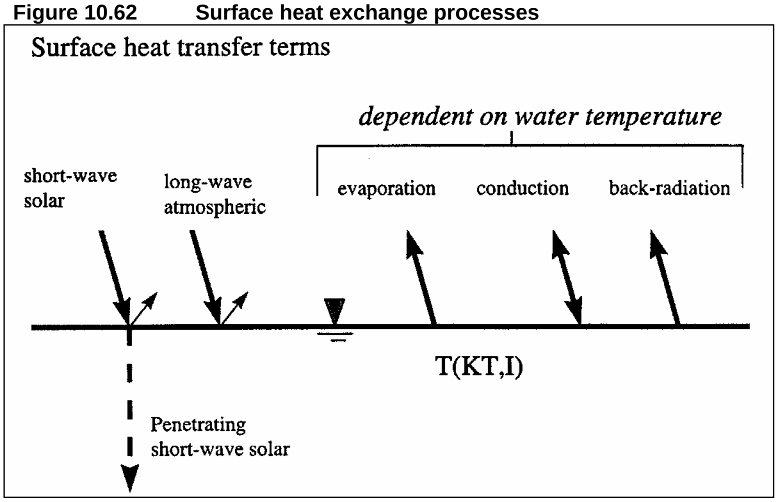


Model Calibration – Thermodynamics

This section describes CE-QUAL-W2 (W2) model calibration related to model predictions of temperature.

Stream temperature in Amazon Creek is controlled primarily by surface heat exchange processes (see Figure 10.62) and stream width and depth characteristics.

Figure 10.62 Surface heat exchange processes



Surface heat exchange processes consist of shortwave solar radiation (H_s), long wave atmospheric radiation (H_a), long wave back-radiation (H_b), heat loss or gain due to evaporation or condensation (H_e), reflected solar and atmospheric radiation(H_{sr} and H_{ar}), and loss or gain by conduction (H_c), with net surface heat flux (H_N) is calculated as follows:

$$H_N = H_s - H_{sr} + H_a - H_{ar} - H_b \pm H_c \pm H_e$$

Units are in energy per unit area per unit time (BTU/ft^2/day, cal/cm^2/day or Watts/m^2).

Heat flux due to short wave radiation flux is a function of the total solar radiation available and the reduction in solar radiation provided by vegetative and topographic shading. Heat fluxes due to evaporation and conduction are dependent on meteorological conditions, including air temperature, humidity and wind speed. Therefore, it is important to accurately estimate solar radiation, vegetative and topographic shading, and meteorological conditions.

The source for solar radiation for the model was hourly data from the University of Oregon Solar Radiation Monitoring Laboratory (SRML) in Eugene. In order to improve the model calibration for temperature, solar radiation inputs to the model were set to 90% of observed.

The SRML was also the source for air temperature and wind speed. No deviations were made from the observed data.

Cloud cover was derived from the SRML, Eugene solar radiation data. Dewpoint temperature was derived from SRML, Eugene air temperature and humidity data.

Shade inputs were calculated by the Heat Source model described earlier. No changes were made to these during the calibration process.

Diel temperature fluctuations are also a function of stream depth, as indicated by the following equation:

$$\Delta T = \frac{H_N}{c \rho d}$$

where:

ΔT = allowable temperature change, C

H_N = net energy per square area, Joules / m^2

c = specific heat, Joules / g C

d = depth, m

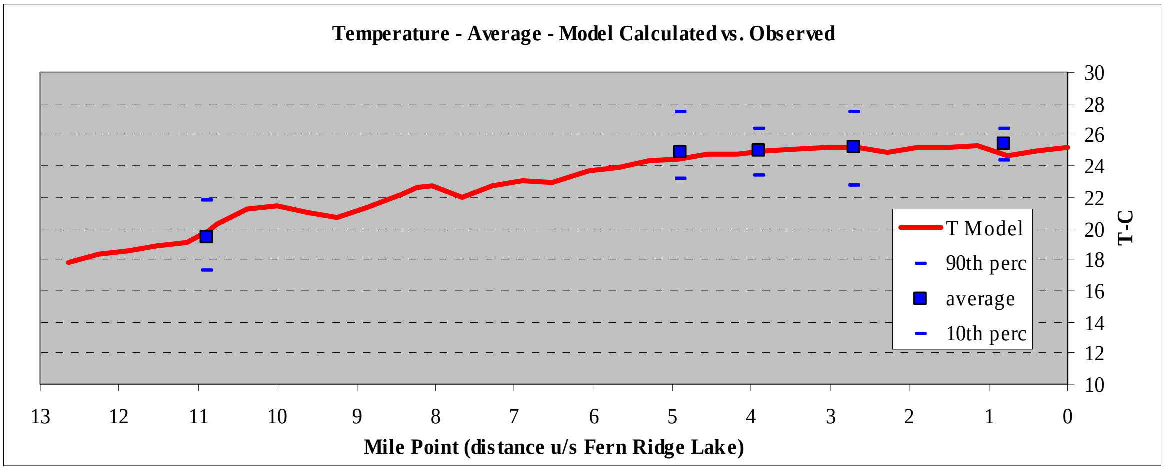
ρ = water density, g / m^3

As stream depth is increased, diel temperature fluctuations are reduced. Therefore, stream depth is an important calibration parameter.

Stream depth is influenced by flow rate, stream width, and friction (Manning's n). Adjustments were made to stream widths and Manning's n values until a reasonable temperature calibration was achieved.

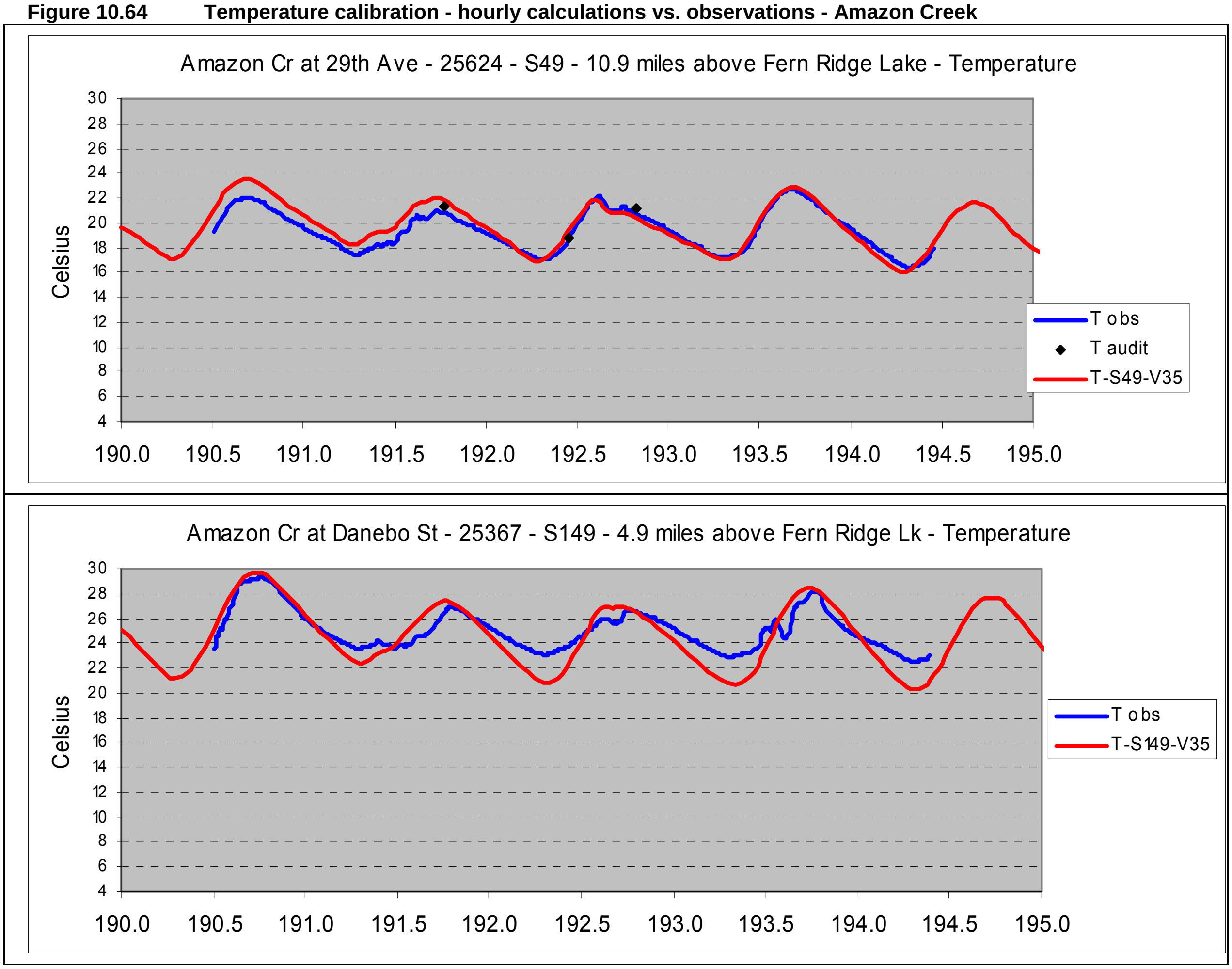
The model calculated 3-day average water temperatures for July 10-12, 2001 (Julian days 191.0-194.0) are compared to observed temperatures in Figure 10.63. Shown are mean, 10th percentile, and 90th percentile temperatures recorded at four multi-parameter "Hydrolab" continuous monitoring stations and one thermistor station during the period July 9-13, 2001. In general, the observed means are 3-d means for Julian days 191.0-194.0. For 3 days, data was not available for the full period and slightly different averaging periods were used, as follows: RM 3.9, 190.678-193.605; RM 2.7, 190.604-193.605; RM 0.8, 190.657-193.657. As shown, the model calibration for daily average temperature is quite good.

Figure 10.63 Model calculated average stream temperatures vs. observed



Model calculated hourly temperatures are compared to observations in Figures 10.64 and 10.65. As shown, the model provides reasonable predictions of temperature.

Figure 10.64 Temperature calibration - hourly calculations vs. observations - Amazon Creek



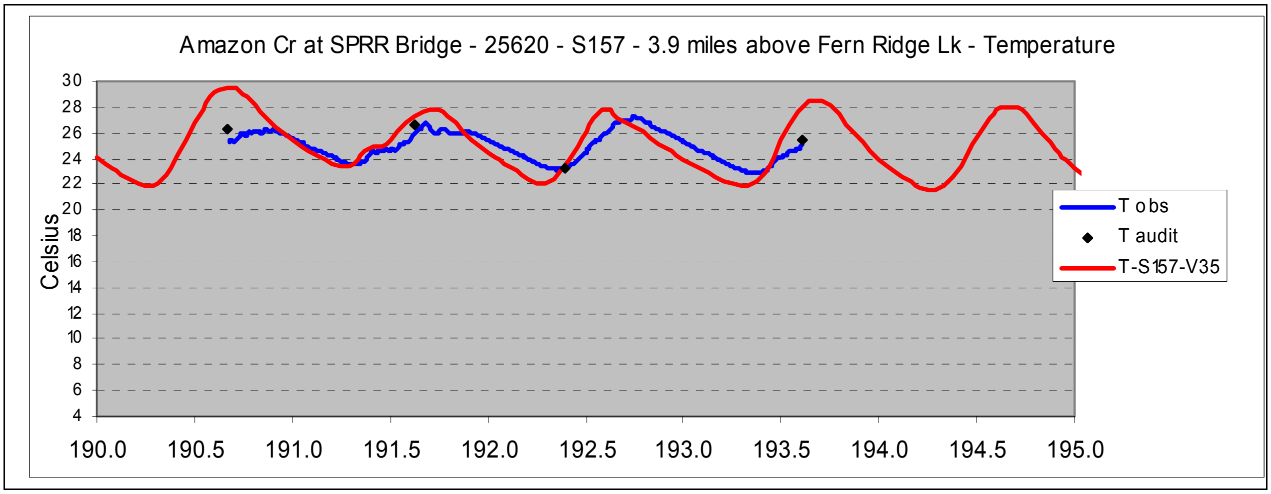
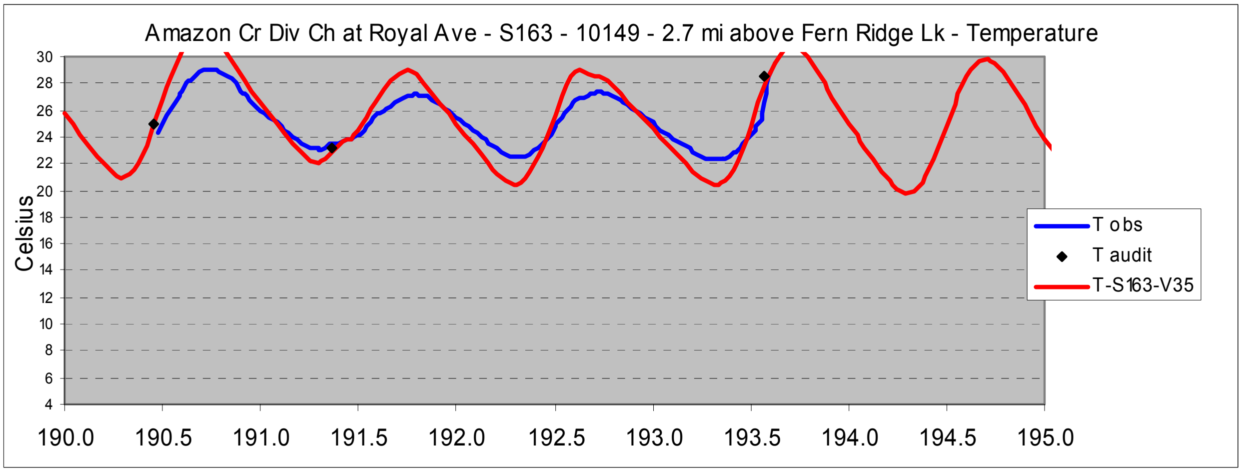
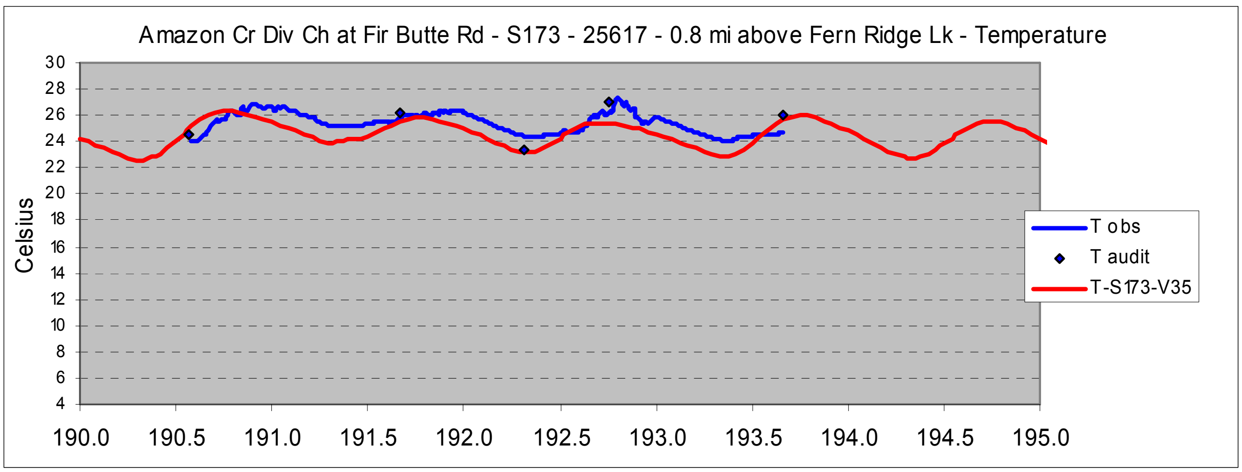

Amazon Cr at SPRR Bridge - 25620 - S157 - 3.9 miles above Fern Ridge Lk - Temperature
Celsius
30
28
26
24
22
20
18
16
14
12
10
8
6
4
190.0
190.5
191.0
191.5
192.0
192.5
193.0
193.5
194.0
194.5
195.0
T obs
T audit
T-S157-V35

Figure 10.65 Temperature calibration-hourly calculations vs. observations – Amazon Diversion Channel





Error statistics for hourly predictions are presented in Table 10.51. As shown, root mean square (RMS) error ranges from 0.73 to 1.47 °C.

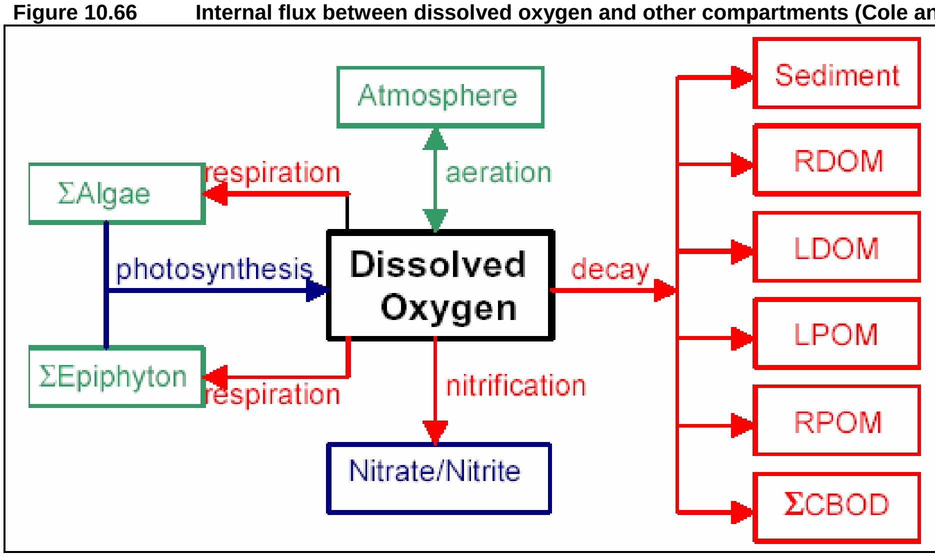
Table 10. 51 Temperature calibration - error statistics - hourly calculations

Stations	Mean Error (ME) °C	Absolute Mean Error (AME) °C	Root Mean Square_Error (RMS) °C
Amazon Cr at 29th Ave – 25624 - Segment 49 10.9 miles above Fern Ridge Lake	0.37	0.58	0.73
Amazon Cr at Danebo St - 25367 – Segment 149 4.9 miles above Fern Ridge Lk	-0.38	1.04	1.25
Amazon Cr at SPRR Bridge - 25620 – Segment 157 3.9 miles above Fern Ridge Lk	0.08	1.08	1.31
Amazon Cr Div Ch at Royal Ave – 10149 Segment 163 - 2.7 mi above Fern Ridge Lk	0.26	1.22	1.47
Amazon Cr Div Ch at Fir Butte Rd – 25617 Segment 173 - 0.8 mi above Fern Ridge Lk	-0.74	0.92	1.01

Model Calibration – Water Quality Constituents

Active water quality constituents include total dissolved solids, *E. coli* (coliform), conductivity, inorganic suspended solids, phosphorus (total, organic, and orthophosphate), nitrogen (total, organic, ammonia, and nitrate), organic matter (labile and refractory dissolved and particulate), carbonaceous biochemical oxygen demand (CBOD), phytoplankton (suspended algae), periphyton (attached algae), and dissolved oxygen. Of these parameters, phosphorus, nitrogen, organic matter, CBOD, phytoplankton, and periphyton directly or indirectly influence dissolved oxygen concentrations (Figure 10.66). Other constituents were modeled either because of other water quality concerns, i.e., bacteria, or to aid in the calibration process.

Figure 10.66 Internal flux between dissolved oxygen and other compartments (Cole and Wells, 2002)



Model calibration for dissolved oxygen focused on rates and coefficients related to dissolved oxygen. Some important calibration parameters related to the dissolved oxygen calibration are described in Table 10.52, along with selected values.

Table 10. 52 Model Rates, Constants, and Kinetics

Parameter	Description	Default	Typical Range	Selected
ER	Maximum periphyton respiration rate, day^{-1}	0.04		0.10
AR	Maximum algal respiration rate, day^{-1}	0.04	0.04-0.05	0.10
EN	Stoichiometric equivalent between periphyton biomass and nitrogen (mg N / mg OM)	0.08		0.08
AN	Stoichiometric equivalent between algal biomass and nitrogen (mg N / mg OM)	0.08	0.08-0.10	0.08
EP	Stoichiometric equivalent between periphyton biomass and phosphorus (mg P / mg OM)	0.005		0.010
AP	Stoichiometric equivalent between algal biomass and phosphorus (mg P/mg OM)	0.005	0.005-0.02	0.010
K2 (Br.1-4)	Reaeration rate equation for Branches 1-4 (Amazon Creek)			River Eq.8 Melching and Flores
K2 (Br.5)	Reaeration rate equation for Branch 5 (Amazon Diversion Channel)1`			River Eq. 1 O'Connor and Dobbins
KBOD	CBOD decay rate, day^{-1}			0.10
CBODP	Phosphorus stoichiometry for CBOD decay		0.011	0.005
CBODN	Nitrogen stoichiometry for CBOD decay		0.08	0.08
EG	Maximum periphyton growth rate, day^{-1}	2.0	0.2-2.0	1.5
AG	Maximum algal growth rate, day^{-1}	2.0	1.5-2.5	2.5

AS	Maximum algal settling rate, m/day	*0.1*	*0.01-0.5*	*0.20*

An iterative calibration process was employed in which nutrient and BOD loads and parameters were adjusted until the calibration was optimized. Estimated system average calibration current condition unit loads per day for the stream are shown in Table 10.53. Note that these are loads estimated for the July 2001 calibration week, which was a low flow period without rainfall. Loads during a rainfall event would be much greater.

Table 10. 53 Calibration Current Condition Loads

Pollutant	Loads added (kg/day/km)
E. coli	73.6
Inorganic Suspended Solids	88.9
Orthophosphate	0.027
Ammonia nitrogen	0.026
Nitrite + Nitrate Nitrogen	0.086
Carbonaceous BOD (ultimate)	3.5

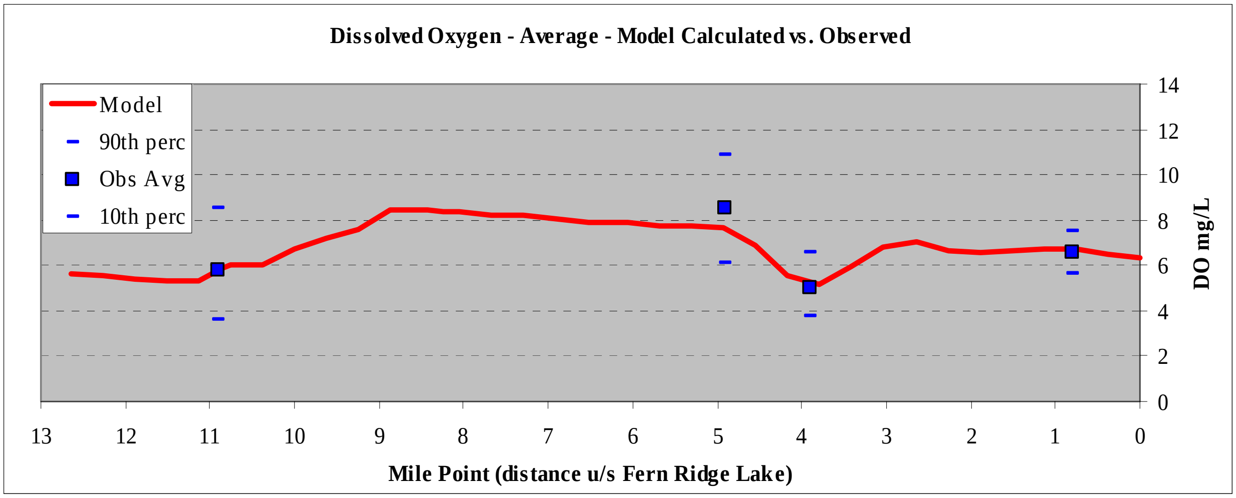
The final step of the calibration was derivation of sediment oxygen demand. Sediment oxygen demand was adjusted until observed 3-day regulatory average dissolved oxygen concentrations were met (when calculating regulatory averages, dissolved oxygen concentrations greater than saturation DO are set equal to saturation DO). Model SOD rates and coefficients are presented in Table 10.54.

Table 10. 54 Calibration Current Condition SODs (g O_2/m^2/day)

Reach (miles u/s Lake)	Model Segments	Zero-order SOD input to model	*Corresponding SOD @ 20^0C [1]*
12.7 to 10.4	2-62	4.0	*3.5*
10.4 to 4.6	65-150	1.0	*0.9*
4.6 to 3.5	151-158	3.5	*3.1*
3.5 to 0.0	159-177	1.5	*1.3*
[1] Conversion from input SOD to SOD @ 20^oC via rate multipliers of SODT1=4, SODT2=30, SODK1=0.1, and SODK2=0.99. These multipliers define the equation used for temperature correcting SOD rates.			

Model calculated 3-day average dissolved oxygen concentrations for July 10-12, 2001 (Julian days 191.0-194.0) are compared to observed concentrations in Figure 10.67 Shown are mean, 10th percentile, and 90th percentile DO concentrations recorded at the four “Hydrolab” continuous monitoring stations. In general, the observed means are 3-d means for Julian days 191.0-194.0. For three days, data was not available for the full period and slightly different averaging periods were used, as follows: RM 3.9, 190.678-193.605; RM 2.7, 190.604-193.605; RM 0.8, 190.657-193.657. As shown, the model calibration for daily average DO is quite good.

Figure 10.67 Model calculated average DO concentrations vs. observed


Dissolved Oxygen - Average - Model Calculated vs. Observed
Model
90th perc
Obs Avg
10th perc
14
12
10
8
6
4
2
0
DO mg/L
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Mile Point (distance u/s Fern Ridge Lake)

Model calculated hourly DO concentrations are compared to observations in Figure 10.68, and error statistics are presented in Table 10.55. The model provides excellent predictions of regulatory average DO. Predictions of hourly DO are also acceptable, except for RM 4.9 where RMS error is 2.26 mg/L. Fortunately, of the four continuous DO monitoring stations, DO was highest at this station and well above standards, so it was not a control point for load allocation calculations.

Table 10. 55 Dissolved Oxygen calibration - error statistics - hourly calculations

Stations	Mean Error (ME) mg/L	Absolute Mean Error (AME) mg/L	Root Mean Square Error (RMS) mg/L
Amazon Cr at 29th Ave – 25624 - Segment 49 10.9 miles above Fern Ridge Reservoir	0.21	0.55	0.75
Amazon Cr at Danebo St - 25367 – Segment 149 4.9 miles above Fern Ridge Lk	-0.86	1.96	2.26
Amazon Cr at SPRR Bridge - 25620 – Segment 157 3.9 miles above Fern Ridge Lk	0.11	1.00	1.16
Amazon Cr Div Ch at Fir Butte Rd – 25617 Segment 173 - 0.8 mi above Fern Ridge Lk	0.13	0.71	0.89

Model calibration plots for other parameters, including BOD and nutrients are presented in Figures 10.69 and 10.70. The model does a good job predicting dissolved reactive nutrients: orthophosphate and inorganic nitrogen. Model calculations of BOD and E. coli are also reasonable (Figure 10.70).

For algae, the model calculates both periphyton (attached benthic algae) and phytoplankton (suspended algae) concentrations. The model calculates that shallow, fast flowing upper reaches of Amazon Creek are dominated by periphyton, while lower reaches of Amazon Diversion Channel, which are much deeper and slower moving, are dominated by phytoplankton. This is consistent with qualitative observations. Based on an algal biomass to chlorophyll *a* ratio of 50, the model provides reasonable predictions of phytoplankton concentrations in lower Amazon Creek Diversion Channel. However, calculated phytoplankton concentrations are significantly less than observed at RM 3.9 (Amazon Creek at SPRR Bridge) and the ratio of phytoplankton to periphyton may be greater in this area than predicted by the model. Unfortunately, no quantitative measurements of periphyton are available for comparison.

Figure 10.68 Dissolved oxygen calibration - hourly calculations vs. observations - Amazon Creek

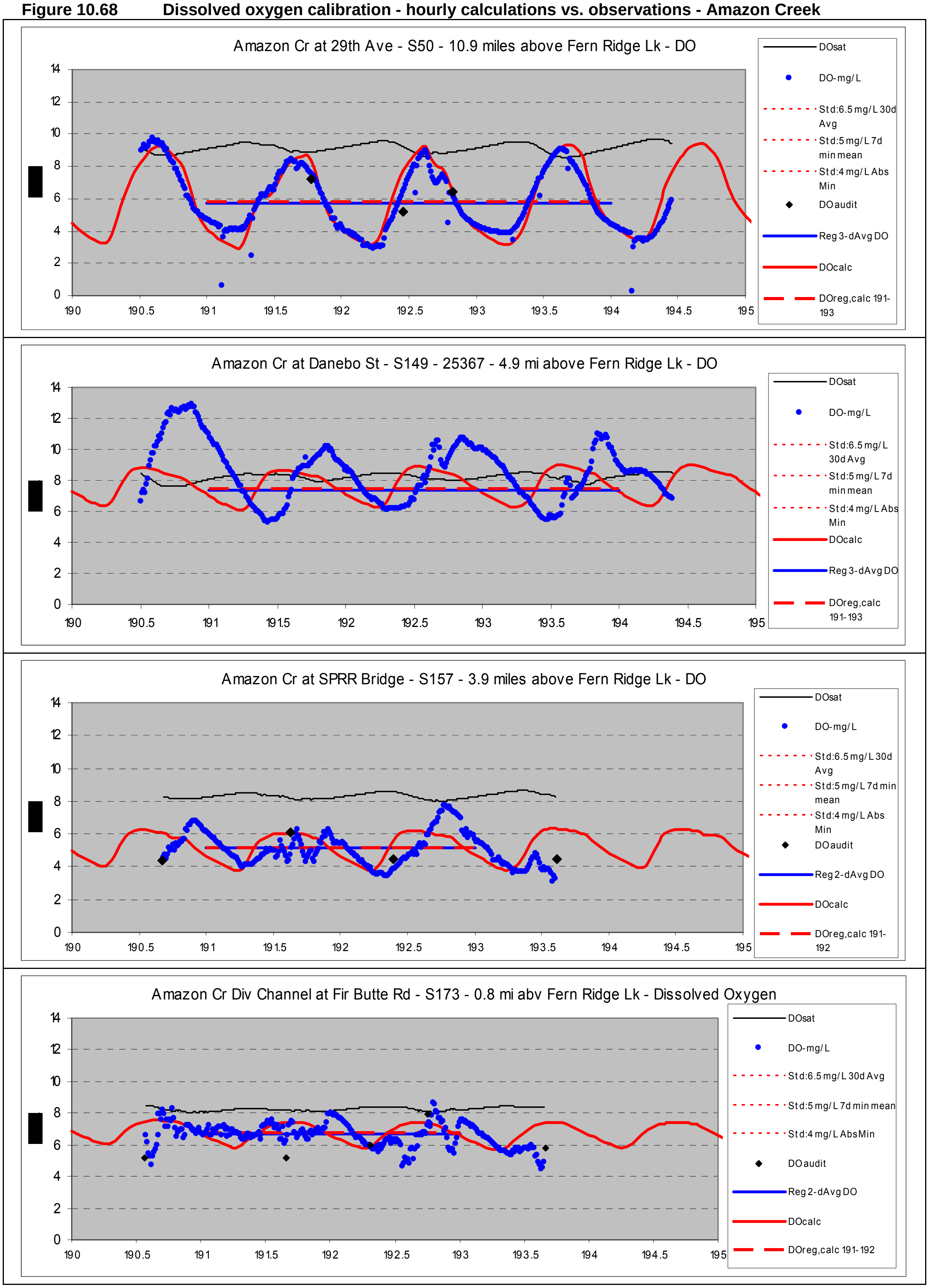


Figure 10.69 Model calculated nutrients vs. observations

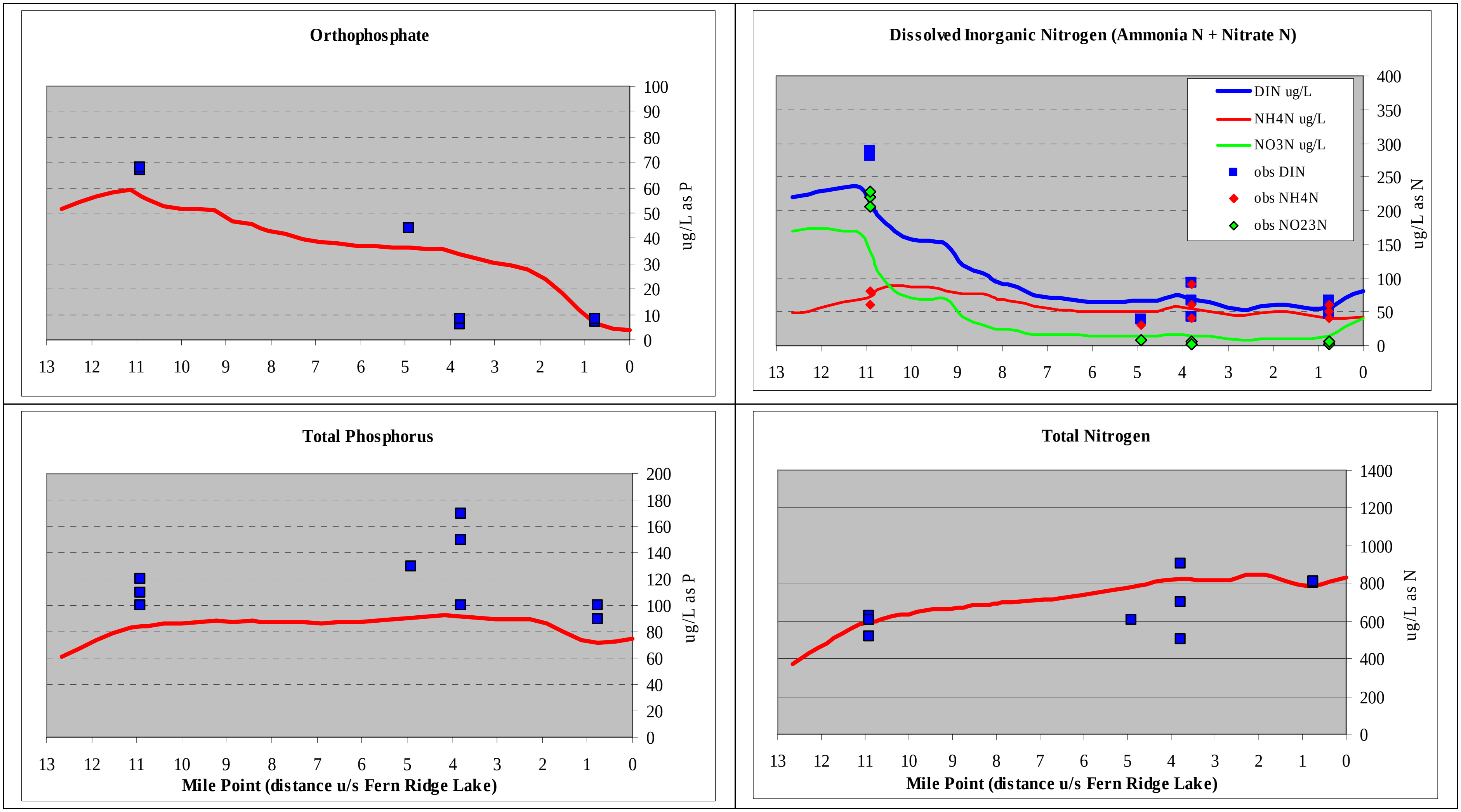
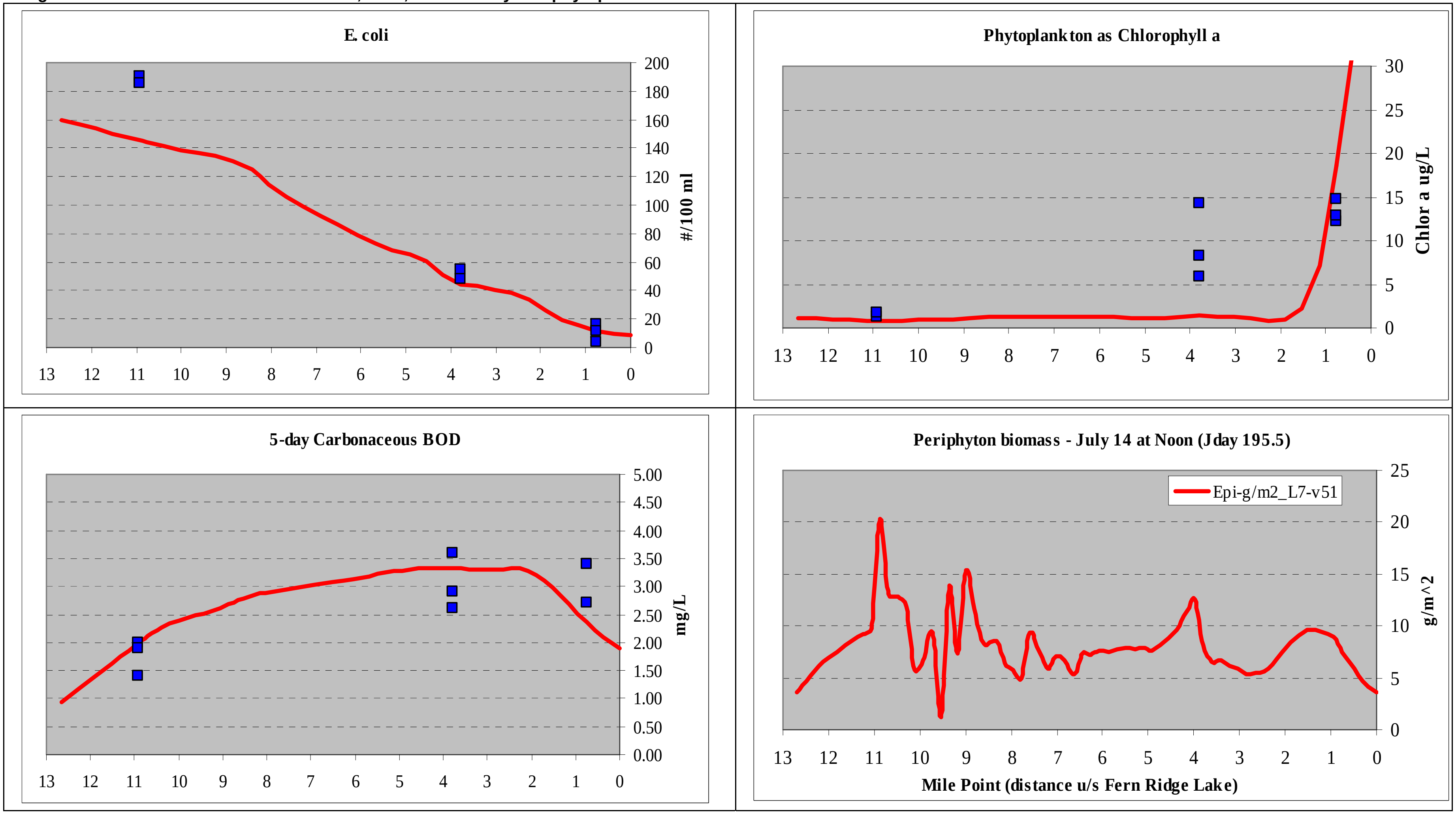


Figure 10.70 Model calculated E. coli, BOD, conductivity and phytoplankton vs. observed



System Potential Vegetation Scenarios – Temperature Sensitivity

Three system potential vegetation scenarios were developed in accordance with ODEQ methodologies (DEQ, 2004b) and evaluated with the model, as follows:

1. System Potential A (SysPotA). This is a maximum shade scenario in which all vegetation has been set to vegetation type Qbf-Forest (Veg code 811, see Map 10.23), which is the vegetation type expected for the dominant geomorphic classification for Amazon Creek, Qbf (see Table 10.56). This is a forest condition with a vegetation height of 29.7 m, a vegetation density of 75%, and an overhang of 3.6 m. In this scenario vegetation is grown on all surfaces outside of the active stream channel, including dikes.
2. System Potential B (SysPotB). This is a variation on the SysPotA and allows for a degree of disturbance. In this, vegetation types are randomly distributed between vegetation types Qbf-Forest, Qbf-Savanna, and Qbf-Prairie. As with SysPotA, vegetation is grown on all surfaces outside of the active stream channel, including dikes.
3. System Potential C (SysPotC). This is the same as SysPotB except that Heat Source model zones 0 and 1, which comprise the first 10 m beyond the active stream channel, are kept at the calibration current condition (CCC) . This reflects the possibility that no vegetation can be grown on dikes, channel riprap, etc., due to dike stability and flood control concerns.

System Potential Vegetation methodology is discussed in detail in Appendix C: Temperature

Map 10.23 Geomorphology Classifications - Upper Willamette Subbasin

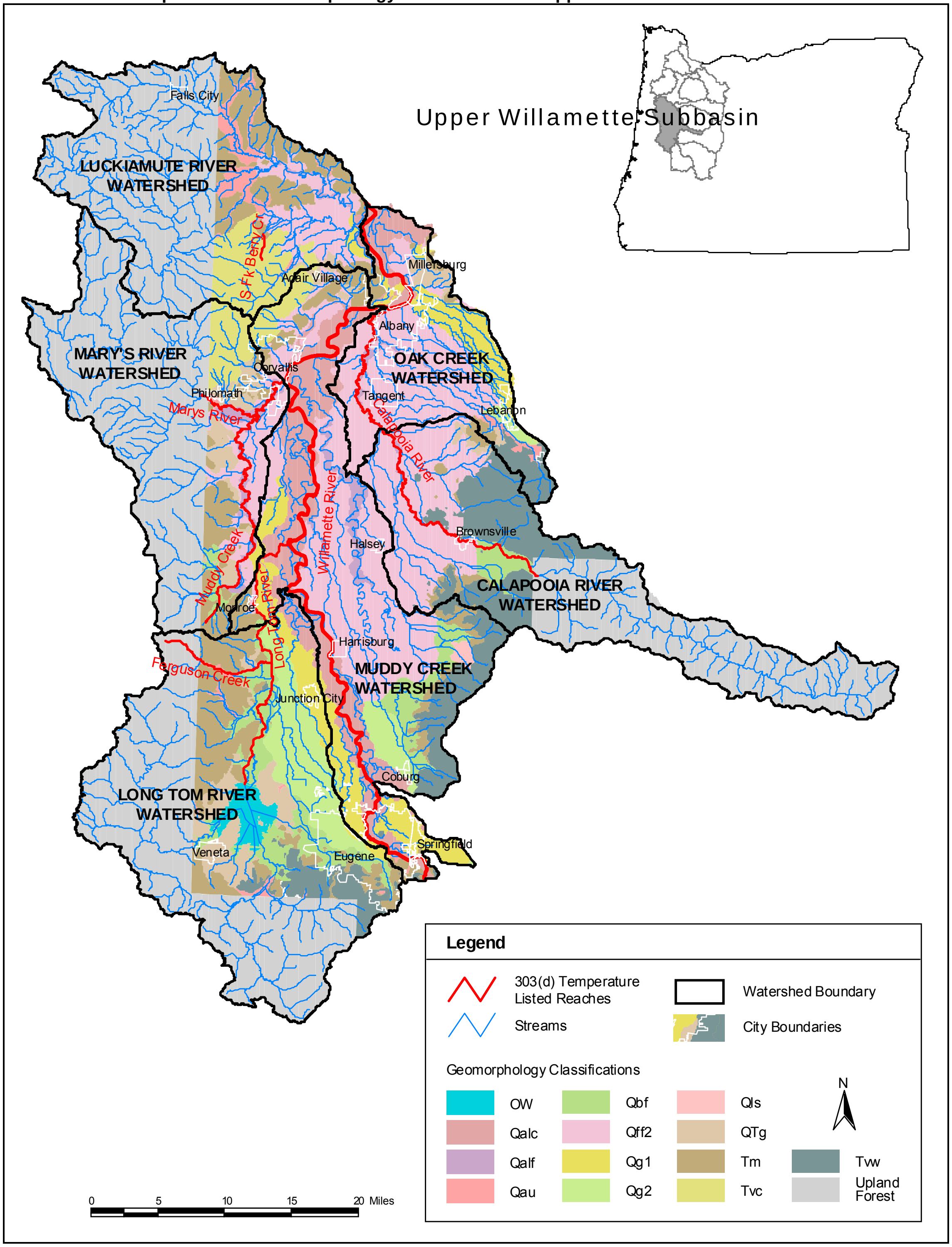
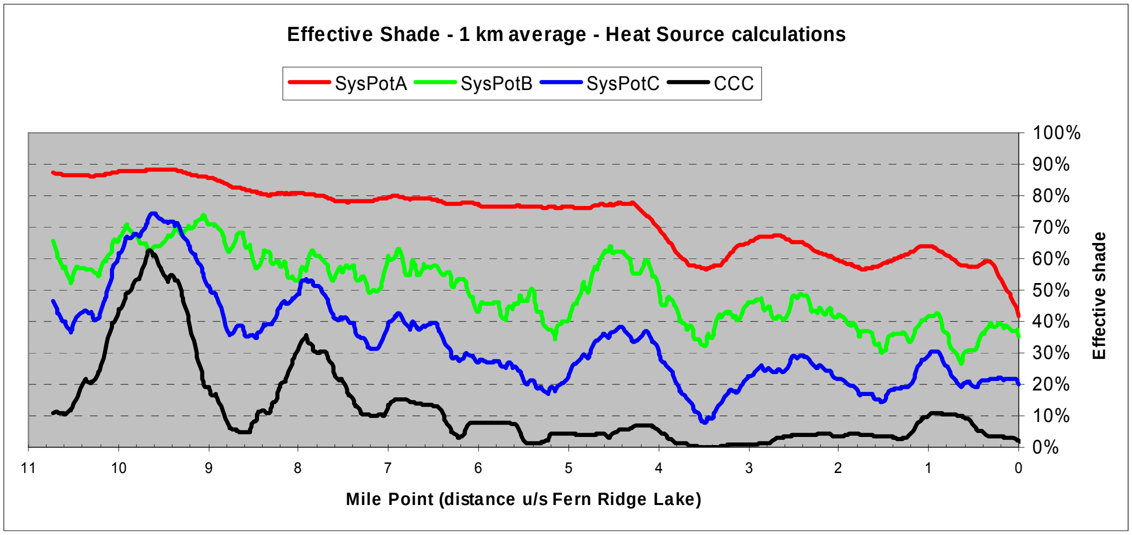


Table 10. 56 Vegetation types applied to Amazon Creek

Code	Source	Description	Height (m)	Density (%)	Overhang (m)
811	DEQ	Qbf Forest	29.7	75%	3.6
812	DEQ	Qbf Savanna	26.1	50%	3.1
813	DEQ	Qbf Prairie	0.9	75%	0.0

The model Heat Source was used to calculate shade conditions for the three vegetation conditions (Figure 10.71). SysPotA represents a maximum potential shade scenario. Effective shade ranges from 70 to 90% on upper reaches and 40% to 70% on lower where impoundments and channel alterations result in a wider channel.

Figure 10.71 System Potential Shade Scenarios – 1 km average effective shade



CE-QUAL-W2 modeling simulations show the sensitivity of temperature to shade. Daily average temperatures are shown in Figure 10.72 and hourly temperatures in Figure 10.73

Figure 10.72 Average temperature - Sensitivity to shade

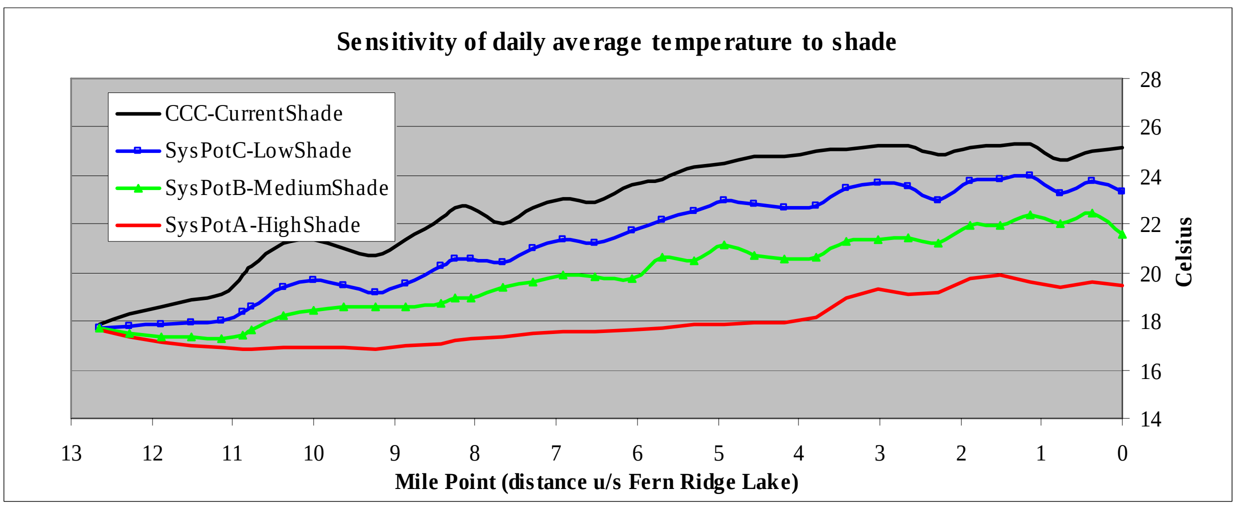
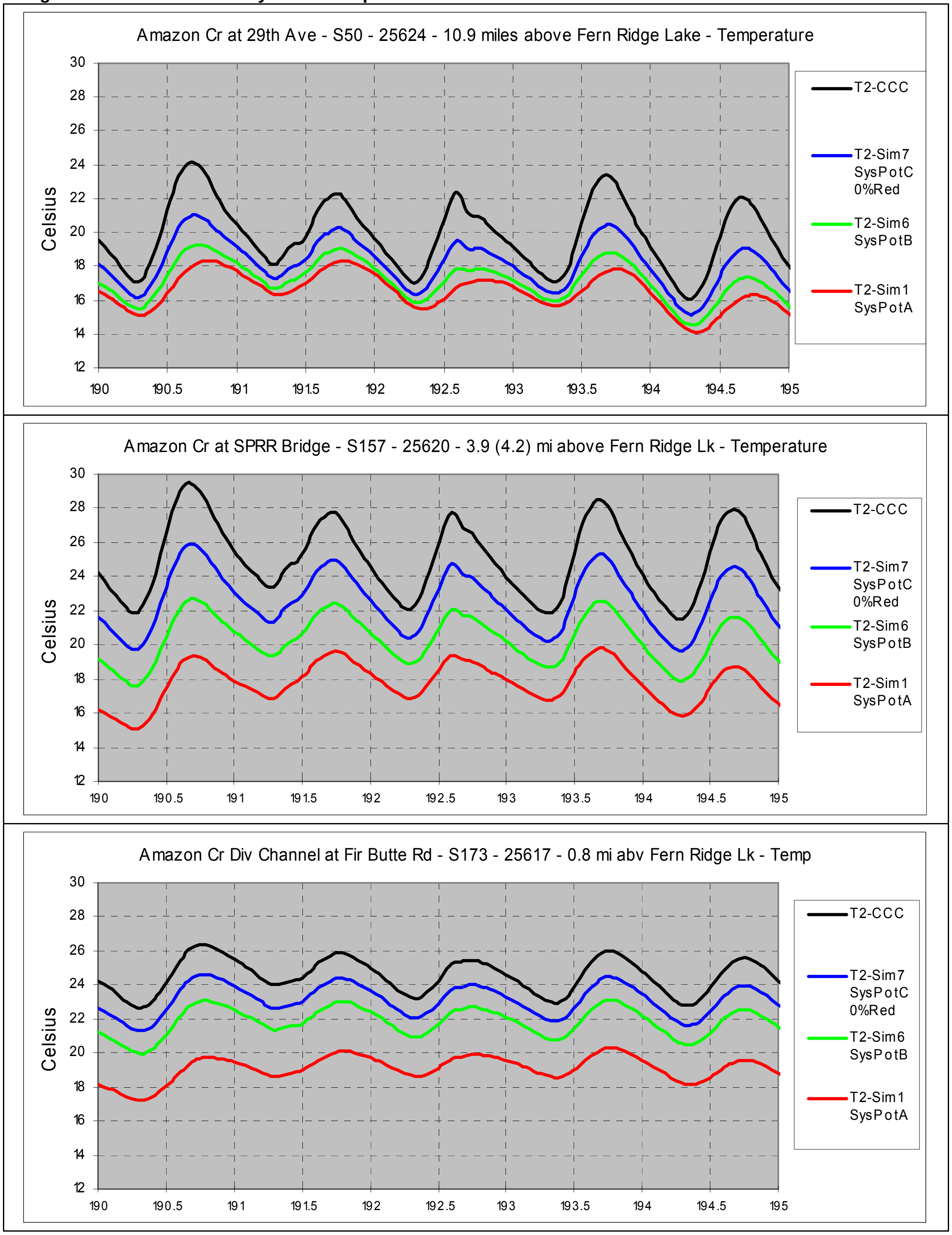


Figure 10.73 Sensitivity of diel temperature to shade



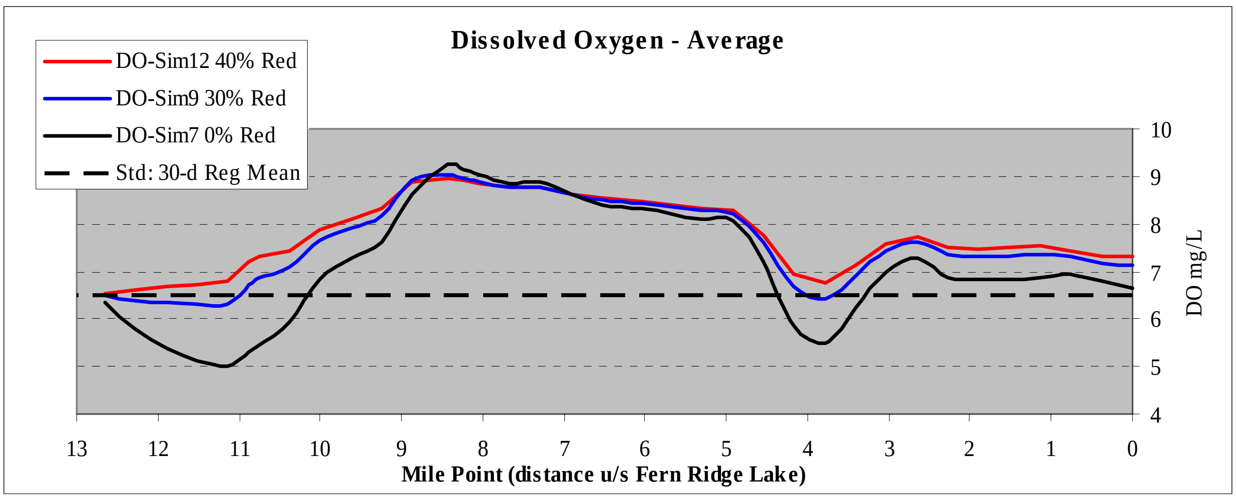
The modeling indicates potential for reducing daily maximum temperatures in the stream as much as 8°C, if shade scenario SysPot A is fully implemented. For the more realistic SysPot C scenario, where dikes are not revegetated and there is some disturbance, temperatures improvements of 2-4°C are likely.

Loading Capacity-Amazon Creek

Dissolved oxygen is sensitive to both stream temperature and solar radiation and, therefore, shade improvements can result in improved dissolved oxygen levels. In addition to reductions in solar radiation loads, modeling indicates that reductions in oxygen demanding pollutant loads are needed in order for water quality standards for DO to be met. Therefore, the loading capacity is comprised of a number of surrogate measures, each of which must be attained in order for compliance with the dissolved oxygen criteria. These surrogates include solar radiation, BOD, nutrients and SOD.

To determine the loading capacity of the stream, estimated loads of BOD and nutrients were incrementally reduced, along with sediment oxygen demand (SOD) rates, until all standards for DO were met. In order to provide a margin of safety, modeling was performed using the least conservative system potential shade scenario, SysPotC (disturbed system potential vegetation with no change in vegetation within 10 m of active channel edge). The response of average (3-day) DO is shown in Figure 10.74, and hourly DO in Figures 10.75 and 10.76.

Figure 10.74 Response of 3-day average DO to load and SOD reductions



For a 3-d average DO target of 6.5 mg/L and a daily minimum target of 5.0 mg/L, the model indicates that the loading capacity equates to a 30 to 40% reduction in nutrient loads and SOD. Note that a daily minimum target of 5.0 mg/L provides for a margin of safety over the 4.0 mg/L absolute minimum standards. Corresponding loading capacities are shown in Table 10.57 and Table 10.58. In order to provide for a margin of safety, the loading capacity for this TMDL is specified as a 40% reduction in BOD, nutrients and SOD.

Table 10. 57 Loading Capacities for BOD and nutrients

Pollutant	Loads added (kg/day/km)	
	CCC	**40%**
Ecoli	*73.6*	44.1
ISS	*88.9*	53.3
PO4P	*0.027*	0.016
NH4N	*0.026*	0.016
NO34N	*0.086*	0.052
DIN	*0.113*	0.068
CBODu	*3.5*	2.1

Figure 10.75 Amazon Creek - Response of DO to load reductions for System Potential C shade condition

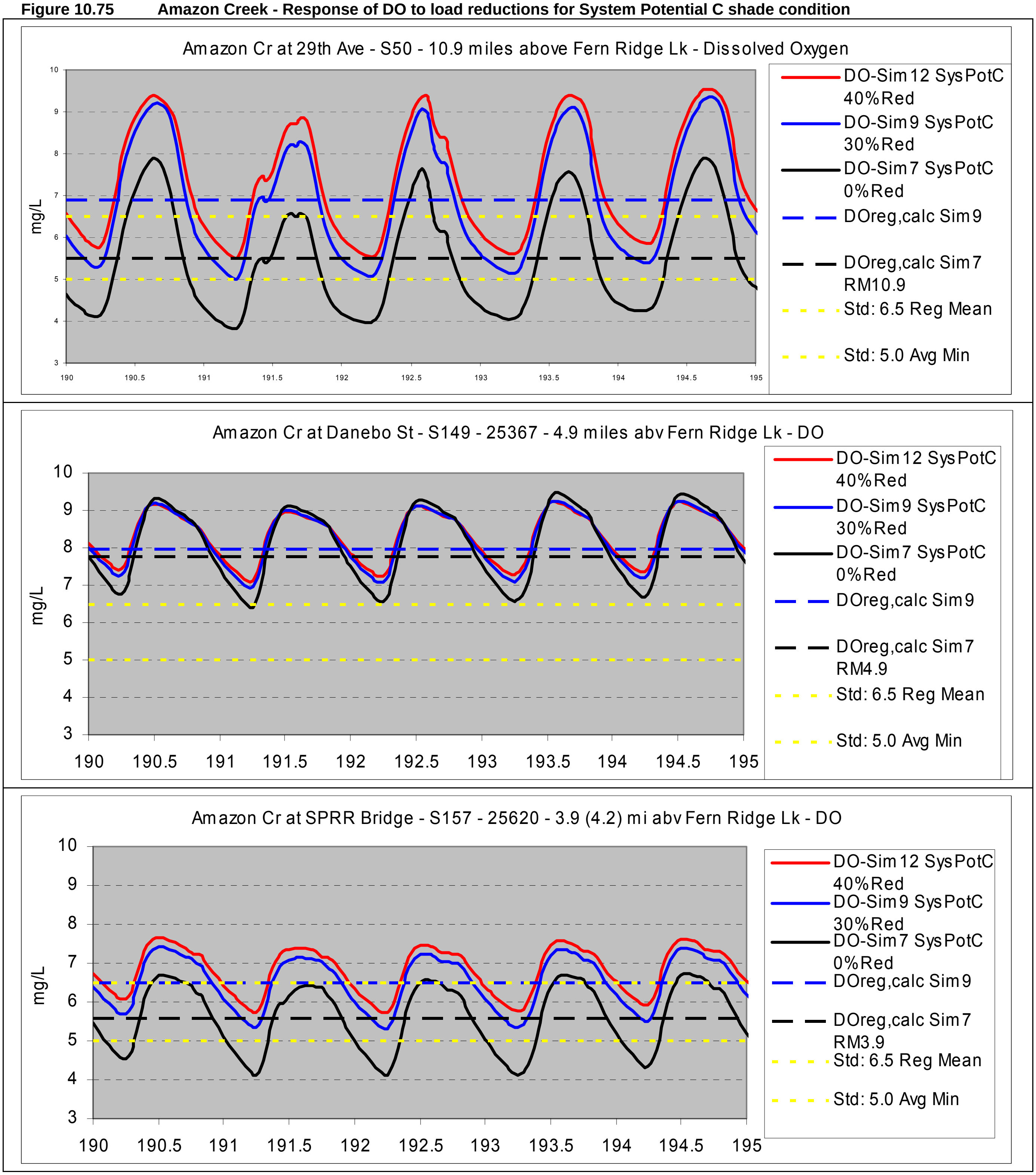


Figure 10.76 Amazon Diversion Channel - Response of DO to load reductions for System Potential C shade condition

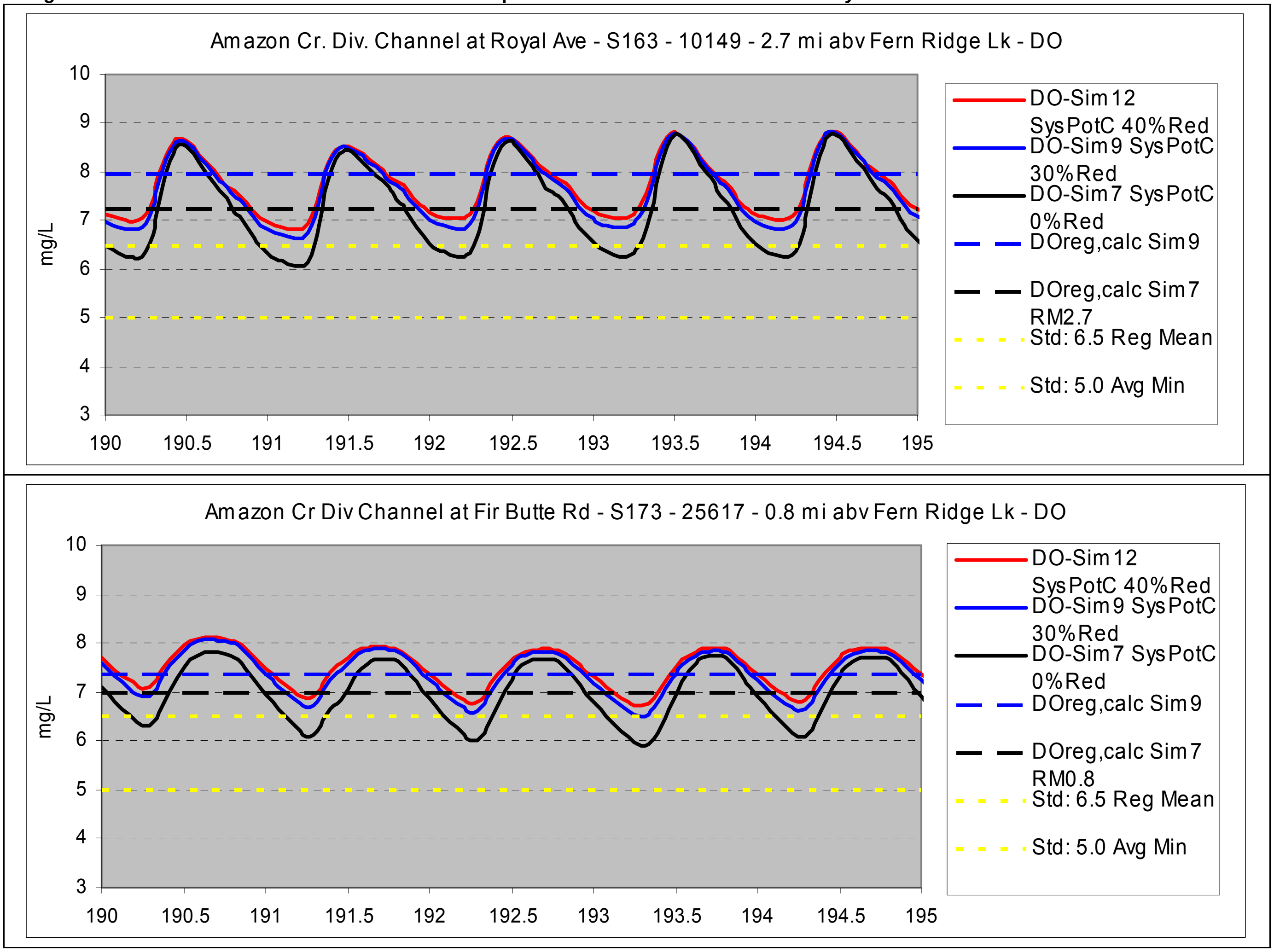


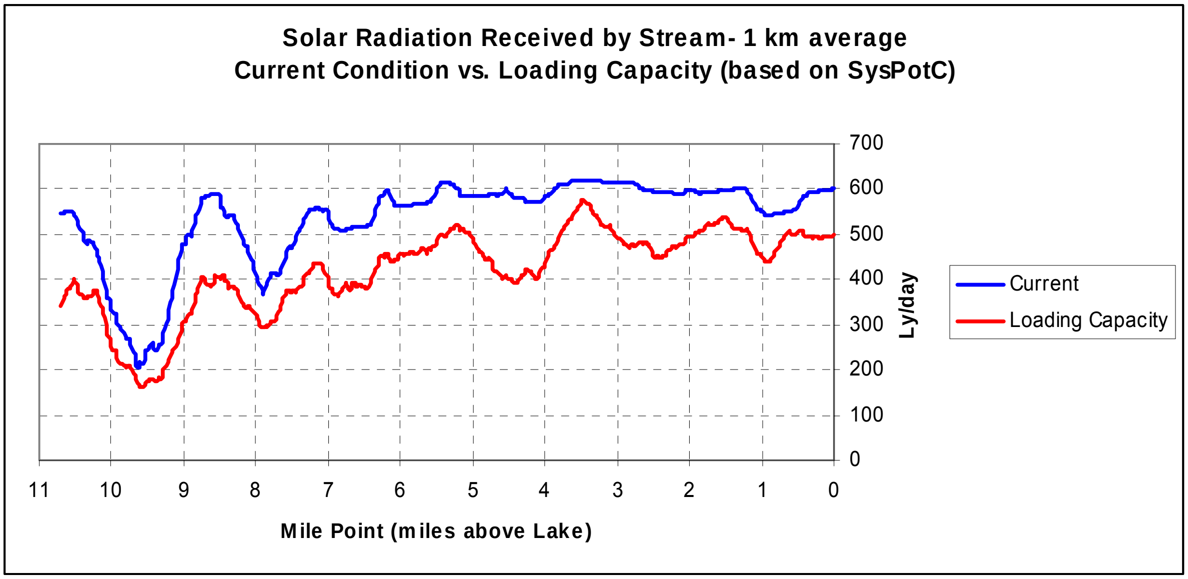
Table 10. 58 Loading Capacities for Sediment Oxygen Demand

Reach (miles u/s Lake)	Model Segments	CCC SOD_{20}	40% SOD_{20} Reduction
12.7 to 10.4	2-62	3.5	2.1
10.4 to 4.6	65-150	0.9	0.5
4.6 to 3.5	151-158	3.1	1.9
3.5 to 0.0	159-177	1.3	0.8

Sediment oxygen demand is due to volatile suspended solids which settle to the stream bottom and exert an oxygen demand as they decay. Much of these solids may enter the stream during storm events. Therefore, it's important to reduce the amount of solids which enter the stream during such events.

For solar radiation, the loading capacity is the load associated with the SysPotC shade scenario (Figure 10.77).

Figure 10.77 Amazon Creek - Loading Capacity for Solar Radiation



The overall average daily solar radiation loads estimated by Heat Source for the current condition and the three system potential conditions, along with overall average effective shade estimates, are shown in Table 10.59. The analyses were performed for a sunny day with solar radiation above the vegetation of 690 Ly/day (i.e., if there were no shade, 690 Ly/day of solar radiation would reach the stream surface). Note that effective shade is based on the solar radiation which reaches the stream surface, while solar radiation load is based on solar radiation which enters the stream (some solar radiation is reflected off of the stream surface and does not enter the stream). As shown the loading capacity for solar radiation is 421 Ly/day (Table 10.59).

Table 10. 59 Amazon Creek solar radiation loads

	CCC	SysPotC	SysPotB	SysPotA
Overall average effective shade (percent)	14.3%	33.2%	50.0%	72.3%
Overall average solar radiation load entering stream (Ly/day)	536.8	**421.4**	314.6	175.7

Excess Load-Amazon Creek

The excess load is the difference between the actual pollutant load in a waterbody and the loading capacity of that waterbody (OAR 340-042-0040).

For solar radiation, the excess load is the difference between the solar radiation currently entering the stream and that which would enter the stream for the selected system potential shade scenario. Using shade as a surrogate measure for solar radiation, the excess load is the difference between calibration current condition (CCC) shade and the system potential shade scenarios, as shown in Figure 10.78. Note that, as discussed previously, SysPotA is the desired shade scenario, while SysPotC is the shade scenario upon which required BOD, nutrient, and SOD reductions are based. The overall average excess solar radiation load, calculated using the difference between the current load and the SysPotC load, is 115 Ly/day. The excess solar radiation load for the entire stream is presented in Figure 10.79.

Figure 10.78 Excess Load - Surrogate measure shade

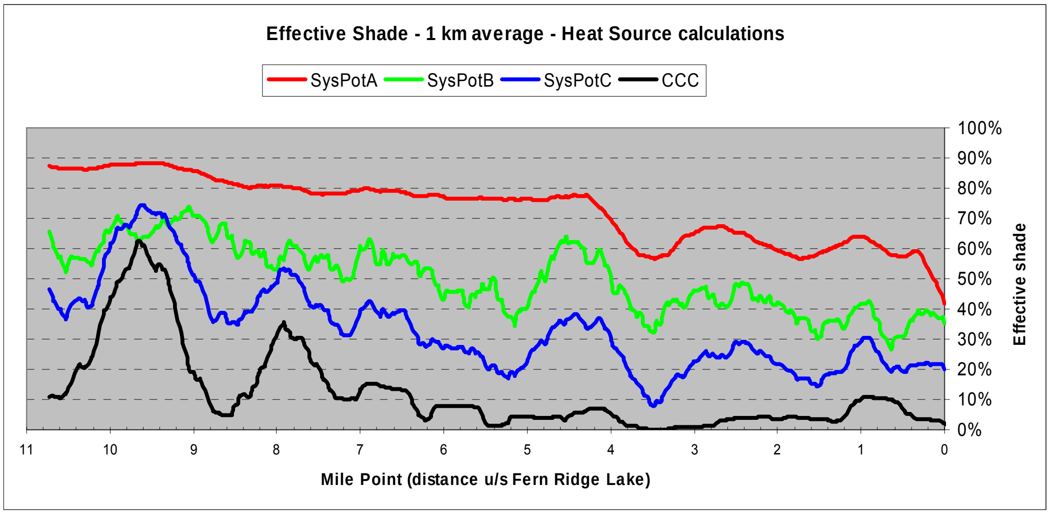
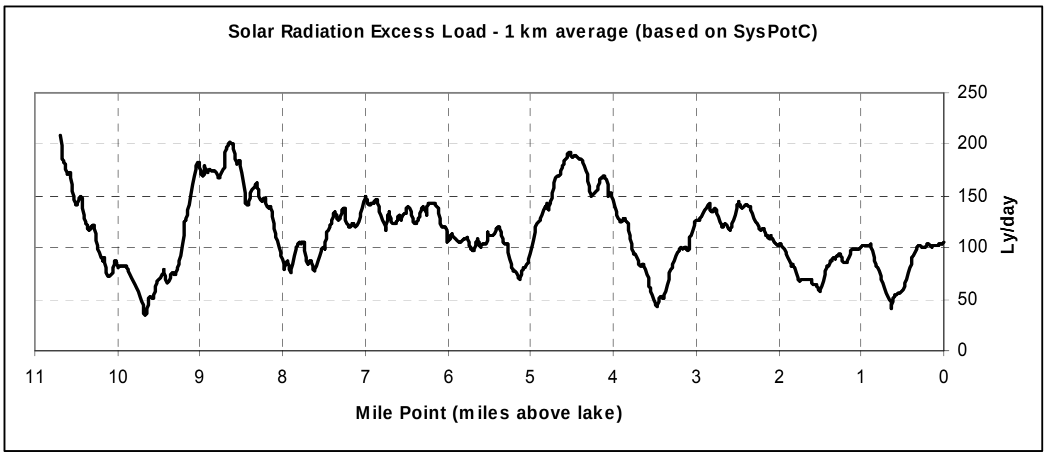


Figure 10.79 Amazon Creek - Excess Load - Solar Radiation



The excess loads of dry weather BOD and nutrients are shown in Table 10.60, while the excess load of sediment oxygen demand (SOD), which represents dry and wet weather volatile suspended solids loads, is shown in Table 10.61. These are based on loading capacities corresponding to 40% reductions in loads and SODs.

Table 10. 60 Excess Load of BOD and Nutrient loads

Pollutant	Loads added (kg/day/km)		
	Current loads	Loading Capacity based on 40% reduction in loads	Excess Load based on 40% reduction in loads
PO4P	0.027	0.016	**0.011**
NH4N	0.026	0.016	**0.011**
NO34N	0.086	0.052	**0.034**
CBODu	3.5	2.1	**1.4**

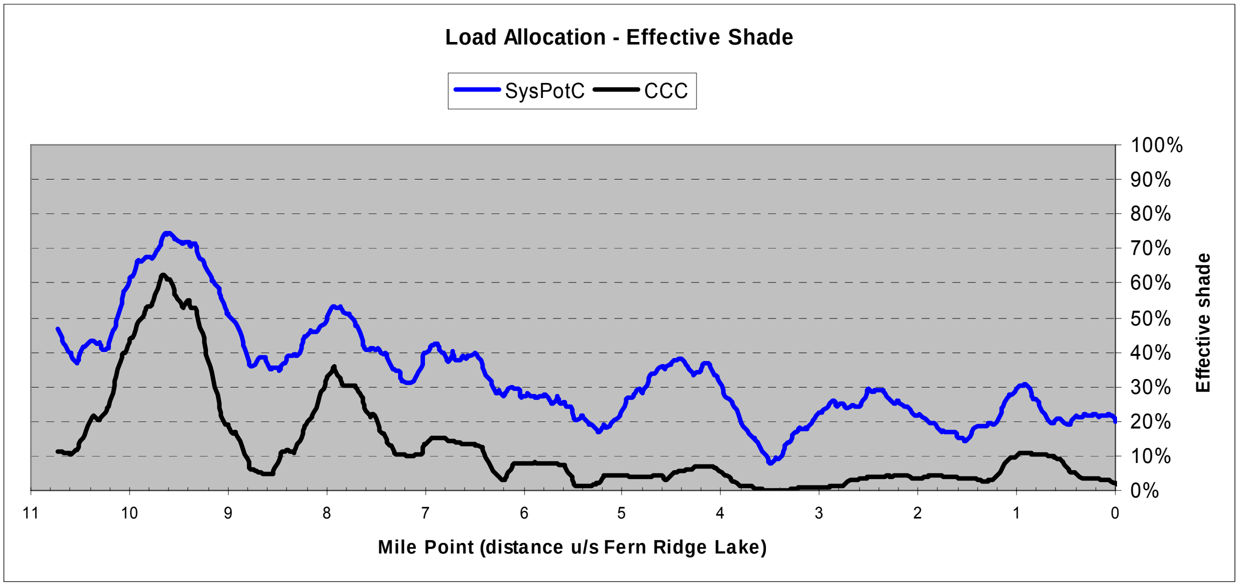
Table 10. 61 Excess Load of Sediment Oxygen Demand (g O_2/m^2/day)

Reach (miles u/s Lake)	Model Segments	Current SOD	Loading Capacity based on 40% reduction in SOD	Excess Load based on 40% reduction in SOD
12.7 to 10.4	2-62	3.5	2.1	***1.4***
10.4 to 4.6	65-150	0.9	0.5	***0.4***
4.6 to 3.5	151-158	3.1	1.9	***1.2***
3.5 to 0.0	*159-177*	*1.3*	*0.8*	***0.5***

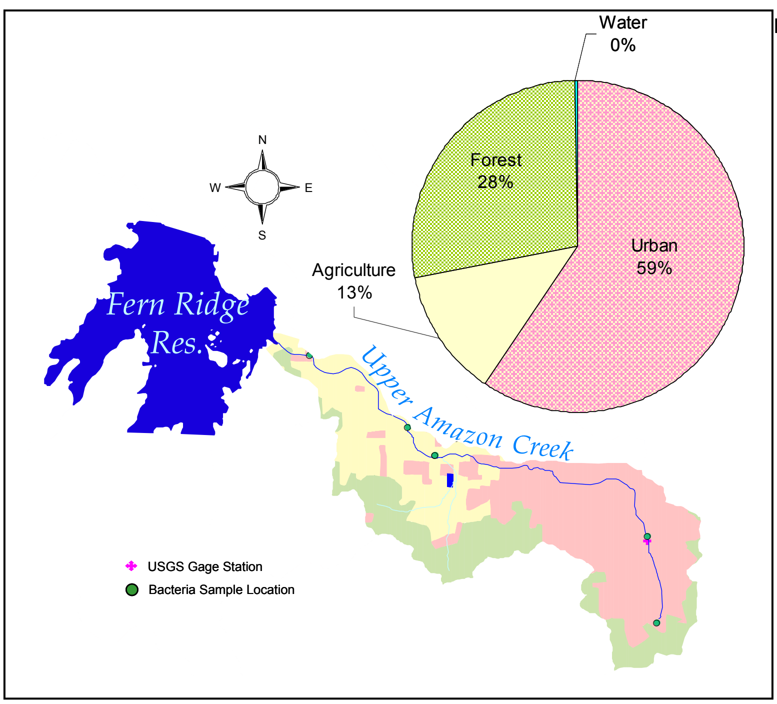
Load Allocations-Amazon Creek

The loading capacity of Amazon Creek and Diversion Channel corresponds to a 40% reduction in load and SOD for system potential shade scenario SysPotC. While a more conservative shade scenario than SysPotC may be required by the Willamette Basin temperature TMDL, in order to address only dissolved oxygen concerns the load allocation for shade is SysPotC, as shown in Figure 10.80. This corresponds to an overall average load allocation for solar radiation of 421 Ly/day.

Figure 10.80 Load Allocation for Shade



Loads of BOD, nutrients, and SOD causing volatile suspended solids enter the steam from all land use categories. The dominant land use category for the Amazon watershed is urban, (see Map 10.24). As shown, for the upper half of the system the land close to the stream is mostly urban. For the lower half it is mostly agriculture. Only a limited amount of land near the stream is forestland.



Map 10.24 Upper Amazon Creek Watershed Land Use

Since forestland generally does not contribute large organic loads to streams, and since only a limited amount of forestland is located near Amazon Creek, all of the specified load reductions are assigned to urban and agriculture land use categories.

Reductions in loads of BOD, nutrients and volatile suspended solids are required both during dry weather and wet weather conditions. Wet weather loads are significant because they contribute to SOD. The loading capacity of the stream equates to a 30-40% reduction in loads and SOD. In order to provide a margin of safety, the loading capacity and the required percent reduction in loads and SOD (the load allocation) is set to 40%, as shown in Table 10.62.

Sources of loads during rainfall events include runoff from urban and agricultural areas. Sources of loads during dry weather periods may include direct discharge of waste to streams, failing septic tanks, and improper discharge of sewage.

Table 10. 62 Land Use Based Load Allocations for the Amazon Creek Watershed.

Land Use Categories	Coverage Percentage	Required Percent Reduction in BOD loads, nutrient loads, and SOD
Urban	59%	40%
Agriculture	13%	40%
Forest	28%	0%

The load allocations apply to both point and nonpoint sources.

Confined animal feeding operations are not allowed to discharge wastes from specific areas covered by the general NPDES permit. Therefore, for BOD and nutrients, CAFOs are allocated loads of zero from regulated portions of operations.

No other point sources appear likely to discharge significant quantities of BOD or nutrients. If any point sources are found to discharge such pollutants in quantities likely to result in DO concentration impacts, wasteload allocations will be developed to address the discharges.

Margin of Safety-Amazon Creek

TMDLs must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load allocations and water quality. Amazon Creek load allocations provide for margins of safety by:

1. Targeting cool-water rather than warm-water DO standards,
2. Targeting a DO concentration of 5.0 mg/L (rather than 4.0 mg/L),
3. Basing load allocations for BOD, nutrients and volatile suspended solids loads on loads needed to meet standards for the SysPotC system potential shade condition, and
4. Setting the loading capacity and required load reductions to 40%, this is the upper range of required load reductions based on the loading capacity of the stream.

The use of these margins of safety will ensure that the TMDL, when implemented, will be protective of designated beneficial uses.

Seasonal Variation-Amazon Creek

The season of concern for dissolved oxygen is May 1 through October 31. The shade improvements mandated by this TMDL will result in improved dissolved oxygen concentrations year-round.

Reductions in loads of BOD, nutrients and volatile suspended solids are required both during dry weather and wet weather conditions. Therefore, the mandated load reductions for these pollutants apply year-round.

Coyote Creek Model

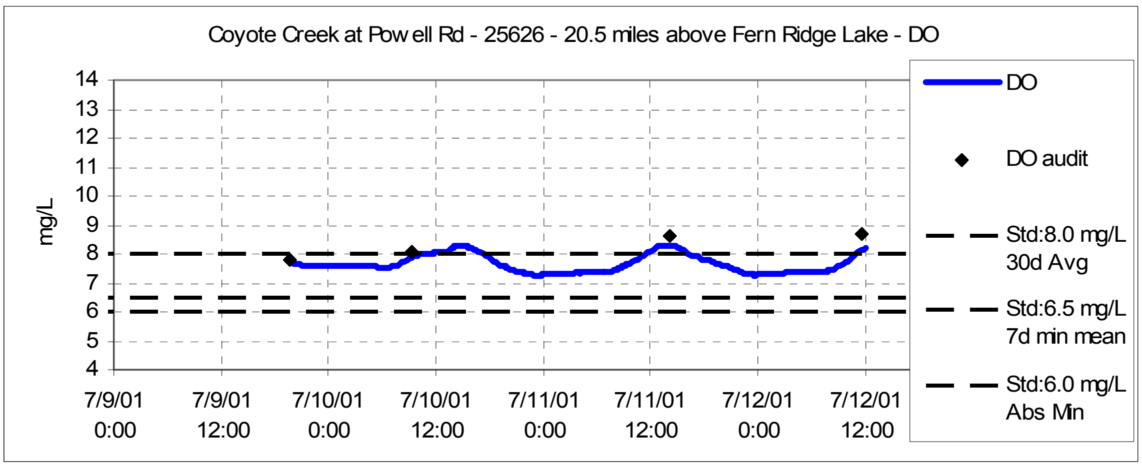
Modeling indicates that improving shade from current conditions to system potential conditions will significantly improve DO conditions in the stream. In addition, reductions in BOD, nutrients, and SOD causing volatile suspended solids concentrations are necessary to insure that DO standards will be met. Modeling performed to calculate the loading capacity and the required load allocations is described in the following sections.

Model Calibration

Oxygen solubility in water declines as temperature increases. Therefore, the high temperatures of Coyote Creek contribute to dissolved oxygen standard violations.

The stream experienced large diel fluctuations in temperature and DO during the July 2001 study. However, the only DO standard violation observed during the study was a possible violation of the 30-day average DO standard. The average DO over a 48 hours period monitored at RM 20.5 was 7.7 mg/L, which is less than the 8.0 mg/L standard (Figure 10.81).

Figure 10.81 Coyote diel dissolved oxygen observations showing potential DO standard violation



Since only modest violations of the DO standard were observed, a less rigorous modeling approach was used for Coyote Creek. The ODEQ Periphyton Control Model (PCM), developed previously for the Upper Grande Ronde River, was applied to Coyote Creek (DEQ, 2000). This model allows the sensitivity of DO to temperature, solar radiation, and nutrient concentrations to be evaluated (for more information on PCM, see the section ***Periphyton Control Model (PCM) – Technical Discussion*** below).

In order to determine the sensitivity of solar radiation and stream temperature to streamside vegetation, a Heat Source temperature model of the stream was also developed. This was calibrated on observed temperature data and used to provide inputs to the PCM model.

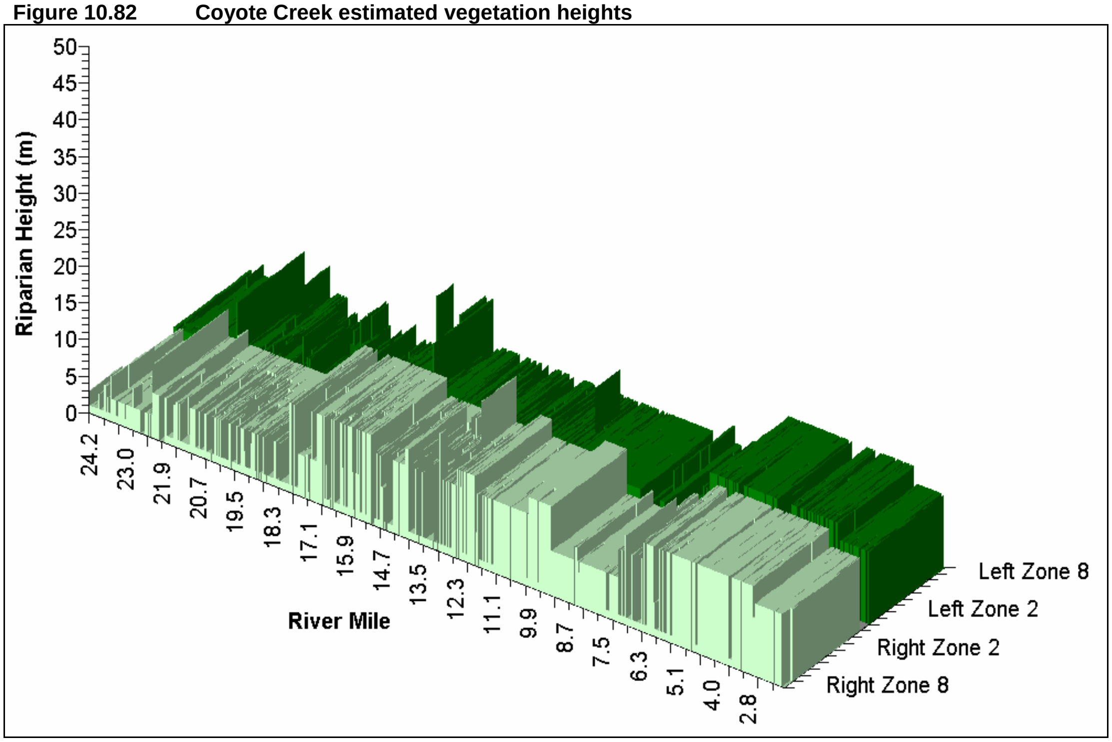
Two reaches of the stream were modeled. An upper reach from RM 22.9 to RM 20.5 and a lower reach from RM 7.0 to RM 2.5.

Coyote Creek Heat Source Model

As with Amazon Creek, a vegetation assessment was performed for Coyote Creek in order to derive shade inputs for the PCM model. Digital orthophoto quadrangle (DOQ) images were used in conjunction with orthorectified color aerial photographs and field data to digitize vegetation polygons. Vegetation characteristics of height, density, and overhang were assigned to each vegetation type and GIS, via TTools vegetation analysis programs (Boyd and Kasper, 2002), and the modeling framework Heat Source (Boyd and Kasper, 2004) were used to calculate daily average effective shade for every 100 ft. Heat Source model segment.

Vegetation heights calculated by TTools for a 40 m buffer on each side of the stream are presented graphically in Figure 10.82. As shown, much of the system is poorly shaded.

Figure 10.82 Coyote Creek estimated vegetation heights



Daily average effective shade as calculated by Heat Source (v.6.5.1) is presented in Figure 10.83. Comparison of Coyote Creek effective shade (Figure 10.83) to Amazon Creek effective shade (Figure 10.84) shows that Coyote Creek is, in general, significantly better shaded than Amazon Creek. Coyote Creek 1 km average effective shade is generally greater than 40%, whereas Amazon Creek effective shade is frequently less than 10%.

Figure 10.83 Coyote Creek Heat Source estimated effective shade (calibrated current condition)

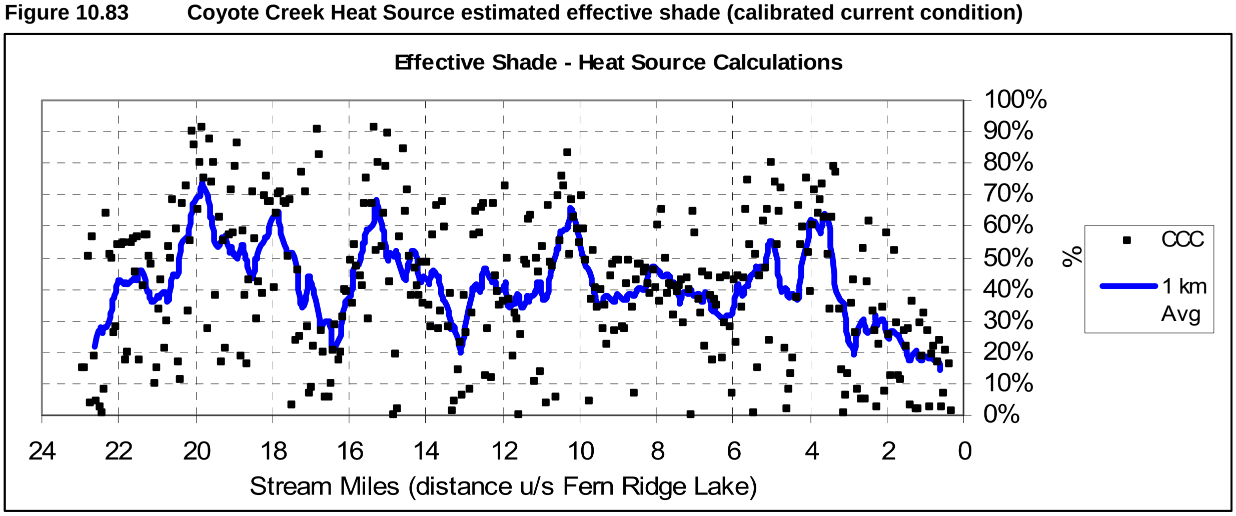
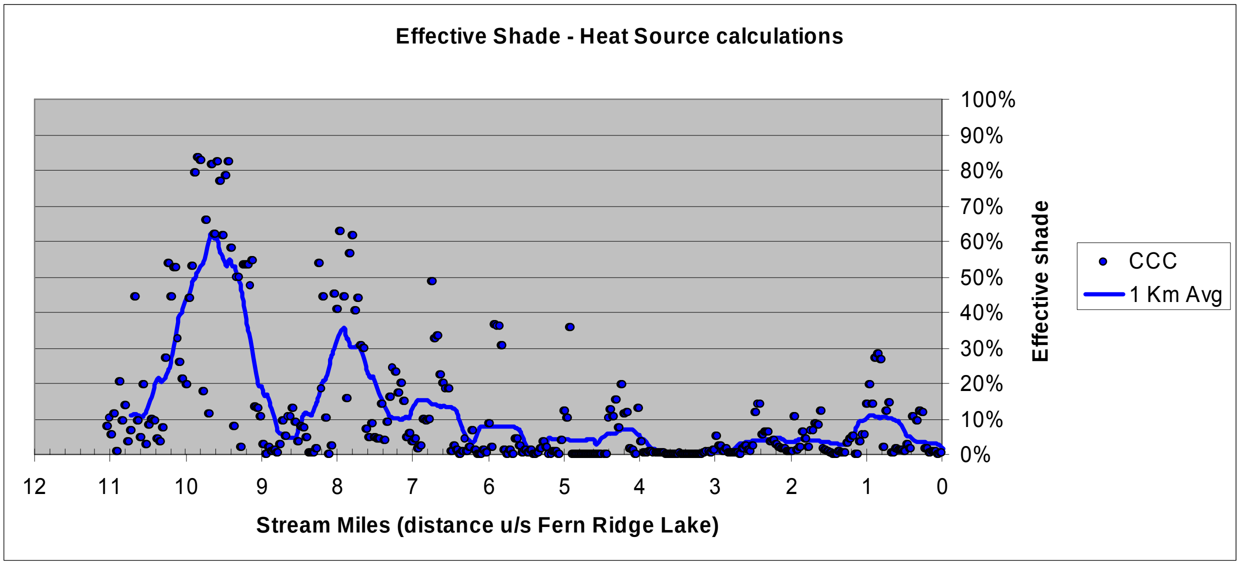


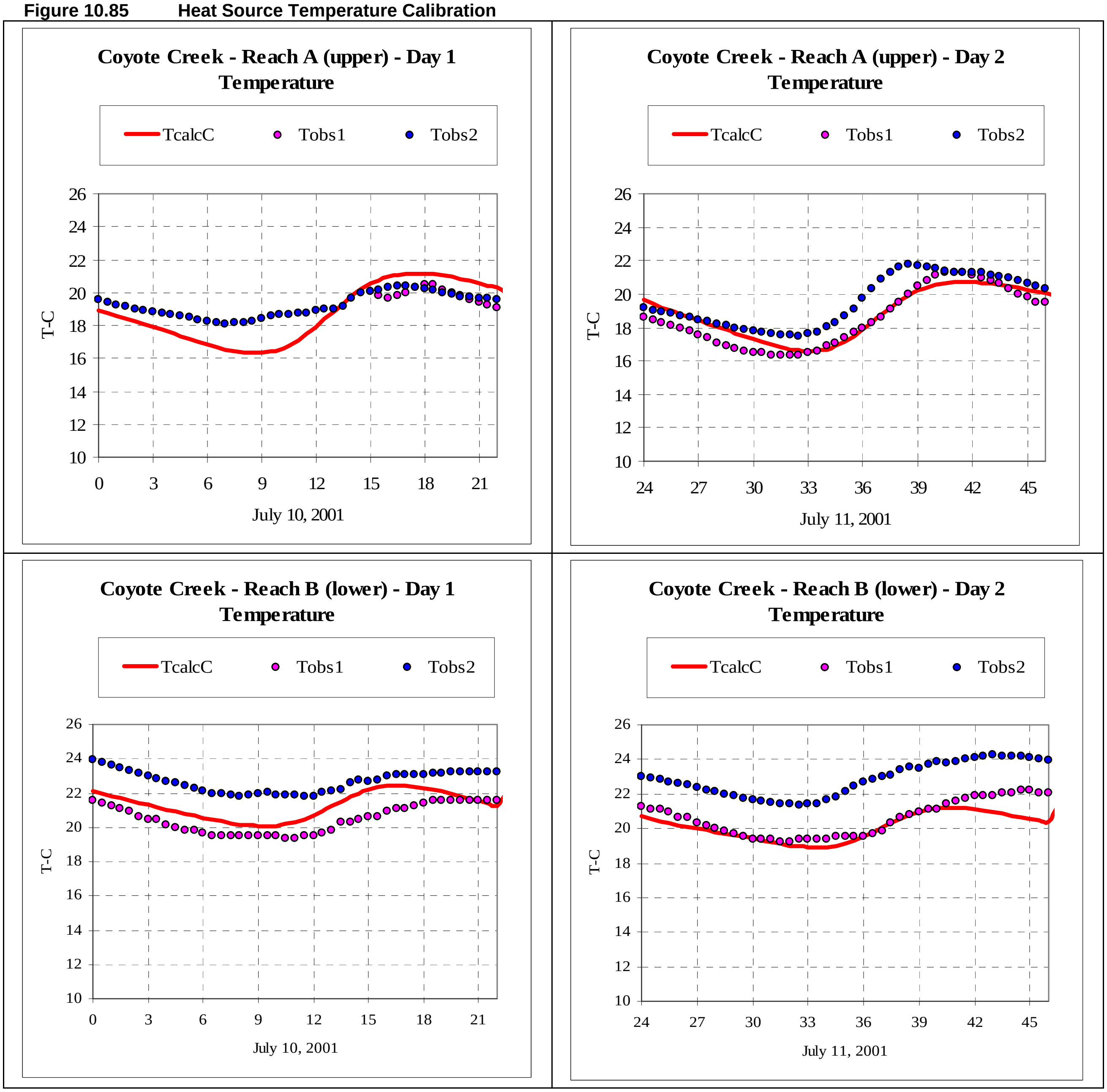
Figure 10.84 Amazon Creek Heat Source estimated effective shade (calibrated current condition)



PCM Model Calibration

The PCM model was calibrated using reach average values for velocity, temperature, and solar radiation calculated by the Heat Source model (Figure 10.85).

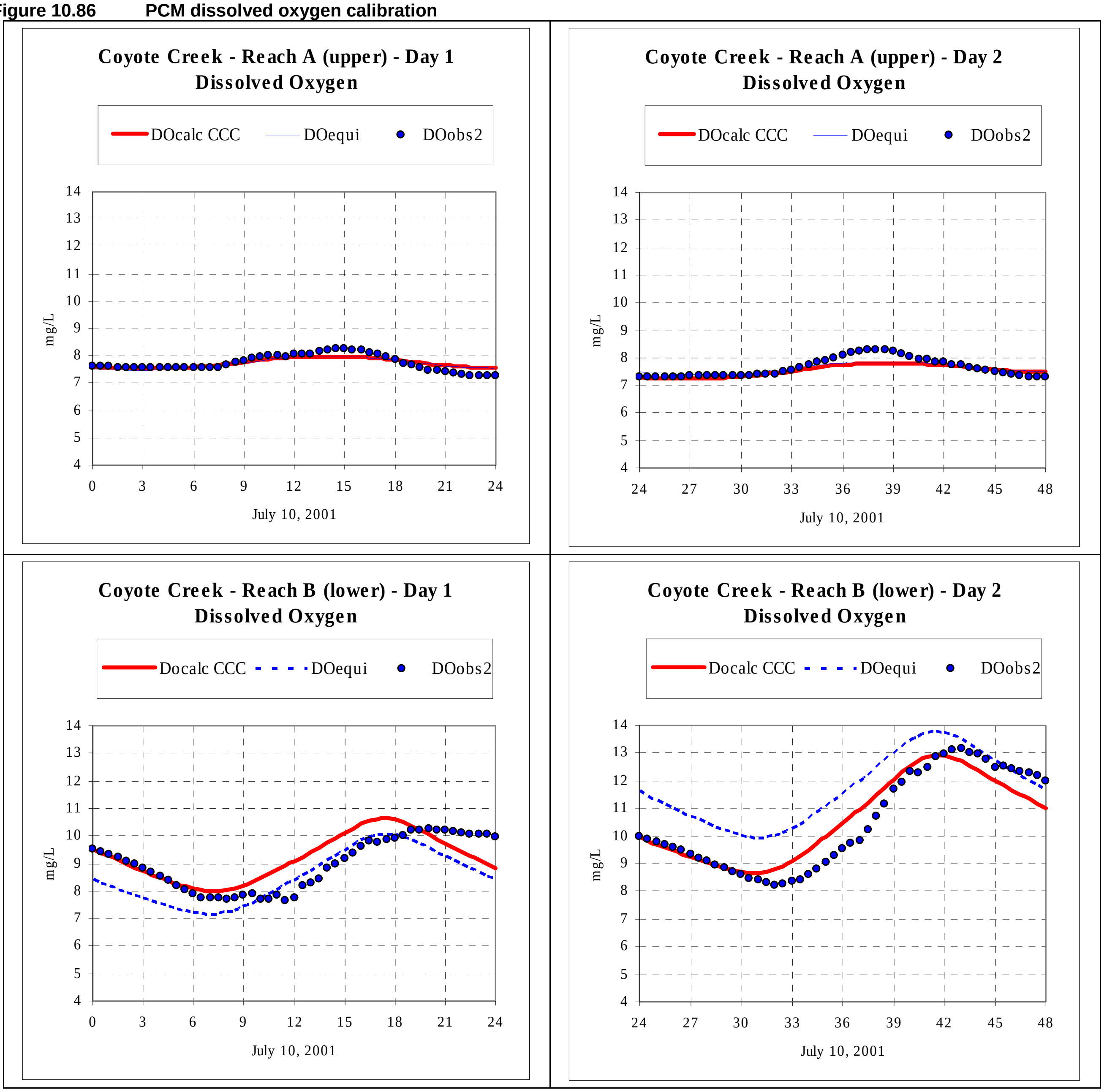
Figure 10.85 Heat Source Temperature Calibration



Two separate 24 hour Heat Source model runs were performed for each of two modeled reaches. For day 1 the model was run was from July 10, 2001 0000 hrs to 2400 hrs and for day 2 from July 11, 2001 0000 hrs to 2400 hrs. The upper reach, Reach A, extends from RM 22.9 (Coyote at Gillespie 25627) to RM 20.5 (Coyote @ Powell Rd 25626), while the lower reach, Reach B, extends from RM 7.0 (Coyote @ Petzold Rd 10151) to RM 2.5 (Coyote @ Cantrell Rd 10150). On each figure are shown two sets of observations. Tobs1 is temperature at the most upstream station in the reach, while Tobs2 is the temperature at the most downstream station.

Calculated DO vs. observations are shown in Figure 10.86. Two sets of model calculations are presented, DOcalc and DOequi. DOcalc are calibration calculations for a single model iteration. DOequi are dynamic equilibrium calculations for model runs in which the model is run for a series of days of identical meteorological conditions until the model reaches equilibrium. DOequi calculations are useful for comparing current condition simulations to future scenario simulations. Unlike for the temperature plots, DO data is only available at the most downstream station in each reach. This is shown as DOobs2 on the figures.

Figure 10.86 PCM dissolved oxygen calibration



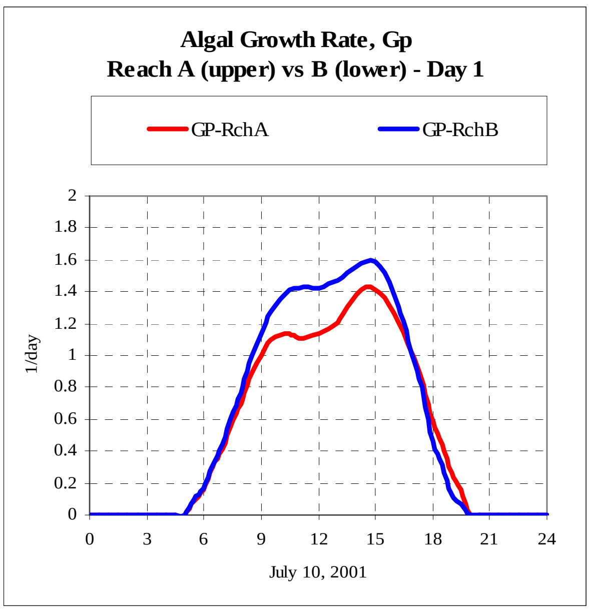
Calibration statistics are shown in Table 10.63. As shown, the model provides accurate predictions of DO, with calibration standard errors of the estimate (root mean squares) ranging from 0.16 to 0.67 mg/L and percentage relative errors of 1.6 to 6.0 %.

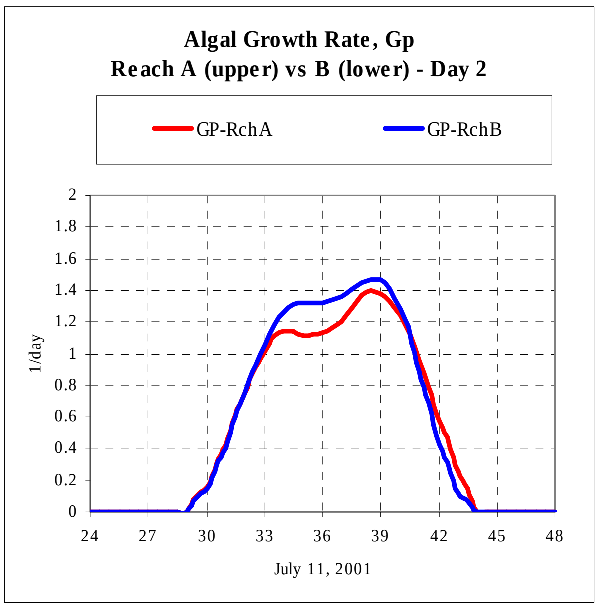
Table 10. 63 PCM calibration statistics

	Reach A Day 1	Reach A Day 2	Reach B Day 1	Reach B Day 2
Calibration:				
Average Error:	-0.0038 mg/L	-0.1099 mg/L	0.2514 mg/L	0.1182 mg/L
Relative Error:	1.6 %	2.0 %	6.0 %	4.6 %
Std Error of the Estimate:	0.1568 mg/L	0.2094 mg/L	0.6691 mg/L	0.6019 mg/L
Coefficient of Variation:	2.0 %	2.7 %	7.5 %	5.7 %
Equilibrium:				
Average Error:	-0.0257 mg/L	-0.0249 mg/L	-0.4624 mg/L	1.2036 mg/L
Relative Error:	1.8 %	1.9 %	7.5 %	11.9 %
Std Error of the Estimate:	0.1630 mg/L	0.1899 mg/L	0.7873 mg/L	1.4107 mg/L
Coefficient of Variation:	2.1 %	2.5 %	8.8 %	13.4 %

Algal growth rates are functions of temperature, solar radiation, and nutrient concentrations. As shown by Figure 10.87, algal growth rates in lower reaches are greater than in upper reaches. This is due to the higher temperatures and nutrient concentrations in the lower reaches.

Figure 10.87 Model calculated algal growth rates





System Potential Vegetation Scenarios – Coyote Creek

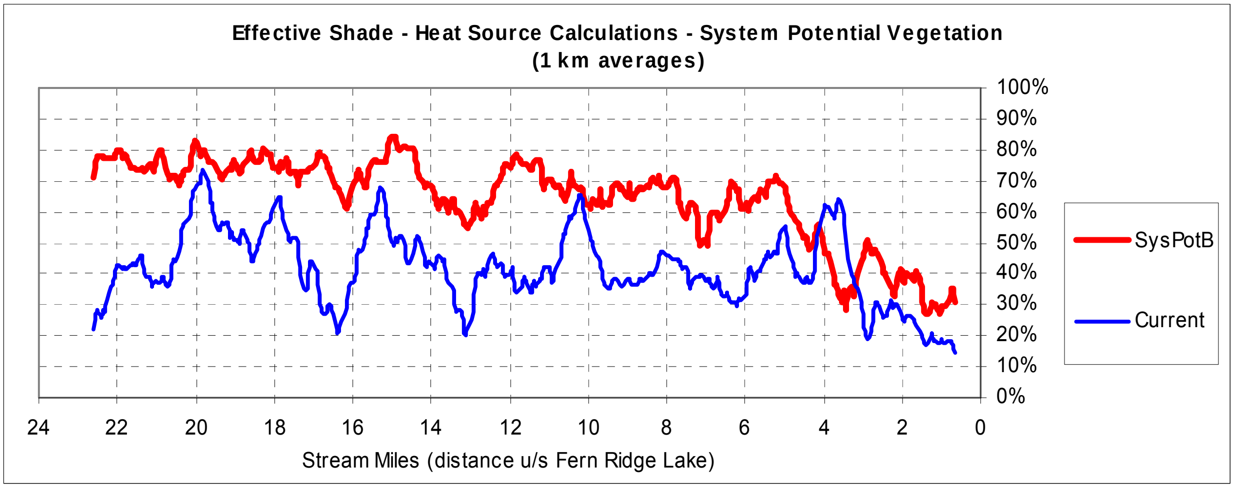
A system potential vegetation scenario was developed based on site geomorphology (see Map 10.23) in accordance with ODEQ methodologies (DEQ, 2004) and evaluated with the model. The scenario, System Potential B (SysPotB), is similar to the SysPotB scenario applied to Amazon Creek (see Amazon Creek discussion) and allows for a degree of disturbance, such as that which may occur due to fires, etc. In this, vegetation types are randomly distributed between vegetation at site potential and vegetation not yet at site potential (see Table 10.64 for vegetation types applied). The SysPotC scenario, in which dikes and rip rapped areas in the riparian area are not vegetated beyond current levels, was not applied to Coyote Creek, as it was for Amazon Creek, since Coyote Creek is mostly a natural channel for which the riparian zone beyond the active channel can generally support vegetation. As with SysPotB for Amazon Creek, vegetation is grown on all surfaces outside of the active stream channel.

Table 10. 64 Vegetation types applied to Coyote Creek

Code	Source	Description	Height (m)	Density (%)	Overhang (m)
511	DEQ	Qau Forest	28.6	75%	3.4
512	DEQ	Qau Savanna	23.0	50%	2.8
513	DEQ	Qau Prairie	0.9	75%	0.0
811	DEQ	Qbf Forest	29.7	75%	3.6
812	DEQ	Qbf Savanna	26.1	50%	3.1
813	DEQ	Qbf Prairie	0.9	75%	0.0
1925	DEQ / USFS	Disturbed: Forest Mature Conifer	17.1	25%	1.7
1950	DEQ / USFS	Not Disturbed: Forest Mature Conifer	48.8	75%	4.9

Heat Source was used to calculate shade conditions for the system potential shade scenario SysPotB. The Heat Source calculated effective shade is compared to the current condition in Figure 10.88. As shown, stream shade can be significantly improved. System potential effective shade ranges from 60 to 80% on most of the stream reaches and 30% to 50% on the lowermost reaches.

Figure 10.88 Coyote Creek System Potential Shade (SysPotB)

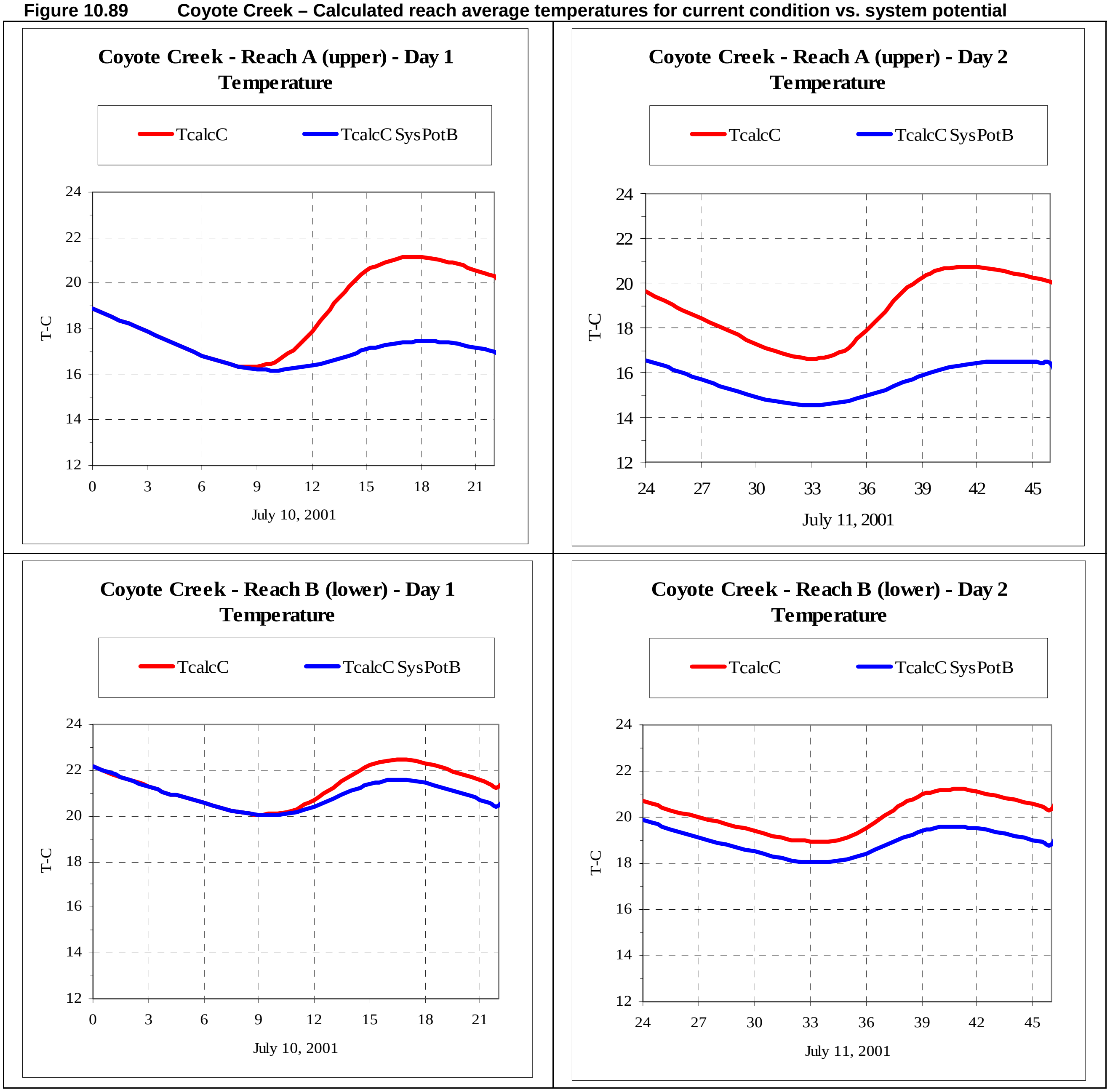


Loading Capacity – Coyote Creek

Sensitivity of Temperature and Dissolved Oxygen to Shade

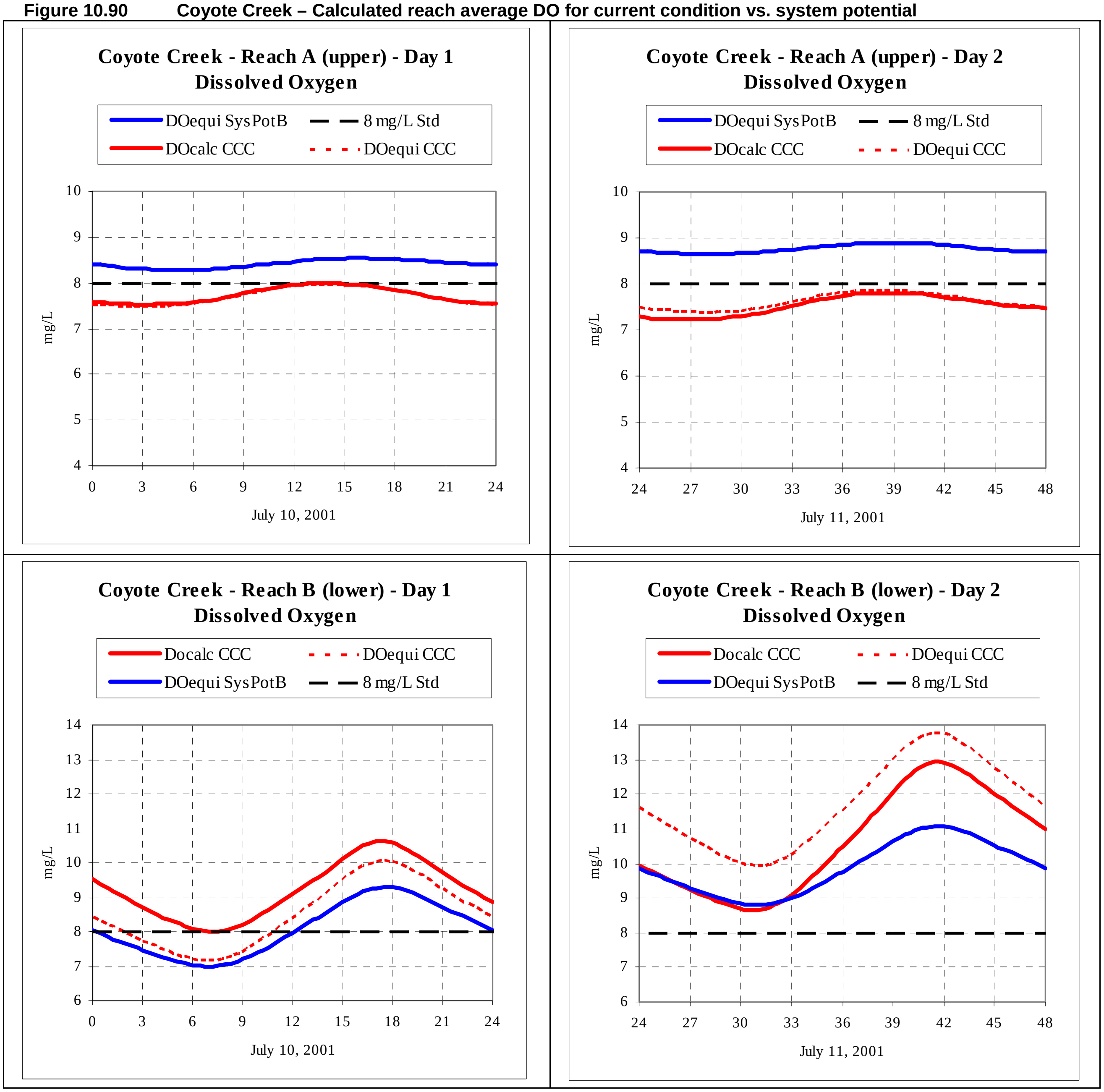
Dissolved oxygen is sensitive to stream temperature and, therefore, improvements in shade should result in improved dissolved oxygen levels. Figure 10.89 shows calculated reach average temperatures throughout each day for both the upper and lower reaches. As shown, the Heat Source model indicates that improving shade from the current condition to the system potential condition SysPotB will result in daily maximum temperatures that are 3-4^{o}C cooler for Reach A (the upper reach from RM 22.9 to RM 20.5) and 1-2^{o}C cooler for Reach B (the lower reach from RM 7.0 to RM 2.5).

Figure 10.89 **Coyote Creek – Calculated reach average temperatures for current condition vs. system potential**



Dissolved oxygen modeling using PCM indicates that shade improvements will reduce algal growth in the stream and limit diel dissolved oxygen fluctuations. Figure 10.90 shows model calculated reach average DO concentrations for both days and reaches. Shown are calculated DO concentrations for calibration current conditions (DOcalc CCC and DOequi CCC) and system potential conditions (DOequi SysPotB). As described previously, DOcalc values are calibration calculations for a single model iteration while DOequi values are dynamic equilibrium calculations for model runs in which the model is run until dynamic equilibrium is reached.

Figure 10.90 Coyote Creek – Calculated reach average DO for current condition vs. system potential



The model indicates that improvements in shade will result in increased DO concentrations in the upper reach, mainly due to expected reductions in temperature, which will increase DO saturation levels (the concentration at which the water is saturated with oxygen). In the lower reach, however, where high levels of algae are present, the model indicates that improvements in shade will reduce oxygen levels. This is because the reach is supersaturated with DO due to large amounts of algal productivity. Increasing shade and reducing temperature will reduce algal growth rates and concentrations and reduce the amount of oxygen production.

While the model indicates that improving shade will result in lower DO concentrations in the lower reach on the days modeled, it is likely that it will improve DO on other days. This is because on subsequent days the large concentration of algae grown on the days modeled will exert an oxygen demand as it decays and respires, which could result in dramatic declines in DO. The large amount of algae in the system may be the reason why historic data shows frequent DO standard violations in the stream. Improvements in shade will reduce the amount of algae in the stream, decrease diel fluctuations in DO, and reduce the likelihood of DO "crashes."

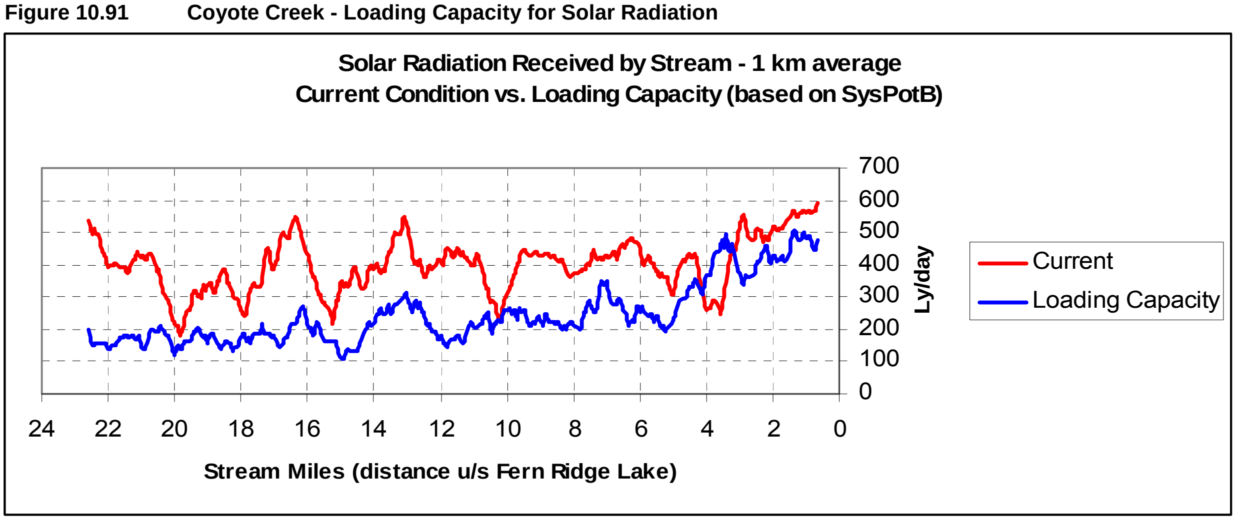
The modeling indicates that improving shade from current conditions to system potential conditions (SysPotB) will reduce diel DO fluctuations in the upper reach (Reach A: RM 22.9 to RM 20.5) from a range of 0.5 to 0.6 mg/L to a range of 0.2 to 0.3 mg/L (see Figure 10.90). For the lower reach (Reach B: RM 7.0 to RM 2.5) improving shade will reduce diel DO fluctuations from a range of 2.6 to 4.2 mg/L to a range of 2.3 to 2.5 mg/L.

Improvements in shade will also result in improved daily average DO concentrations and should result in the 30-day mean minimum dissolved oxygen standard, as defined by OAR-41-006, being met in all reaches. This regulatory average standard of 8.0 mg/L provides no credit for supersaturation (i.e., when DO exceeds saturation; the DO used for calculating the average is capped at saturation). Modeling indicates that increasing shade to system potential levels will result in similar regulatory average DO in both reaches for the 48 hour period modeled. For the upper reach, the 48-hr regulatory average will be increased from 7.6 mg/L to 8.6 mg/L, while for the lower reach the 48-hr regulatory average will be reduced slightly from 8.7 mg/L to 8.5 mg/L. Based on the 48 hours modeled, it appears likely that the 30-day mean minimum dissolved oxygen standard of 8.0 mg/L will be met in all reaches if targeted system potential shade levels are achieved.

Loading Capacity for Solar Radiation

Since modeling indicates that dissolved oxygen standards will be met if shade is improved to SysPotB system potential levels, the loading capacity for solar radiation is equal to that expected to be received by the stream for the SysPotB condition. This is the loading capacity for solar radiation (Figure 10.91).

Figure 10.91 Coyote Creek - Loading Capacity for Solar Radiation



The overall average effective shade for system potential for all reaches modeled is 62.9%, as compared to the current condition average of 41.1%.

The overall average solar radiation load for system potential for all reaches modeled is 248.2 Ly/day, as compared to the current condition average load of 405.1 Ly/day. 248.2 Ly/day is the overall average loading capacity for the stream.

Loading Capacity for Other Pollutants

Oxygen demanding pollutants

Modeling indicates that if shade is improved to system potential levels, standards for DO should be met without the need for additional reductions in BOD, nutrients, or sediment oxygen demand. However, in order to provide for a margin of safety to account for uncertainty the loading capacity for these pollutants is set to a 20% reduction from current levels in the lower reaches below Spencer Creek.

During the July 2001 survey, BOD_5 concentrations averaged 1.2 mg/L in the upper reach and 2.0 mg/L in the lower reach. A 20% reduction in concentrations in the lower reaches equates to a BOD_5 concentration of 1.6 mg/L. For a flow rate of 1.9 cfs, this equates to loads for BOD_5 for upper and lower reaches of 12.3 and 16.4 lbs/day (5.6 and 7.4 kg/day), respectively.

Note that suspended solids concentrations were low during the July 2001 study, which occurred during a dry, low flow period. However, much of the volatile suspended solids load that contributes to SOD enters during storm events. Therefore, suspended solids load reductions may also be needed during storm events.

Ammonia toxicity

Ammonia toxicity is also of concern. When nitrogen in the form of ammonia is introduced to natural waters, the ammonia may "consume" dissolved oxygen as nitrifying bacteria convert the ammonia into nitrite and nitrate. To what extent this process occurs, and how much oxygen is consumed, is related to several factors, including residence time, water temperature, ammonia concentration in the water and the presence of nitrifying bacteria.

During the July 2001 survey, large concentrations of ammonia were observed at RM 2.5 (Cantrell Rd.). At upper Coyote stations ammonia averaged 0.05 mg/L as N during the survey, while at RM 2.5 ammonia averaged 0.71 mg/L as N. Such concentrations may exceed chronic toxicity based standards for ammonia.

Ammonia toxicity is a function of pH and temperature, mainly because the fraction of ammonia present in the toxic un-ionized form increases with pH and temperature. At the high temperatures and pH levels observed in Coyote Creek, the chronic (4-day average) criteria for ammonia toxicity may be exceeded.

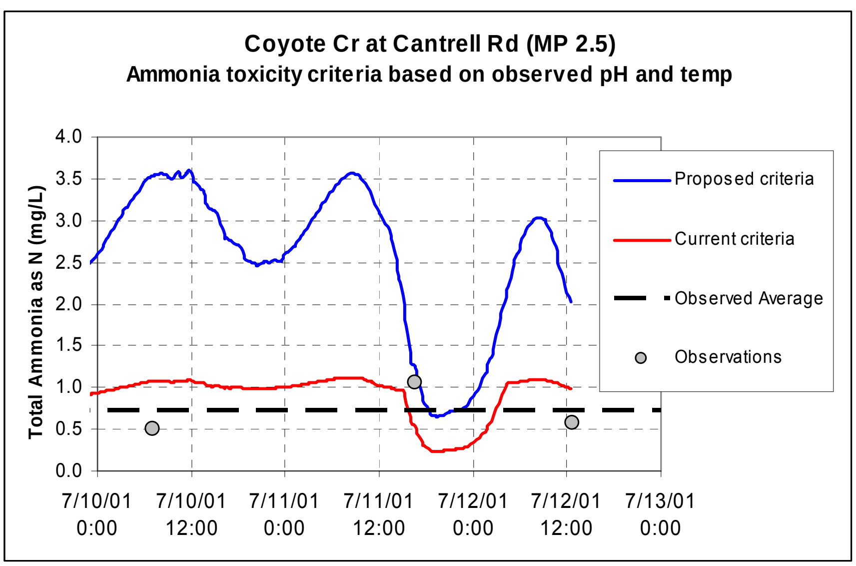


Figure 10.92 Ammonia criteria and observed concentrations

Figure 10.92 shows chronic criteria values calculated using Hydrolab observations at RM 2.5. Shown are both criteria calculated using methodologies in the current Oregon standards and methodologies contained in recently proposed Oregon standards. As shown, criteria in current standards are more stringent than those in proposed. Shown also are ammonia concentrations observed during the July 2001 study. The observed ammonia concentrations of 0.71 mg/L as N equaled about 78% of the criteria for the current standard and 35% of the criteria for the proposed standard. Based on the current ammonia standards, reductions in ammonia may be necessary to insure that standards are met in the stream.

In addition to reducing diel DO fluctuations, improvements in shade will also reduce pH and temperature levels in the stream. This will reduce the percentage of ammonia in the more toxic un-ionized phase and will reduce the frequency at which ammonia toxicity standards are exceeded. In order to address ammonia toxicity concerns, in addition to concerns related to impacts of ammonia on dissolved oxygen levels, a toxicity based ammonia TMDL has been established.

The Heat Source model indicates that improving shade from the current condition to the system potential condition will result in daily maximum temperatures that are 1-2°C cooler in the lower reach (RM 7.0 to RM 2.5). In order to calculate the applicable criteria for total ammonia, observed temperatures at RM 2.5 were reduced 1.5°C, while pH levels were left unchanged (a conservative assumption since improvements in shade should reduce maximum pH levels). For these temperature and pH levels, the maximum allowable 4-day average concentration for ammonia is 1.0 mg/L as N. During the July 2001 survey, observed ammonia concentrations averaged 71% of this concentration.

A concentration of 1.0 mg/L for total ammonia as N should be an appropriate concentration upon which to base the loading capacity for the stream. While available data is insufficient to conclude that pH levels higher than those observed in July 2001 do not occur, it is anticipated that improvements in shade mandated by this TMDL should reduce future pH levels. In addition, the proposed ammonia toxicity standard is less stringent than the current standard (Figure 10.94). Therefore, a target concentration of 1.0 mg/L as N should be fully protective of stream beneficial uses.

Pollutant loading capacity is a function of both the target concentration and the stream flow rate. Hence, the loading capacity is reduced as flow is reduced. Loading capacities are frequently based on 7Q10 low flow rates. However, since irrigation diversions result in occasional reductions in flow in the stream to zero, it is not appropriate to base the loading capacity on the 7Q10 flow. Instead, the loading capacity is set to a target ammonia concentration. In order to provide a margin of safety, the loading capacity to set 20% lower than the maximum allowable 4-d average concentration of 1.0 mg/L as N described above. Thus, the loading capacity for ammonia is 0.8 mg/L as N.

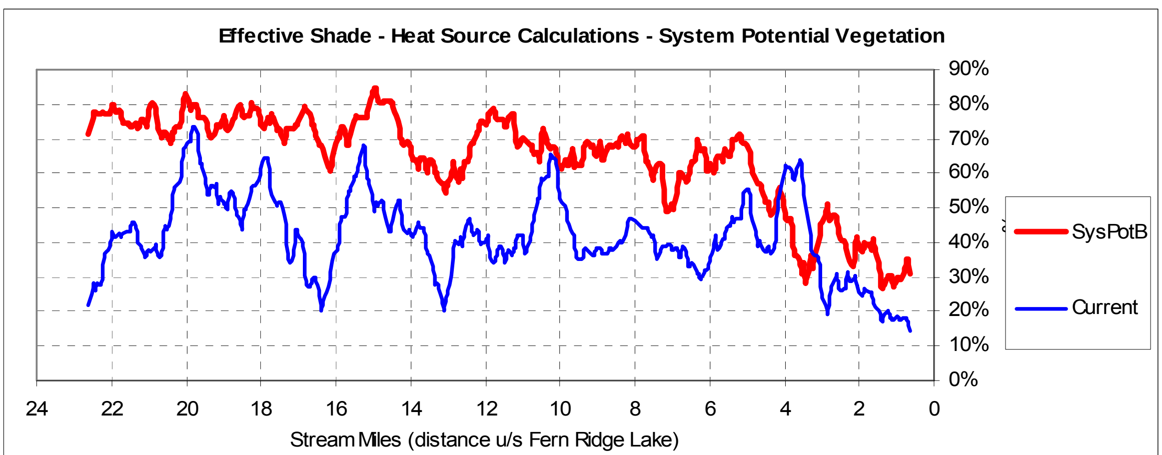
During the July 2001 survey the flow rate was 1.9 cfs. For this flow rate the load of ammonia (as N) is 8.2 lb/day (3.7 kg/day).

Excess Load – Coyote Creek

Excess Load of Solar Radiation

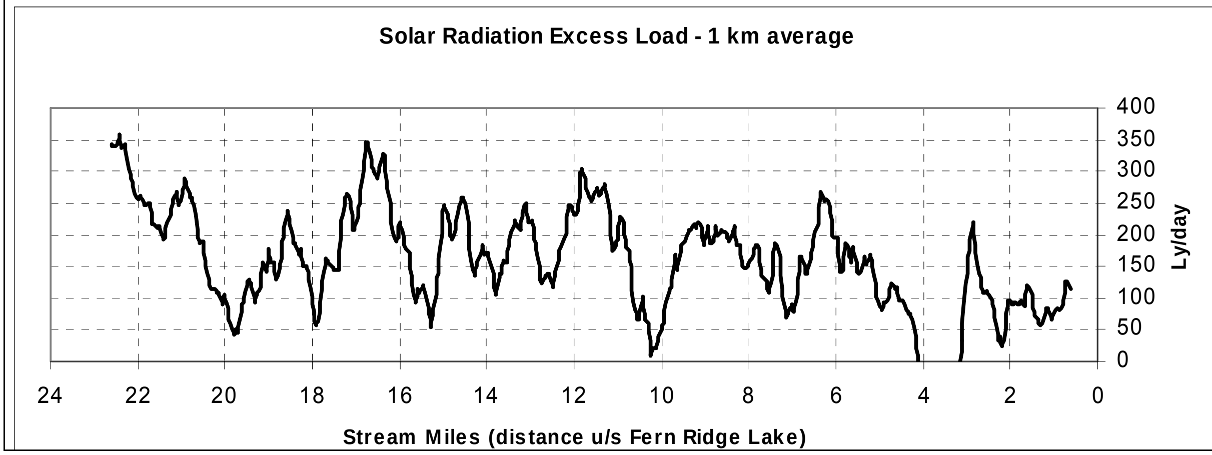
Using shade as a surrogate measure for solar radiation, the excess load is the difference between CCC shade and the system potential shade scenario, SysPotB. This is shown in Figure 10.93.

Figure 10.93 Coyote Creek - Excess Load - Current vs. system potential effective shade



In terms of solar radiation, the excess load is the difference between the solar radiation currently entering the stream and that which would enter the stream for the selected system potential shade scenario. This excess load is presented in Figure 10.94.

Figure 10.94 Coyote Creek - Excess Load - Solar radiation



Since the overall average solar radiation load for system potential for all reaches modeled is 248.2 Ly/day and the current condition average load is 405.1 Ly/day, the excess load for solar radiation is 156.9 Ly/day.

Excess Load for Other Pollutants

For BOD, nutrients, and volatile suspended solids, the excess load in the upper reach is zero, and in the lower reach is equal to 20% of current levels.

For ammonia, the excess load is the difference between the load calculated using current ammonia concentrations and the allowable load. Since concentrations observed during the July 2001 were slightly less than the calculated standard, the excess load is zero.

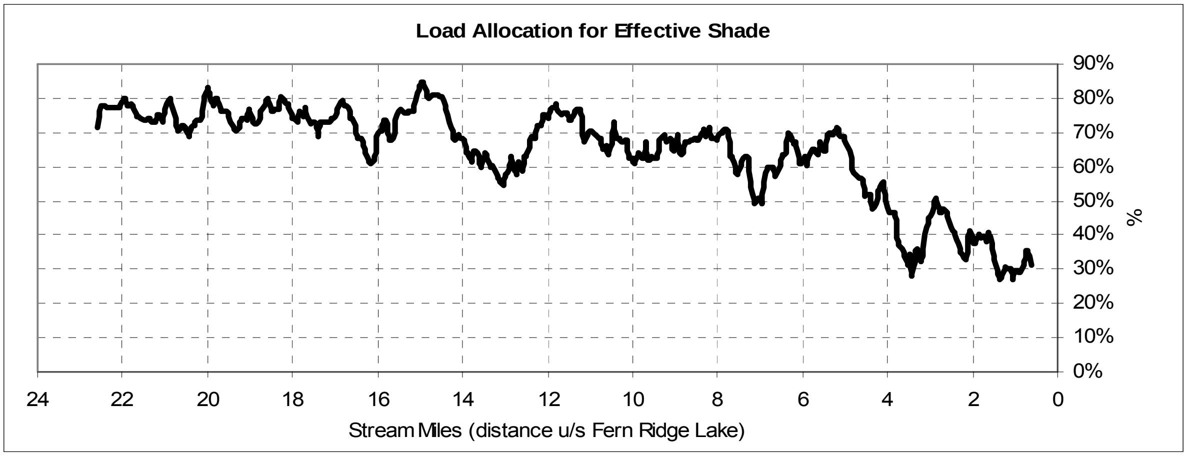
Load Allocations – Coyote Creek

Load Allocation for Solar Radiation

The load allocation for solar radiation for Coyote Creek is set equal to the overall average loading capacity for solar radiation of 248.2 Ly/day. This equates to a 38.7% reduction in solar radiation load from current levels. This corresponds to an overall average effective shade for system potential for all reaches modeled of 62.9%.

In order to provide targets for land management, load allocations are presented in terms of effective shade. The load allocation for effective shade for Coyote Creek is presented in Figure 10.95.

Figure 10.95 Coyote Creek - Load Allocation for effective shade

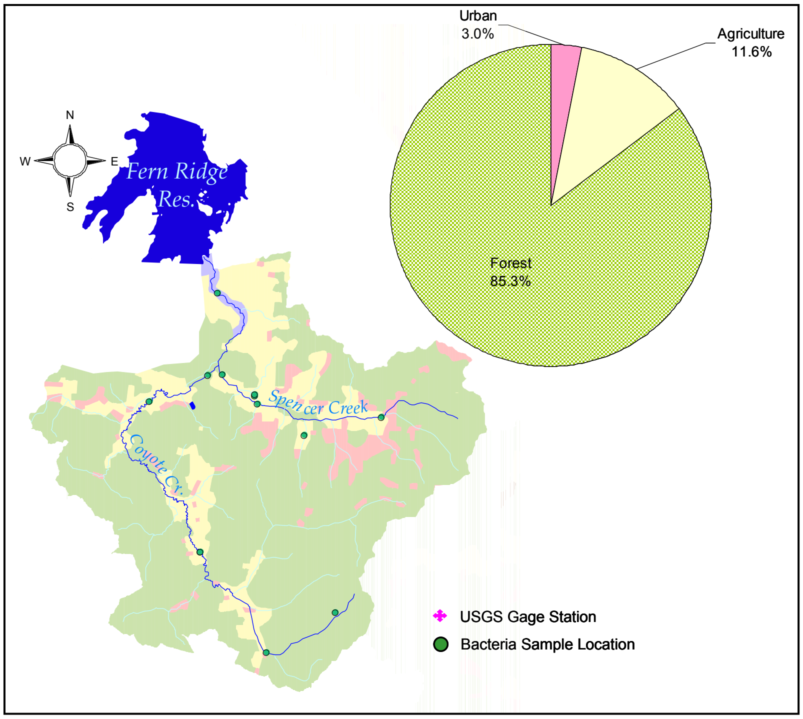


Load Allocations for Other Pollutants

In Coyote Creek above Spencer Creek, no reduction is required for BOD, nutrients or volatile suspended solids. However, below Spencer Creek, where pollutant concentrations are high, a 20% reduction in BOD, nutrients, and SOD causing volatile suspended solids concentrations is specified. The 20% reduction in BOD, nutrients, and SOD causing volatile suspended solids concentrations also applies to Spencer Creek. This is because, even though Spencer Creek is currently not included on the 303(d) list, data collected in 2001 and 2002 shows that it fails to meet DO standards and that it contributes loads of nutrients and oxygen demanding pollutants to Coyote Creek.

The 20% reduction in nutrients applies also to ammonia, since it consumes oxygen as it is oxidized and because it provides nitrogen that can promote excessive algal growth. Ammonia is also potentially toxic and concentrations should not exceed the toxicity based loading capacity concentration of 0.8 mg/L as N. Therefore, the load allocation for ammonia is set to 80% of the toxicity based loading capacity and the 4-day average ammonia concentration should not exceed 0.8 mg/L as N.

Map 10.25 Coyote Creek Watershed Land Use



In order to provide for an explicit 20% margin of safety, the load allocation for ammonia is set to 80% of the toxicity based loading capacity. Therefore, the 4-day average ammonia concentration should not exceed 0.8 mg/L as N.

Loads of BOD, nutrients, and SOD causing volatile suspended solids loads enter the steam from all land use categories. The dominant land use categories for the Coyote watershed are forestry and agriculture, (see Map 10.25). Since forestland generally does not contribute large organic loads to streams, all of the specified load reductions are assigned to urban and agriculture land use categories.

Land use based BOD, nutrient and volatile suspended solids reductions are specified in Table 10.65.

Table 10. 65 Land Use Based Load Allocations for the Coyote Creek Watershed.

Land Use Categories	Coverage Percentage	Required Percent Reduction in BOD loads, nutrient (including ammonia nitrogen) loads, and SOD causing volatile suspended solids loads
Urban	3%	20%
Agriculture	12%	20%
Range	0.0%	0%
Forest	85%	0%

Confined animal feeding operations are not allowed to discharge wastes from specific areas covered by the general NPDES permit. Therefore, for BOD and nutrients, CAFOs are allocated loads of zero from regulated portions of operations.

No other point sources appear likely to discharge significant quantities of BOD or nutrients. If any point sources are found to discharge such pollutants in quantities likely to result in DO concentration impacts, wasteload allocations will be developed to address the discharges.

Margin of Safety-Coyote Creek

TMDLs must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load allocations and water quality. Coyote Creek load allocations provide for margins of safety by:

1. Targeting cold-water rather than cool-water DO standards,
2. Targeting a minimum DO concentration of 6.5 mg/L (rather than 6.0 mg/L).
3. Providing an explicit 20% MOS for ammonia, BOD and other parameters

The use of these margins of safety will ensure that the TMDL, when implemented, will be protective of designated beneficial uses.

Seasonal Variation-Coyote Creek

The season of concern for dissolved oxygen is May 1 through October 31. The shade improvements mandated by this TMDL will result in improved dissolved oxygen concentrations year-round.

The season of concern for ammonia is also the summer period, since this is when temperature and pH levels are greatest and ammonia is most toxic. The load allocations for solar radiation and its surrogate effective shade will reduce temperature and pH levels and reduce the toxicity of existing ammonia. In addition, mandated ammonia load reductions will reduce overall concentrations of ammonia in the stream and ensure that ammonia toxicity standards are met year-round.

20% reductions in BOD, nutrients, and SOD are specified. The concentrations of these pollutants in the stream must be reduced 20% during the May 1 through October 31 season of concern. However, since pollutants which contribute to oxygen deficits via SOD and fluxes of BOD and nutrients from the sediment may actually enter the stream via runoff during high precipitation winter and spring periods, reductions in loads during the winter and spring, as well as in the summer, are necessary in order to achieve the specified load allocations.

Linkages with Other TMDLs

In addition to the TMDLs to address dissolved oxygen concerns described in this document, TMDLs are also proposed by ODEQ to address bacteria concerns in Amazon and Coyote Creeks and turbidity concerns in Fern Ridge Reservoir. Implementation of these TMDLs will result in reduction in volatile suspended solids loads that contribute to BOD and SOD. In addition, indirect loads of ammonia from the decay of volatile suspended solids should also be reduced. Direct loads of ammonia, such as from confined animal feeding operations (CAFOs), may also be reduced if efforts are made to control discharges of bacteria and turbidity causing sediments.

The Willamette Basin Temperature TMDL also applies to Amazon and Coyote Creeks. This addresses high temperatures by providing load allocations for effective shade.

Periphyton Control Model - Technical Discussion

The following provides an overview of the equations and methodology used by the Periphyton Control Model (PCM).

Introduction

PCM was developed to simulate periphyton in streams and evaluate the impact of potential control measures on diurnal pH and dissolved oxygen. The model is designed for relatively fast flowing streams in which the algae present are dominated by periphyton. Consequently, all algae present in the system is treated as periphyton. While the model is designed for periphyton, it is calibrated on observed oxygen data and, therefore, also works well for streams in which a significant portion of oxygen production is due to phytoplankton or macrophytes. The following provides an overview of the equations used in PCM.

The change in periphyton concentrations with time is calculated as follows:

$$\frac{dP}{dt} = (G_P - D_P - F_{slough})P \qquad \text{(eq. 1)}$$

where:

P = periphyton concentration, gC/m^2

G_P = algal growth rate, day^{-1}

D_P = algal death or respiration rate, day^{-1}

F_{slough} = algal loss due to non-respiration related loss mechanisms, day^{-1}

Periphyton is modeled in terms of algal carbon in order to facilitate carbonate system modeling. Output is also provided in terms of chlorophyll, with conversion via literature derived chlorophyll to carbon ratios.

The equation for dissolved oxygen is:

$$\frac{dO_2}{dt} = (G_P - D_P)\frac{P}{H}a_{oc} + K_a(O_{2sat} - O_2) - K_d(BOD) \qquad \text{(eq. 2)}$$

where:

O_2 = dissolved oxygen, g/m^3

H = depth, m

a_{oc} = oxygen to algal carbon ratio, $\mathrm{gO_2/gC}$

K_a = reaeration coefficient, day^{-1}

$O_{2,sat}$ = dissolved oxygen at saturation, g/m^3

K_d = BOD oxidation coefficient, day^{-1}

BOD = biochemical oxygen demand, g/m^3

Photosynthesis and respiration affect water column oxygen and carbon dioxide concentrations as follows (Stumm and Morgan, 1981):

$$106\,CO_2 + 16\,NO_3^{-} + HPO_4^{2-} + 122\,H_2O + 18\,H^{+} \Leftrightarrow \underbrace{\{C_{106}H_{263}O_{110}N_{16}P_1\}}_{\text{"algae"}} + 138\,O_2 \qquad \text{(eq. 3)}$$

$$106\,CO_2 + 16\,NH_4^{+} + HPO_4^{2-} + 108\,H_2O \Leftrightarrow \{C_{106}H_{263}O_{110}N_{16}P_1\} + 107\,O_2 + 14\mathrm{H}^{+} \qquad \text{(eq. 4)}$$

The forward reaction is photosynthesis and the reverse respiration. The first equation is for nitrate as the nitrogen source and the second for ammonia. As shown, depending upon the nitrogen source, anywhere from 107 to 138 moles of oxygen can be produced per mole of algae generated. Since each mole of algae contains 106 moles of carbon, this equates to 1.009 to 1.302 moles of oxygen produced per mole of water column carbon consumed.

In order to model periphyton, the growth and respiration rates, sloughing rates, and periphyton mass must be known. Since these are very difficult to accurately measure directly, PCM calculates them based on observed conditions. Growth rates are estimated using observed temperatures and nutrient concentrations, solar insolation either directly measured or from a separate temperature model, and observed channel geometry and stream flow rates. Algal respiration rates, sloughing rates, and mass are then derived via mass balance calculations using observed diurnal dissolved oxygen concentrations.

Derivation of Algal Growth Rate, G_P

The algal growth rate, G_P, is estimated for each timestep (usually every 15 min to 1 hr) using observed data and literature derived relationships. Algae requires light, nutrients, and heat to grow. If quantities of any of these are insufficient for algal growth needs, algal growth will be limited. This is expressed mathematically as follows:

$$\begin{aligned} Gp &= G_{\max} \bullet (\text{temperature effect}) \bullet (\text{light effect}) \bullet (\text{nutrient effect}) \\ &= G_{\max} \bullet G(T) \bullet G(I) \bullet G(N) \end{aligned} \quad \text{(eq. 5)}$$

In this equation G_{max} is the maximum growth rate of the algae at 20°C under optimal light and nutrient concentrations and G(T), G(I), and G(N) are factors which adjust the growth rate for other temperature, light and nutrient conditions.

Nutrient Effect, G(N)

Phosphorus and nitrogen are essential nutrients with potential for limiting periphyton growth. Both are present in natural waters in several forms, not all of which can be directly used by algae. The phosphorus form that is readily available for algal growth is the soluble reactive phosphorus (SRP, which is equivalent to dissolved orthophosphate, measured as P). Other less available forms include inorganic phosphorus attached to soil particles and organic particulate phosphorus. Nitrogen forms that are readily available for growth are the dissolved inorganic nitrogen (DIN) forms ammonia, nitrite and nitrate. Nitrogen in the form of organic nitrogen is not directly available. Note that while particulate phosphorus is not readily available for algal growth, some may become available through diagenesis or desorption and flux from the sediment.

Similarly, organic nitrogen may become available through conversion to ammonia in the water column or the benthic layer.

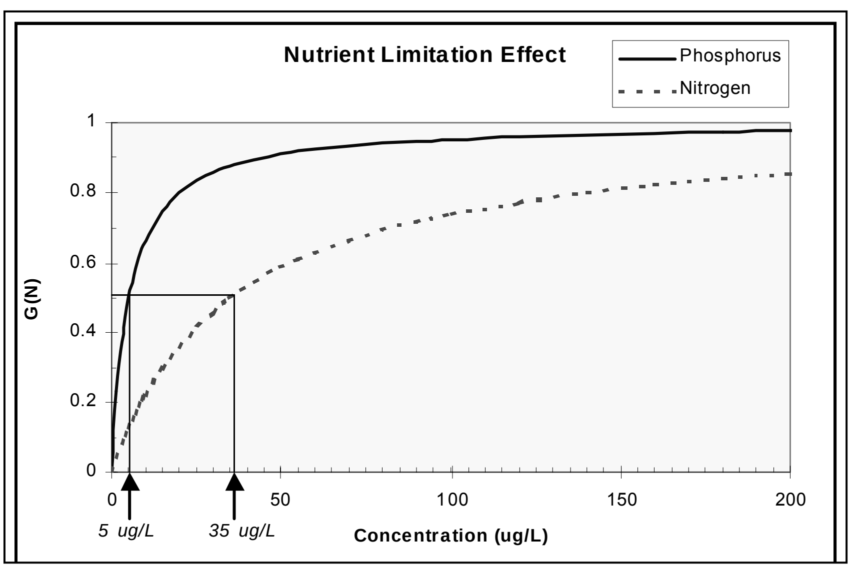


Figure 10.96 Nutrient Limitation Factor, G(N)

Control of excessive algal concentrations frequently is focused on reducing algal growth rates by controlling the nutrients nitrogen and phosphorus. At low nutrient concentrations algal growth is inhibited while at high nutrient concentrations algal nutrient demands are fully met and growth is limited only by temperature and available light. The algal growth rate dependence on nutrients is represented by the relationship shown in Figure 10.96.

As shown, at a nutrient concentration, N, of zero, G(N) is zero and there is no algal growth. As N increases, G(N) increases until it approaches unity, at which point subsequent increases in nutrient concentrations result in insignificant increases in the algal growth rate. At this point the water can be viewed as saturated with the nutrient with respect to algal growth.

An equation which represents this relationship is the Michaelis-Menten equation, as follows:

$$G(N) = \frac{N}{K_{mN} + N}$$

where K_{mN} is the nutrient concentration at which G(N) is 0.5 and is referred to as the Michaelis half-saturation constant. For phosphorus, typical half-saturation constants range from 1 to 5 μg P/L for phytoplankton (Thomann and Mueller, 1987) and from 4 to 8 μg P/L for periphyton (USEPA, 1985), although constants significantly outside these ranges have been identified. For illustrative purposes, the Michaelis-Menton equation for a phosphorus half-saturation constant of 5 ug/L is plotted on Figure 10.96. Since the stoichiometric ratio of algal cellular nitrogen to phosphorus is about 7 on a mass basis , the corresponding half-saturation constant for nitrogen is 35 ug/L. The Michaelis-Menton equation for nitrogen is also plotted on Figure 10.98. As shown, at concentrations several times greater than the half-saturation constant, G(N) approaches 1 and the nutrient does not significantly limit growth. For example, at a phosphorus concentration of 25 μg/L, which is 5 times the phosphorus half-saturation constant, G(N) is 0.83, indicating a growth rate 83% of the maximum rate. At concentrations less than the half-saturation constants, algal growth is severely inhibited.

Several options are available for combining limitation due to nitrogen with limitation due to phosphorus (USEPA, 1985). These include: 1) a multiplicative formula in which the nutrient limitation factor for phosphorus, G(phosphorus), is multiplied by the limitation factor for nitrogen, G(nitrogen), to obtain G(N); 2) a minimum formulation in which the most severely limiting factor is assumed to limit growth; 3) a harmonic mean formulation which combines the reciprocal of each limiting factor; and 4) an arithmetic formulation which uses the average of each limiting factor.

The second method, which is the approach used in many recent algal models (USEPA 1985) is the method utilized in PCM. In this formulation the nutrient in shortest supply relative to algal needs defines the nutrient limitation factor, G(N). For example, if a water contains 50 μg/L of SRP and 100 μg/L of DIN, G(phosphorus) would be 50/(5+50) = 0.91 and G(nitrogen) would be 100/(35+100) = 0.74. G(N) would therefore be the lesser of the two, i.e., 0.74.

Light Effect, G(I)

Since the energy source for algal growth is light, algae growth responds positively to increased light levels. This is illustrated by Figure 10.97 and represented by the following equation (Thomann and Mueller, 1987):

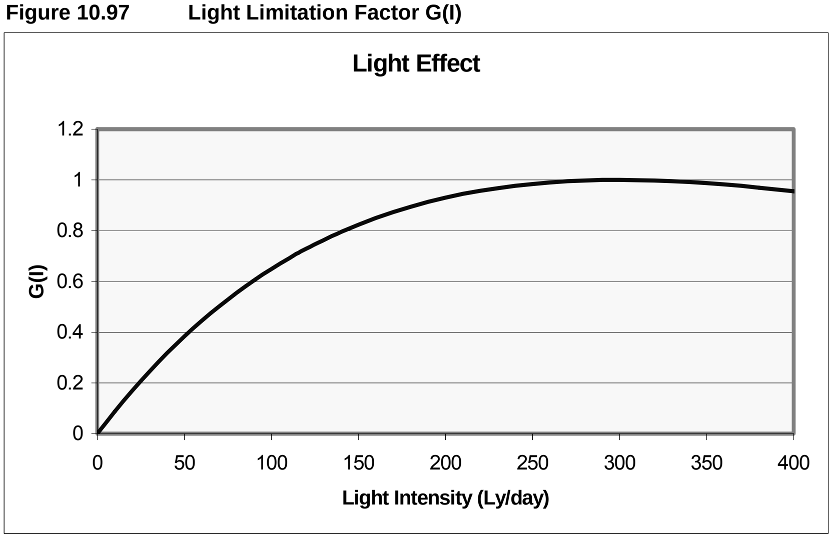
$$G(I) = \frac{I}{I_s} \exp\left(\frac{-I}{I_s} + 1\right) \qquad \text{(eq. 6)}$$

where :

I = light intensity at algae depth (Ly)

I_s = saturating light intensity (Ly)

Figure 10.97 Light Limitation Factor G(I)



The light intensity which impacts periphyton is a function of the light intensity at the surface, the light absorption in the water column, and water depth. Light intensity at the surface is a function of location, time of year, time of day, meteorological conditions, and shading from topographic features or riparian vegetation. Light extinction in the water column is a function of water depth and water turbidity due to inorganic solids, detrital particles, suspended phytoplankton, etc.

In order to calculate G(I), data is needed on light intensity. While historical data is available for other parameters affecting algal growth, such as nutrient concentrations, temperature, water depth, etc., historical data is generally not available on light intensity. Light intensity may be derived using a temperature model calibrated on observed temperature, shade and depth data. The estimated solar radiation is converted to photoactive solar radiation by mutiplying it by a factor in the range 0.4 to 0.5.

Light extinction with depth is a calculated via (Thomann and Mueller, 1987):

$$I = I_{surface} \exp(-K_e H) \qquad \text{(eq. 7)}$$

where: I = photoactive active solar radiation at the benthos, Ly/min
$I_{surface}$ = photoactive radiation which penetrates the surface, Ly/min
K_e = light extinction coefficient, 1/m
H = depth, m

K_e is a function of turbidity and ranges from less than 0.5 for relatively clear waters to 2 or more for highly turbid waters (Thomann and Mueller, 1987).

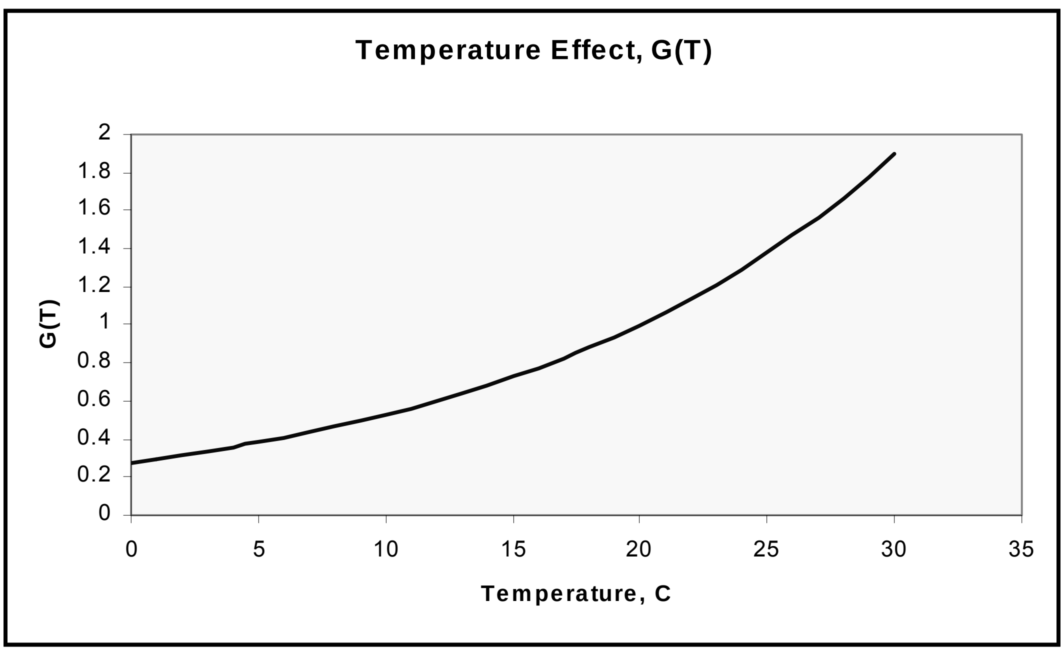
Temperature Effect, G(T)

The temperature factor is calculated as follows (Thomann and Mueller, 1987):

$$G(T) = (1.066)^{T-20} \qquad \text{(eq. 8)}$$

Figure 10.98 presents a plot of the equation 8. As shown, as temperature increases, the growth rate increases. Therefore, stream reaches with elevated temperatures have greater growth rates and are more likely to experience pH and dissolved oxygen violations than those with lower temperatures.

Figure 10.98 Temperature Limitation Factor, G(T)



Note that shade has a compound effect on algal growth rate. Increasing shade directly reduces G(light), and indirectly reduces G(T) by reducing stream temperatures. Therefore, shade can significantly reduce algal activity.

Mass Balance to Estimate Flux of Oxygen Due to P-R, Reaeration, BOD Oxidation

Now that the algal growth rates, G_P, have been estimated, the oxygen mass balance for each time step can be calculated. Oxygen enters and leaves the water column through algal production and respiration (P-R), atmospheric exchange, and BOD oxidation.

The net oxygen flux at each time step is derived as follows (Brown and Barnwell, 1987):

$$Flux_{O_2Net} = Flux_{O_2P-R} + Flux_{O_2K_a} + Flux_{O_2BOD} \qquad \text{(eq.9)}$$

where:

$Flux_{O_2P-R}$ = net oxgen flux due to algae (production - respiration), $g/m^3 - day$

$Flux_{O_2K_a}$ = oxygen flux due to reaeration, $g/m^3 - day$

$Flux_{O_2BOD}$ = oxygen flux due to BOD oxidation (always negative), $g/m^3 - day$

The net oxygen flux, $Flux_{O_2Net}$, is simply the change in dissolved oxygen from one time step to the next. Usually time steps of 1 hour are used, but shorter time steps may be needed in highly aerated waters.

The oxygen atmospheric flux due to reaeration, $Flux_{O_2K_a}$, is calculated using estimated reaeration rates and the observed oxygen deficit, as follows (Brown and Barnwell, 1987):

$$Flux_{O_2K_a} = K_a(O_{2,sat} - O_2) \qquad \text{(eq. 10)}$$

where:

$Flux_{O_2K_a}$ = oxygen flux due to reaeration, $g/m^3 - day$

K_a = reaeration coefficient, day^{-1}

$O_{2,sat}$ = dissolved oxygen at saturation, g/m^3

O_2 = dissolved oxygen, g/m^3

Reaeration coefficients are estimated using empirical formulations from the literature in which reaeration is correlated to velocity and depth or velocity and slope. Three formulations are provided in the model: O'Connor and Dobbins; Owens, Edwards and Gibbs; and Tsivoglou-Wallace (Brown and Barnwell, 1987). The equation applied to the Coyote Creek was the Owens, et al., equation, as follows (Owens 1964):

$$K_{a,20} = \frac{21.7u^{0.67}}{H^{1.85}}$$

where:

$K_{a,20}$ = reaeration coefficient at 20^oC

u = velocity, ft/s

H = mean depth, ft

The oxygen flux due to BOD oxidation, $Flux_{O_2BOD}$, is derived using observed BOD concentrations for the reach being modeled and estimated BOD decay rates. In streams with significant oxygen production due to algae the flux due to BOD oxidation is usually quite small relative to the other components of the oxygen balance. It does not impact the diel oxygen fluctuation, but rather lowers the daily average oxygen concentration.

The net oxygen flux due to algae can now be calculated by solving eq. 9 for $Flux_{O_2P-R}$.

Derivation of Periphyton Respiration Rates, Sloughing Rates, and Mass

Now that the net oxygen flux rate due to algal production and respiration, $Flux_{O_2P-R}$, has been estimated for each time step, the gross algal production rate, $Flux_{O_2P}$, and gross algae respiration rate, $Flux_{O_2R}$, can be derived for each step. The methodology is as follows:

Since no algal production occurs at night, $Flux_{O_2R}$ at night equals $Flux_{O_2P-R}$. The average nighttime respiration flux rate and average nighttime temperature is used to derive a temperature corrected respiration flux rate at 20°C via the following Streeter-Phelps type formulation (Brown and Barnwell, 1987):

$$Flux_{O_2R,20} = {Flux_{O_2R}}\Big/{\theta^{(T-20)}} \quad \text{(eq. 11)}$$

θ is typically around 1.047 and is determined during model calibration (Brown and Barnwell, 1987).

$Flux_{O_2R}$ is subsequently derived for the daytime time steps using this relationship. $Flux_{O_2P}$ is then derived for via $Flux_{O_2P} = Flux_{O_2P-R} - Flux_{O_2R}$.

Now that $Flux_{O_2P}$ is known for each daytime time step, the periphyton mass, P, may be calculated as follows (Thomann and Mueller, 1987):

$$Flux_{O_2P} = G_P P a_{oc} \Delta t$$

$$\text{Therefore} \quad P = \frac{Flux_{O_2P}}{(G_P)(a_{oc})(\Delta t)} \qquad \text{(eq.12)}$$

where

$$P = \text{periphyton mass, } {\text{gC}}\Big/{\text{m}^3}$$

$$\Delta t = \text{timestep, days}$$

The respiration rate, D_P, is derived for each daytime time step via

$$D_P = G_P - \frac{Flux_{O_2P-R}}{(G_P)(a_{oc})(\Delta t)} \qquad \text{(eq. 13)}$$

The respiration rate at 20°C, D_{P20}, is then derived using the average daytime temperature and the 24-hour average D_P is derived using the 24 hour average temperature.

Finally, the daily average periphyton mass is calculated as follows:

$$P_{average} = \frac{\sum Flux_{O_2 P_{t=1-24}}}{(a_{oc})(G_{P,avg})} \qquad \text{(eq.14)}$$

where:

$\sum Flux_{O_2 P_{t=1-24}}$ = total gross oxygen production by algae for 24 hrs

$G_{P,avg}$ = daily average algal growth rate

P is converted to an areal basis, gC/m^2, by multiplying by the depth.

F_{slough} is derived by assuming that the periphyton mass has reached it's maximum extent during the critical model calibration condition (usually late July through mid August) and is in a state of dynamic equilibrium (i.e., the mass at the end of the day equals the mass at the beginning). Therefore:

$$F_{slough} = G_{P,avg} - D_{P,avg} \qquad \text{(eq. 15)}$$

Ammonia Preference Factor

As discussed above (equations 3 and 4), depending upon the nitrogen source, from 107 to 138 moles of oxygen are produced for every 106 moles of carbon converted to algae. In mass terms, this equates to 2.67 to 3.47 g O_2 produced per g algal carbon generated. While both ammonia and nitrate are available for uptake by algae, for physiological reasons the preferred form is ammonia. This preference for ammonia is quantified via the ammonia preference factor, β_{NH4}, as follows (Thomann and Fitzpatrick, 1982; Ambrose et. al, 1988):

$$\beta_{NH4} = NH_4N\left(\frac{NO_3N}{(K_{mN} + NH_4N)(K_{mN} + NO_3N)} + \frac{K_{mN}}{(NH_4N + NO_3N)(K_{mN} + NO_3N)}\right) \qquad \text{(eq.16)}$$

where:

NH_4N = ammonia nitrogen concentration, $\frac{mg}{L}$

NO_3N = nitrate nitrogen concentration, $\frac{mg}{L}$

K_{mN} = michaelis-menton half saturation concentration for nitrogen, $\frac{mg}{L}$

The mass of dissolved oxygen produced per mass of water column CO_2 converted to algal carbon is calculated by PCM as follows (Stumm and Morgan, 1981):

$$a_{oc,NH_4,mol} = 107 \text{ moles } \mathrm{O}_2 / 106 \text{ moles C} = 1.0094 \; {}^{molesO_2}\!\!/_{molesC}$$

$$a_{oc,NO_3,mol} = 138 \text{ moles } \mathrm{O}_2 / 106 \text{ moles C} = 1.3019 \; {}^{molesO_2}\!\!/_{molesC}$$

$$a_{co,NH_4} = {}^{1}\!/_{a_{oc,NH_4,mol}} \bullet \left({}^{12}\!/_{32}\right) \; {}^{gC}\!/_{gO_2}$$

$$a_{co,NO_3} = {}^{1}\!/_{a_{oc,NO_3,mol}} \bullet \left({}^{12}\!/_{32}\right) \; {}^{gC}\!/_{gO_2}$$

$$a_{co} = \beta_{NH4} a_{co,NH_4} + (1 - \beta_{NH4}) a_{co,NO_3} \quad {}^{gC}\!/_{gO_2}$$

$$a_{oc} = {}^{1}\!/_{a_{co}} \quad {}^{gO_2}\!/_{gC}$$

where :

$a_{oc,NH_4,mol}$ = moles O_2 produced per mole CO_2 converted to algal C if ammonia is N source

$a_{oc,NO_3,mol}$ = moles O_2 produced per mole CO_2 converted to algal C if nitrate is N source

a_{co} = mass algal C generated per mass O_2 produced

a_{oc} = mass O_2 produced per mass CO_2 converted to algal C

Photographs of Monitoring Stations – Amazon Creek

Figure 10.99 Amazon Creek at 29th Street – LASAR 25624 – RM 10.9 (u/s Lake) - view u/s left panel, d/s right panel

Figure 10.100 Amazon Creek at Chambers St. – LASAR 25623 - RM 8.3 (u/s Lake) – view u/s left panel, d/s right panel

Figure 10.101 Amazon Creek at S. Pacific RR Bridge – LASAR 25620 - RM 3.9 (u/s Lake) - view u/s left panel, d/s right panel

Figure 10.102 Amazon Creek Diversion Channel at Royal Ave. – LASAR 10149 – RM 2.7 (u/s Lake) - view u/s left panel, d/s right panel

Figure 10.103 Amazon Creek Diversion Channel at Fir Butte Rd. - LASAR 25617 - RM 0.8 (u/s Lake) - view u/s left panel, d/s right panel

Photographs of Monitoring Stations – Coyote Creek

Figure 10.104 Coyote Creek at Gillespie Corners - LASAR 25627 – RM 22.9 - view u/s left panel, d/s right panel

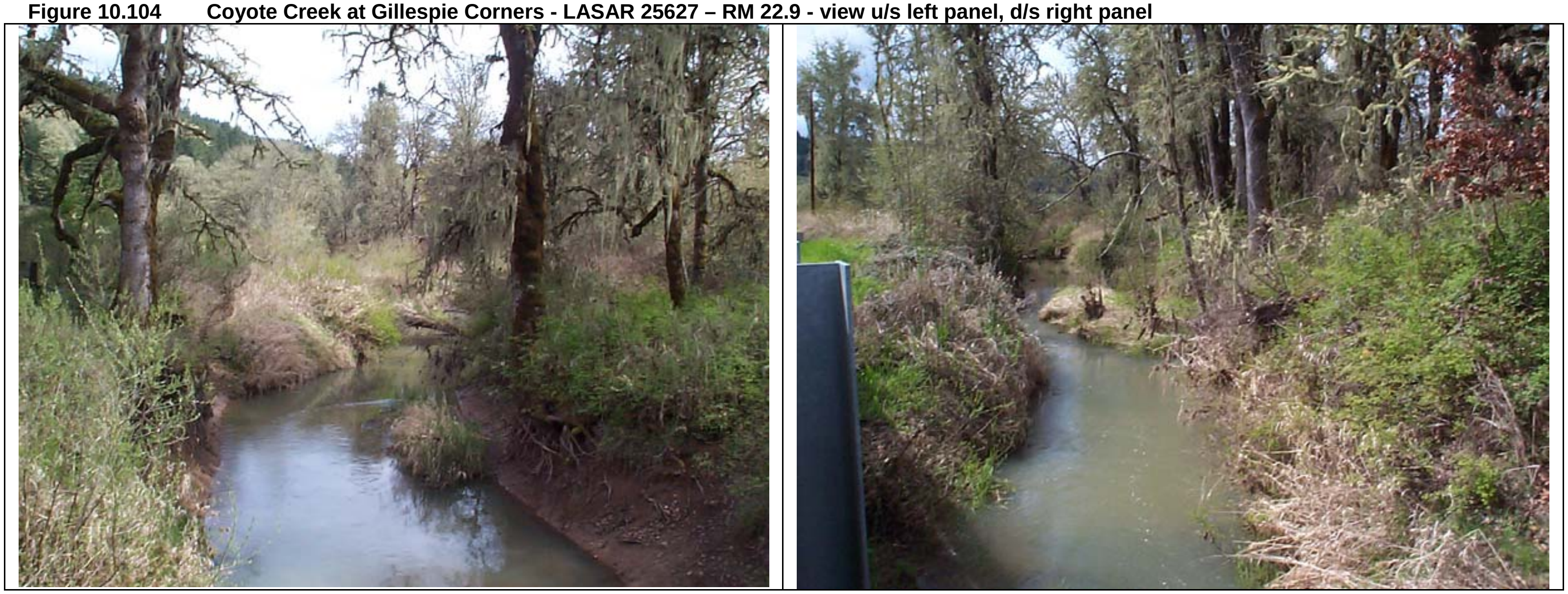


Figure 10.105 Coyote Creek at Powell Rd - LASAR 25626 – RM 20.5 - view u/s left panel, d/s right panel

Figure 10.106 Coyote Creek at Crow Road - LASAR 11148 - RM 11.1 - view u/s left panel, d/s right panel

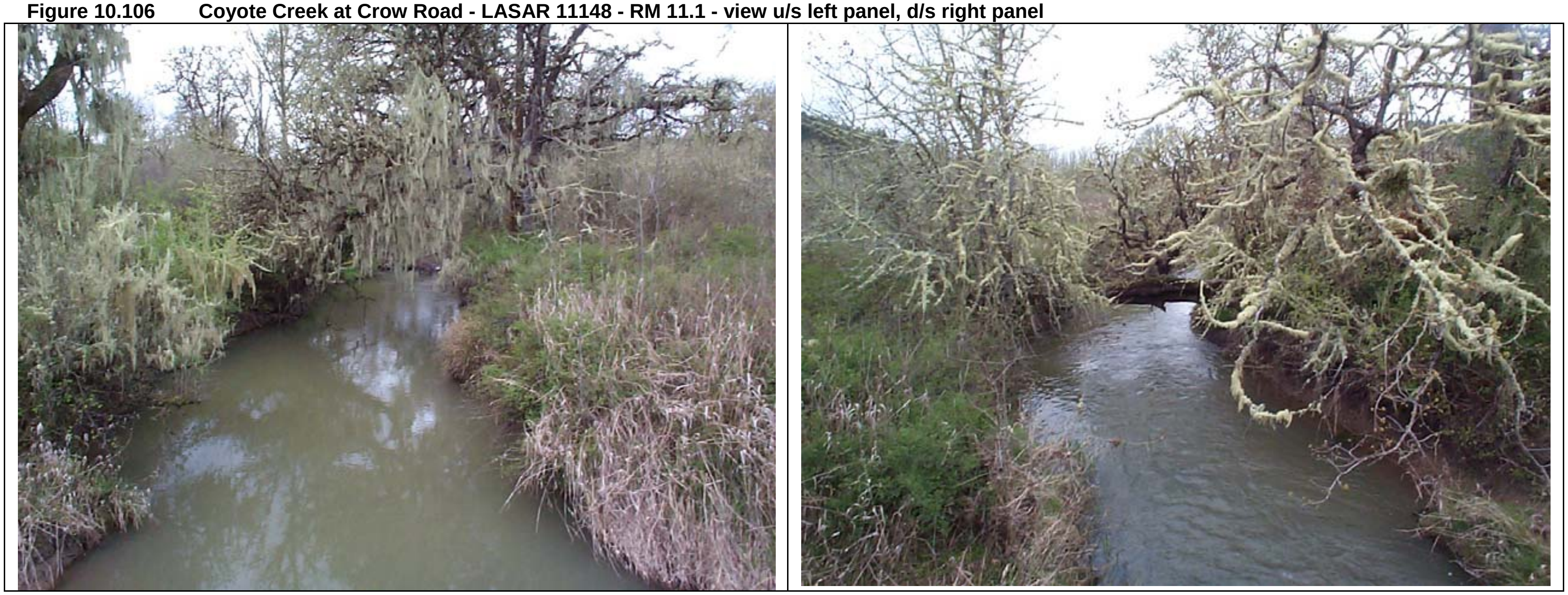


Figure 10.107 Coyote Creek at Petzold Road - LASAR 10151 - RM 7.0 - view u/s left panel, d/s right panel

Figure 10.108 Coyote Creek at Cantrell Road - LASAR 10150 - RM 2.5 - view u/s left panel, d/s right panel

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Dissolved oxygen modeling: James Bloom, ODEQ.
Primary author: James Bloom, ODEQ.
Maps: Tracy Harrison.
Data collection: the City of Eugene; Long Tom Watershed Council volunteers including Andy Lanier; and ODEQ staff including James Bloom, Jared Rubin, Tracy Harrison, Agnes Lut, Steve Mrazik, and Pamela Wright.

TURBIDITY TMDL: FERN RIDGE RESERVOIR

Scope of TMDL

Fern Ridge Reservoir (also know as Fern Ridge Lake) fails to meet minimum water quality standards for turbidity. The reservoir is located in Lane County, Oregon and is popular for swimming, fishing, and other recreation. Amazon and Coyote Creeks, which provide water for the reservoir, contain excessive loads of suspended solids which contribute to the reservoir's turbidity problems. In addition, these streams experience low dissolved oxygen levels due to pollutant loads and habitat degradation, high bacteria levels, and high temperatures.

Because of the turbidity concerns, Fern Ridge Reservoir is included on the 303(d) List of water bodies that do not meet water quality standards for failing to meet minimum standards for turbidity. This document describes "total maximum daily loads (TMDLs)" for pollutants which contribute to turbidity standard violations in Fern Ridge Reservoir.

External sources of turbidity causing solids are storm related inflows of solids from Amazon and Coyote Creeks. Internal sources of turbidity causing solids are resuspension of previously settled solids. The original source of many of these resuspended solids is likely Amazon and Coyote Creeks. In this TMDL, load allocations are provided for external solids loads which contribute to turbidity. To address the internal recycling of solids, management measures are described which limit the resuspension of solids.

Table 10. 66 TMDL components for turbidity TMDL

Name & Location of Waterbodies **OAR 340-042-0040(4)(a)**	Fern Ridge Reservoir (HUC 17090003 0036, Segment ID 22E-FERN)
Pollutant Identification **OAR 340-042-0040(4)(b)**	_Pollutants:_ Turbidity due to elevated suspended solids concentrations
Beneficial Uses **OAR 340-042-0040(4)(c)** **OAR 340-041**	Salmonid fish rearing (trout), resident fish and aquatic life, and fishing. Fern Ridge Reservoir and its major feeder tributaries, the Long Tom River above Fern Ridge Reservoir, Coyote Creek and Amazon Creek, are designated for "salmon and trout rearing and migration" (including all salmon species, steelhead, rainbow, and cutthroat trout) (OAR 340-041, Figure 340A). The Long Tom River below Fern Ridge Reservoir is designated for "cool water" species (OAR 340-041, Figure 340A).
Target Identification **OAR 340-042-0040(4)(c)** **OAR 340-041-0036** **OAR 340-041-0002** ***CWA §303(d)(1)***	OAR 340-041-0036 provides numeric turbidity criteria: "Turbidity (Nephelometric Turbidity Units, NTU): No more than a ten percent cumulative increase in natural stream turbidities may be allowed, as measured relative to a control point immediately upstream of the turbidity causing activity. However, limited duration activities necessary to address an emergency or to accommodate essential dredging, construction or other legitimate activities and which cause the standard to be exceeded may be authorized provided all practicable turbidity control techniques have been applied and one of the following has been granted: (a) Emergency activities: Approval coordinated by the Department with the Oregon Department of Fish and Wildlife under conditions they may prescribe to accommodate response to emergencies or to protect public health and welfare; (b) Dredging, Construction or other Legitimate Activities: Permit or certification authorized under terms of section 401 or 404 (Permits and Licenses, Federal Water Pollution Control Act) or OAR 14l-085-0100 et seq. (Removal and Fill Permits, Division of State Lands), with limitations and conditions governing the activity set forth in the permit or certificate." (340-041-0036) In order to determine natural stream turbidities to use for turbidity targets for the streams, appropriate reference sites were selected in accordance with OAR 340-041-0002: "Appropriate Reference Site or Region" means a site on the same water body, or within the same basin or ecoregion that has similar habitat conditions, and represents the water quality and biological community attainable within areas of concern." Specific flow dependent targets for turbidity and suspended solids are presented in Figures 10.118, 10.119 and 10.124..
Existing Sources **OAR 340-042-0040(4)(f)** ***CWA §303(d)(1)***	Multiple point and nonpoint sources during runoff events, including urban storm water discharge and urban and agricultural run-off, and stream bank erosion because of the removal or reduction of stream side vegetation.

Seasonal Variation **OAR 340-042-0040(4)(j)** ***CWA §303(d)(1)***	Load Allocations for external loads from Amazon Creek Diversion Channel and Coyote Creek apply for high to medium (transition) flow conditions with exceedance probability, as % greater than, of 0 to 60%. Such flows generally occur from Oct 1 through May 31, however, they may occur during any season.
TMDL **Loading Capacity and Allocations** **OAR 340-042-0040(4)(d)** **OAR 340-042-0040(4)(e)** **OAR 340-042-0040(4)(g)** **OAR 340-042-0040(4)(h)** ***40 CFR 130.2(f)*** ***40 CFR 130.2(g)*** ***40 CFR 130.2(h)***	*Loading Capacity:* The loading capacity is the amount of pollutant that a waterbody can receive and still meet water quality standards. Loading capacities for Amazon Creek and Diversion Channel and Coyote Creek are flow dependent and are presented in Figure 10.130 and summarized in Table 10.75. *Load Allocations (All Sources):* Load allocations are provided in terms of suspended solids load and as land use based percent reductions in suspended solids load .Load allocations as percent reductions in suspended solids are summarized in Table 10.80. *Excess Load:* Is the difference between the actual pollutant load and the loading capacity of each waterbody. The excess load of suspended solids at high flows exceeds 100,000 lbs/day in Coyote Creek and 10,000 lbs/day in Amazon Creek. Excess loads for all flow conditions are presented in Figure 10.131.
Surrogate Measures **OAR 340-042-0040(5)(b)** ***40 CFR 130.2(i)***	*Translates Nonpoint Source Load Allocations* Load allocations for turbidity causing suspended solids are provided in terms of suspended solids load per day and as land use based percent reductions.
Margins of Safety **OAR 340-042-0040(4)(i)** ***CWA §303(d)(1)***	*Margins of Safety* This TMDL provides for implicit margins of safety, as follows: 1. The turbidity standard allows no more than a ten percent cumulative increase in natural stream turbidities as measured relative to a control point. For control points, this TMDL targets natural stream turbidities measured at appropriate reference sites. The TMDL targets the reference site turbidities, rather than reference turbidities plus ten percent. Hence, the TMDL provides for an implicit ten percent margin of safety. 2. The TMDL provides for a margin of safety by capping maximum turbidities at levels necessary to protect aquatic species, even if reference site turbidities exceed these levels. 3. A station on the upper Long Tom River was used as a reference site in addition to upper Amazon and Coyote Creek stations. Turbidity and suspended solids concentrations at this location were consistently less than measured at the Amazon and Coyote Creek stations, which provides for a margin of safety over simply using reference sites on Amazon and Coyote Creeks.
Reserve Capacity **OAR 340-042-0040(4)(k)**	*Reserve capacity* provides allocations for increases in pollutant loads from future growth and new or expanded sources. No reserve capacity has explicitly been provided for in the TMDL. However, the conservative margins-of-safety applied in establishing load allocations may allow capacity for future loads after the load allocations have been met.
Water Quality Management Plan **OAR 340-042-0040(4)(l)** ***CWA §303(d)(1)***	*The Water Quality Management Plan (WQMP)* provides the framework of management strategies to attain and maintain water quality standards. The framework is designed to work in conjunction with detailed plans and analyses provided in sector-specific or source-specific implementation plans.
Standards Attainment & Reasonable Assurance **OAR 340-042-0040(4)(l)**	Standards Attainment and Reasonable Assurance are addressed in the WQMP, Chapter 14.

Fern Ridge Reservoir Description

Fern Ridge Reservoir is a U.S. Army Corps of Engineers (USACE) managed reservoir located near Eugene, Oregon (see Map 10.26). It is operated primarily for recreation in the summer and flood control in the winter. It is also a major wildlife management area (LCOE, 1983).

The Fern Ridge Reservoir project is one of 13 multipurpose water projects operated by USACE in the Willamette Valley. Since Fern Ridge Reservoir is just 12 miles from downtown Eugene, it is a popular recreation area for swimming, sailing, powerboating and waterskiing. The surface area of the reservoir when full is 9,000 acres (3688.5 ha). (https://www.nwp.usace.army.mil/)

The dam is an earth fill structure with a gated concrete spillway for regulation of lake levels (see Figure 10.109. The project was completed in 1941.

The pool level at Fern Ridge Reservoir is kept as high as possible from April through September for recreation as well as wetland wildlife habitat stability. The lake level usually drops 2 to 3 feet during the summer due to irrigation needs downstream. During the winter, the level is lowered to provide storage capacity for flood control. (https://www.nwp.usace.army.mil/)

Map 10.26 Fern Ridge Reservoir

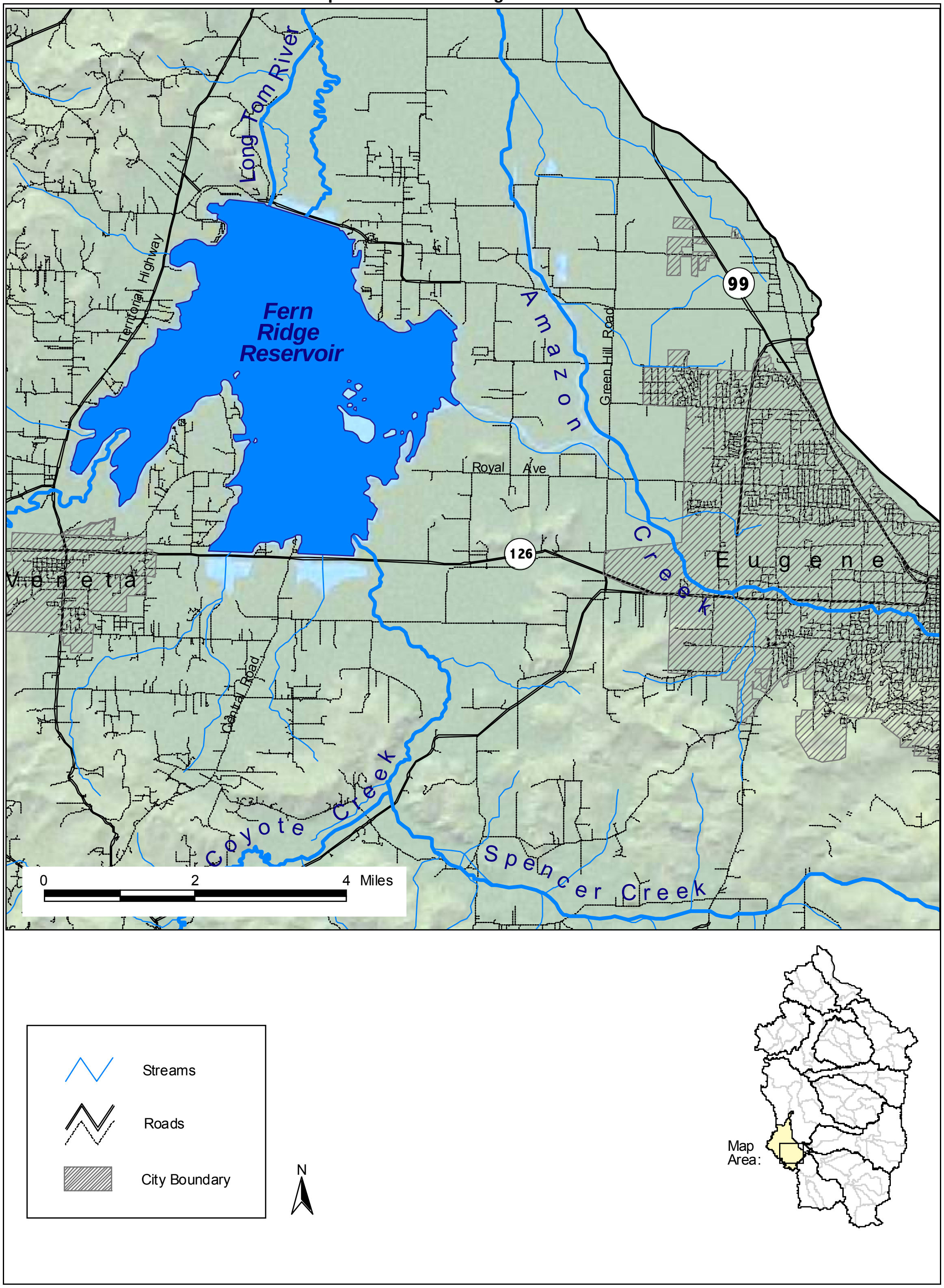


Figure 10.109 Fern Ridge Reservoir photograph (https://www.nwp.usace.army.mil/op/v/images/fer0504.jpg)

Beneficial Uses

Fern Ridge Reservoir and its major feeder tributaries, the Long Tom River above Fern Ridge Reservoir, Coyote Creek and Amazon Creek, are designated for "salmon and trout rearing and migration" (including salmon species, steelhead, rainbow, and cutthroat trout) (OAR 340-041, Figure 340A). The Long Tom River below Fern Ridge Reservoir is designated for "cool water" species (OAR 340-041, Figure 340A).

"Cool-Water Aquatic Life" means aquatic organisms that are physiologically restricted to cool waters, including but not limited to native sturgeon, pacific lamprey, suckers, chub, sculpins and certain species of cyprinids (minnows).

"Salmon and steelhead spawning" is not a designated use for Fern Ridge Reservoir, the Long Tom River above or below Fern Ridge Reservoir, or associated tributaries including Coyote Creek and Amazon Creek (OAR 340-041, Figure 340B).

Pollutant Identification

Turbidity is a measure used to represent the clarity of water. Turbidity is defined as, "an expression of the optical properties of a liquid that cause light rays to be scattered and absorbed rather than transmitted in straight lines through a sample (ASTM 2003)." Both inorganic and organic solids may contribute to turbidity. For regulatory purposes, turbidity is quantified in terms of Nephelometric Turbidity Units (NTU), with zero NTU representing clear water.

Excessive fine particulate material in streams can have a number of undesirable effects on the stream biota (Mulvey and Hamel, 1998). It can decrease primary productivity by smothering, abrading or shading photosynthesizing organisms. Excessive fine particulate material can deposit and adversely impact macroinvertebrate assemblages by filling in habitat space and reducing oxygen supply. Excessive fine particulate material may also harm fish and amphibian communities by covering respiratory surfaces, smothering eggs laid in spawning gravel, trapping emerging newly hatched fry in spawning gravel, decreasing food availability and visual feeding efficiency, and by filling in pools and interstitial habitat spaces.

303(d) Listing

Fern Ridge Reservoir is listed due to violations of the turbidity standard. The listing applies year-round, however, August is identified as a particular period of concern due to high turbidities which are unsafe for swimming (see Figure 10.110).

Figure 10.110 303(d) Listing for turbidity in the Upper Willamette Subbasin

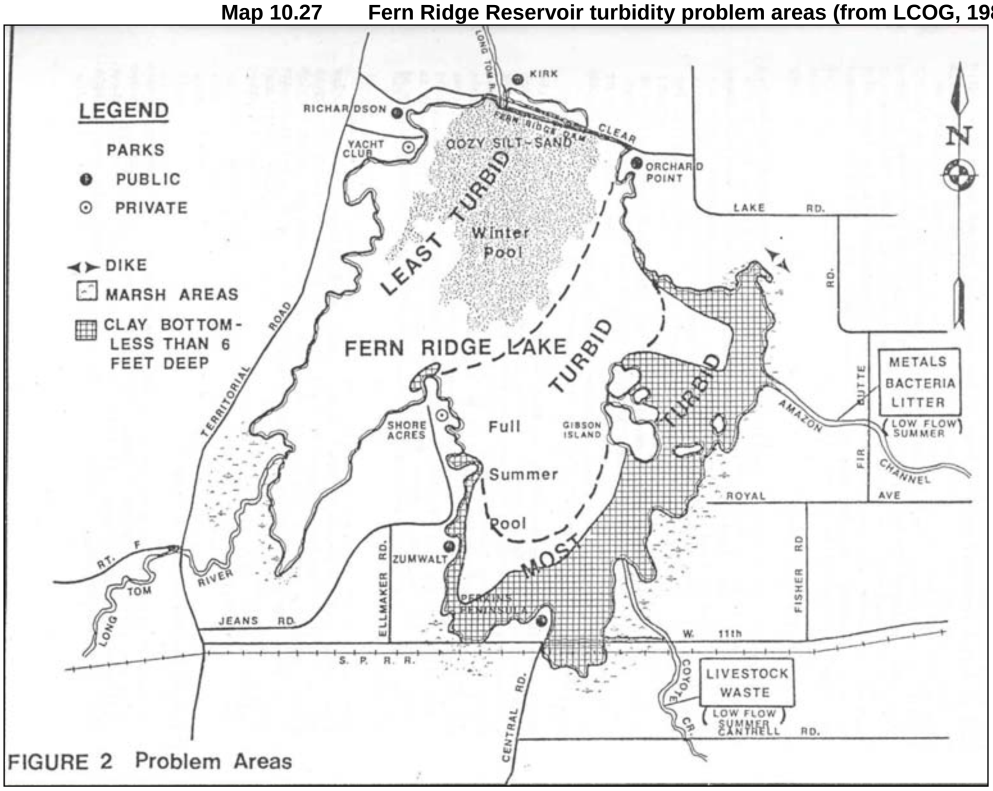
Water Quality Limited Streams Database
Details for Waterbody Segment Record ID 7058

The table below provides details for **Record ID 7058**.

Field	Details
Waterbody Name	Fern Ridge Reservoir/Long Tom River
Sub Basin Name	UPPER WILLAMETTE
HUC	17090003
LLID	1232915440921/1232400443847
River Mile	24.2 to 31.8
Parameter	Turbidity
Criteria	10% increase
Season	
Listing Status	303(d) List
Supporting Data	Fern Ridge Clean Lakes Study - Reservoir is typically clearest in May and June (secchi reading of 6.5 feet) but by August visibility is limited to 1 to 2 feet which can be unsafe for swimming (LCOG, 1983).
Sample Matrix Description	Water Column
List Date	1998
Beneficial Uses	aesthetics resident fish and aquatic life water supply

The basis for the listing is a 1983 Lane Council of Governments report which describes high turbidities in Fern Ridge Reservoir (LCOG, 1983). Highest turbidity levels were identified to be in the southeastern portions of the lake, where Coyote Creek and Amazon Creek (via Amazon Creek Diversion Channel) enter the lake. Turbidity levels are elevated due to both external loads and the internal recycling of solids. External sources include solids loads from Amazon and Coyote Creeks. Internal sources include resuspension of previously settled fine solids. Resuspension of solids occurs because the lake is quite shallow in this area, which allows energy due to wind, boat propellers, etc., to be transferred to the sediment. When resultant hydrodynamic forces acting on the sediment exceed the critical bed shear stress of the sediment, solids are resuspended. Areas of high turbidities are shown on Map 10.27 (from LCOG, 1983).

Map 10.27 Fern Ridge Reservoir turbidity problem areas (from LCOG, 1983)



The following excerpts from LCOG, 1983 describe the external loads of turbidity causing solids to Fern Ridge Reservoir:

> *"The upper Long Tom River drains about 100 square miles of forest on the east side of the Coast Range. In spite of some urban and agricultural uses of the Long Tom, this tributary has relatively clean, clear water and rarely exceeded state water quality standards."*
>
> *"Coyote Creek and its tributary, Spencer Creek, drain about 100 square miles of the hills and valleys south of Eugene. Suspended solids made Coyote Creek very turbid. Monitoring of Coyote Creek consistently showed excessive contamination from livestock wastes, including both bacterial and organic loadings."*
>
> *"Amazon Channel [Amazon Creek and Diversion Channel] drains 25 square miles from the south hills of Eugene through the city." "During storm flows, bacteria, heavy metals, other toxins, organic materials and litter are found in the Amazon Channel. Sediments loads were high during major winter storms."*
>
> *"Both Amazon Channel and Coyote Creek have little, if any, flow during summer and the problems measured in the channels were not found in the nearby open water of the reservoir." "Summer storms rarely would have enough volume to make a significant impact on the reservoir but localized short term problems from urban and agricultural runoff are possible."*
>
> *"Tributary storm runoff pollutants have a strong influence on the reservoir from November through April. In early winter the flow through is so rapid that there is little change in the water quality from the combined inflow to the outflow concentrations. Stream inflow occurring after February when reservoir filling begins, has the greatest influence on water quality for the coming recreational season at Fern Ridge.*

The following excerpts describe internal recycling of turbidity causing solids:

> *"The reservoir is typically clearest in May and June. The deepest secchi disc reading during the study was 6.5 feet. By August, most of the water is so turbid that visibility is limited to a foot or two from the surface. Such turbidity is not only unsightly and unpleasant for swimming, but unsafe."*
>
> *"A major component of the turbidity appeared to originate from the natural clay bottom and settled silts in the shallow southeast portion of the reservoir around Perkins Peninsula Park [see Map 10.28). In August fine clay particles were found throughout the reservoir, but turbidity was always greatest on the south and east sides. Heavier silts and clays are suspended and resuspended by wind waves and probably other factors such as foraging fish, motor boats and beach use." "Waves and general lake circulation disperse the muddy water from the shallow areas to other parts of Fern Ridge."*(LCOG, 1983)

As discussed, external sources of turbidity-causing solids are storm related inflows of solids from Amazon and Coyote Creeks. Internal sources of turbidity-causing solids are resuspension of previously settled solids. The original source of many of these resuspended solids is likely Amazon and Coyote Creeks.

In this TMDL, load allocations are provided for external solids loads which contribute to turbidity. For internal recycling of solids, management measures are described which are intended to limit resuspension of solids. These are the same measures as described in LCOG, 1983.

Water Quality Criteria Identification

Current Standards

Oregon Administrative Rules provide standards for turbidity and bottom deposits, as follows:

Turbidity

"Turbidity (Nephelometric Turbidity Units, NTU): No more than a ten percent cumulative increase in natural stream turbidities may be allowed, as measured relative to a control point immediately upstream of the turbidity causing activity. However, limited duration activities necessary to address an emergency or to accommodate essential dredging, construction or other legitimate activities and which cause the standard to be exceeded may be authorized provided all practicable turbidity control techniques have been applied and one of the following has been granted:
(a) Emergency activities: Approval coordinated by ODEQ with the Oregon Department of Fish and Wildlife under conditions they may prescribe to accommodate response to emergencies or to protect public health and welfare;
(b) Dredging, Construction or other Legitimate Activities: Permit or certification authorized under terms of section 401 or 404 (Permits and Licenses, Federal Water Pollution Control Act) or OAR 14l-085-0100 et seq. (Removal and Fill Permits, Division of State Lands), with limitations and conditions governing the activity set forth in the permit or certificate." (340-041-0036)

Bottom Deposits

"The formation of appreciable bottom or sludge deposits or the formation of any organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry may not be allowed." (340-041-0007 (13))

Proposed Standards

DEQ is currenting considering changes to the turbidity standard that would specify maximum allowable increases in turbidity above background levels in terms of both monthly averages and instantaneous maxima. Increases in monthly average turbidity would be limited to 3 NTU when background levels are less than 30 NTU and 10% when above 30 NTU. Instantaneous increases would be limited to 5 NTU when background levels are less than 33 NTU and 15% when above 33 NTU. Therefore, the proposed standard would address concerns that the current standard is overly protective at low turbidity levels; while at the same time enhance standard enforceability and provide a high level of long-term protection. However, until changes to the standard are adopted, the current standard applies. Therefore, this TMDL specifies load allocations designed only to meet the current standard.

Target Criteria Identification

Degradation Based Targets and Appropriate Reference Sites

This TMDL specifies pollutant load reductions necessary to achieve turbidity levels necessary to meet water quality standards. State of Oregon water quality standards are designed to prevent degradation. These specify that *"No more than a ten percent cumulative increase in natural stream turbidities may be allowed, as measured relative to a control point immediately upstream of the turbidity causing activity* (*340-041-0036)."*
In this TMDL natural stream turbidities for streams which contribute to elevated turbidity levels in Fern Ridge Reservoir (Amazon and Coyote Creeks) are estimated and reductions in turbidity causing pollutants needed to limit turbidity increases in these streams to no more than ten percent above natural levels are determined.

The loads of solids to Fern Ridge tributaries are due to erosion of sediment from uplands during rainfall events (upland sources) and the erosion of sediment from stream banks during high flow events (in-stream sources). In addition to these "non-point sources," solids loads may be provided by "point sources," such as point source discharges from confined animal feeding operations (CAFOs). Such point source loads may occur at low flows, in addition to high flows.

In order to determine natural stream turbidities to use for turbidity targets for the streams, appropriate reference sites must be identified. According to Oregon Rules an *"Appropriate Reference Site or Region" means a site on the same waterbody, or within the same basin or ecoregion that has similar habitat conditions, and represents the water quality and biological community attainable within areas of concern* (340-04l-0002)."

Upper Amazon and Coyote Creek Reference Sites

Stations on the upper reaches of Coyote Creek and it tributaries above the confluence of Fox Hollow Creek with Coyote Creek at RM 24 have been used as reference sites for Coyote Creek. Stations on the upper reaches of Amazon Creek at 29th St (Amazon Park) and Martin St. have been used as reference sites for Amazon Creek (see Map 10.28).

The dominant land use of the upstream sites is forestry, while the stations near stream mouths are impacted by agricultural and urban impacts. All of the data used to establish conditions at Amazon and Coyote reference sites was collected by ODEQ. The bulk of this data was collected in 2001 and 2002 for purposes of developing TMDLs. Note that the station Amazon Creek at 29th St is located in Amazon Park and is potentially impacted to some degree by urban loads. However, insufficient data is available for Amazon Cr at Martin St., so data from both 29th St. and Martin St. was used to estimate background conditions. Turbidity for the Coyote Creek and Amazon Creek reference sites, along with regression lines, is shown in Figure 10.111 and Figure 10.112.

Map 10.28 Reference and compliance point stations

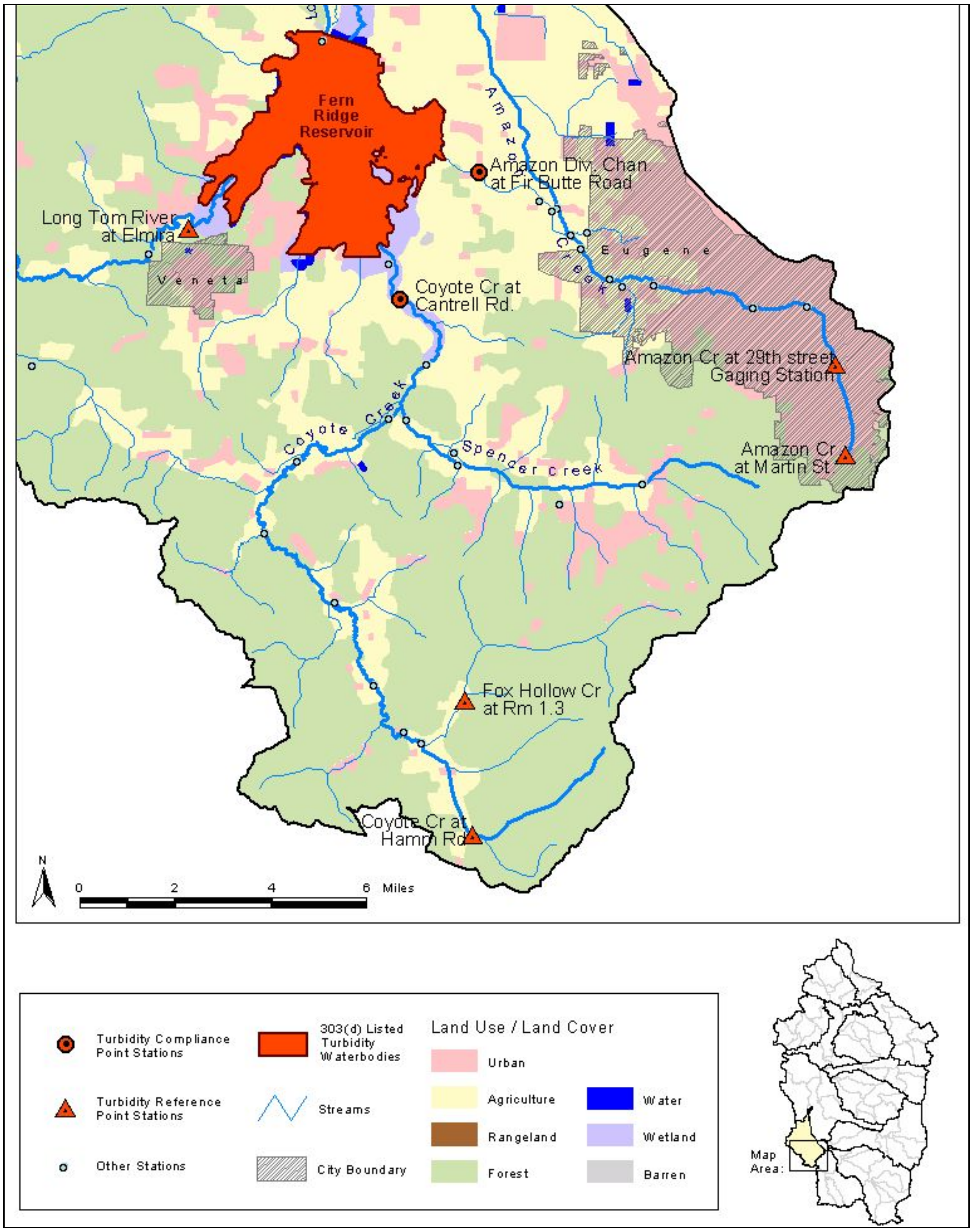

Fern Ridge Reservoir
Amazon Div. Chan at Fir Butte Road
Long Tom River at Elmira
Veneta
Eugene
Amazon Creek
Coyote Cr at Cantrell Rd.
Amazon Cr at 29th street Gaging Station
Coyote Creek
Spencer Creek
Amazon Cr at Martin St
Fox Hollow Cr at Rm 1.3
Coyote Cr at Hamm Rd
N
0 2 4 6 Miles
Turbidity Compliance Point Stations
303(d) Listed Turbidity Waterbodies
Land Use / Land Cover
Urban
Turbidity Reference Point Stations
Streams
Agriculture
Water
Rangeland
Wetland
Other Stations
City Boundary
Forest
Barren
Map Area:

Figure 10.111 Coyote Creek upper reference station

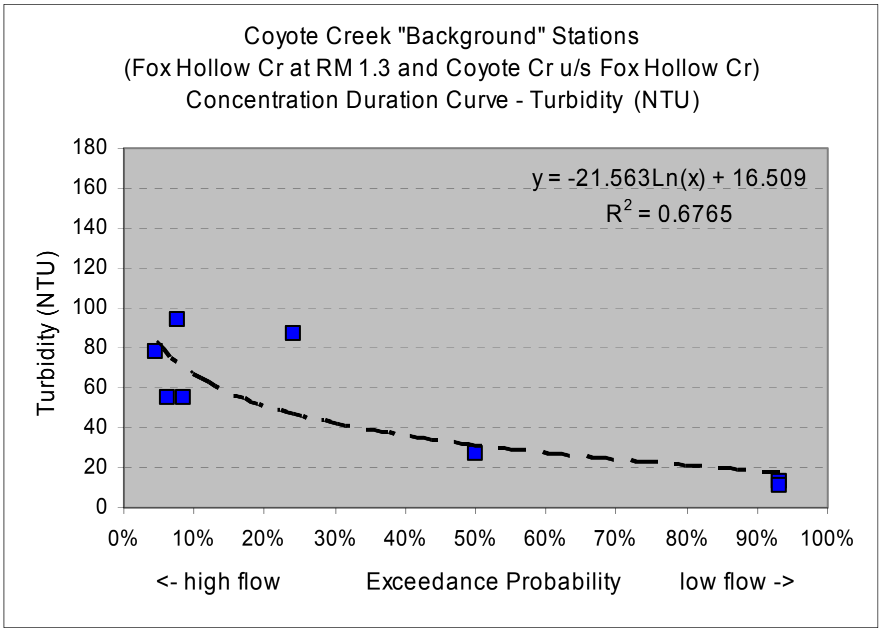
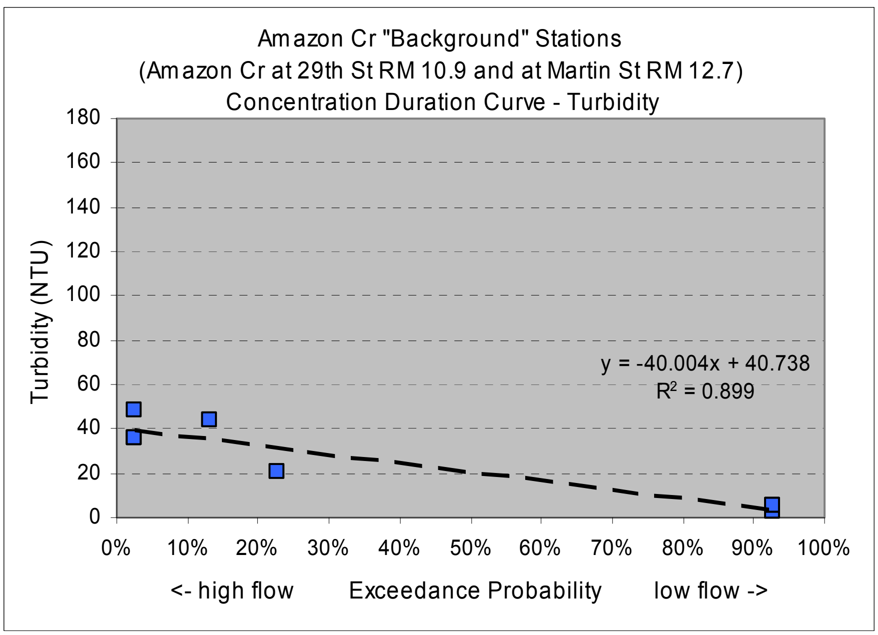


Figure 10.112 Amazon Creek upper reference station



The abscissas for the plots are flow exceedance probabilities (EP). These indicate, for each turbidity sampling date, the percent of time stream flow is greater than the observed flow for the sampling date. For example, an EP of 5% indicates that only 5% of the time is flow greater than the flow that occurred on the sampling date. Therefore, the sample was collected during a high flow condition. An EP of 95% indicates that 95% of the time flow is greater than flow on the sampling date. This, therefore, represents a low flow condition.

In order to derive the EP for each date of sampling, a flow duration curve was developed. To develop a flow duration curve, flows are ranked from maximum to minimum for the period of record at a particular site and the exceedance probability (EP) for each flow was computed. The exceedance probability (EP) for each flow is computed by:

$$EP = \frac{rank}{n+1}$$

where n is number of flow measurements.

Unfortunately, flow gages for Amazon Creek and Coyote Creek have been discontinued. The gage Amazon Creek near Eugene (USGS No. 14169500) was active from Oct, 1960 – Sep, 1968 and Oct, 1979 – May, 1982. The gage Coyote Creek near Crow (USGS No. 14167000) was active Jan, 1960 – Sep, 1987. Since gages on the streams are inactive, discharge from a nearby stream gage was used. The gage used for the flow duration curve applied to both Amazon and Coyote is the upper Long Tom River near Noti gage (USGS No. 14166500). This gage is located upstream of the confluence of upper Long Tom River with Fern Ridge Reservoir. It has been continuously active since 1935.

Derivation of flow exceedance probability is described in more detail below in the section entitled ***Flow Exceedance Probability Methodology***.

Figure 10.111shows that at high flows observed turbidities at upper Coyote Creek stations approach 100 NTU, while at low flows turbidities are less than 20 NTU. Figure 10.112 shows that in Amazon Creek, observed turbidities at upper stations at high flows are roughly half those in Coyote. This may due to the relative lack of soil disturbing agricultural practices in the Amazon Creek watershed vs. Coyote Creek.

Additional Long Tom River Reference Site

A concern with using only upper Amazon and Coyote stations as reference sites is that, while the upper reaches represent conditions more representative of natural potential than the lower reaches, they are still subject to anthropogenic impacts and may not fully represent the water quality attainable within areas of concern. In order to provide for a margin of safety, a station on the Long Tom River near Elmira was also used as a reference site (Figure 10.113). In spite of some urban and agricultural uses the upper Long Tom River has relatively clean, clear water and rarely exceeds state water quality standards (LCOG, 1983). Data collected by the U.S. Army Corps of Engineers (USACE) during 1996 through 1999 (USACE Station LT-4) was used to establish conditions at this site. Turbidity and suspended solids concentrations measured by USACE at this station were consistently less than measured by ODEQ at the upper Amazon and Coyote Creek stations (Figures 10.111 and 10.112).

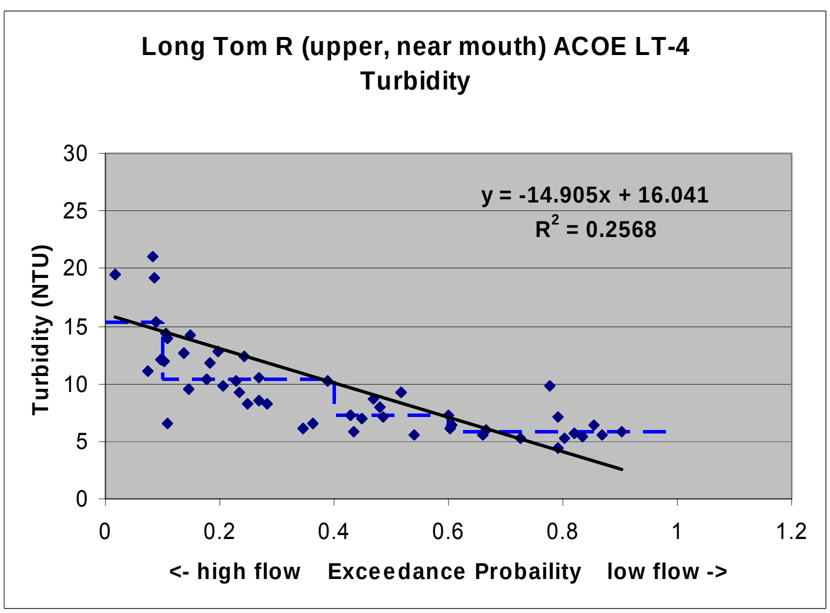
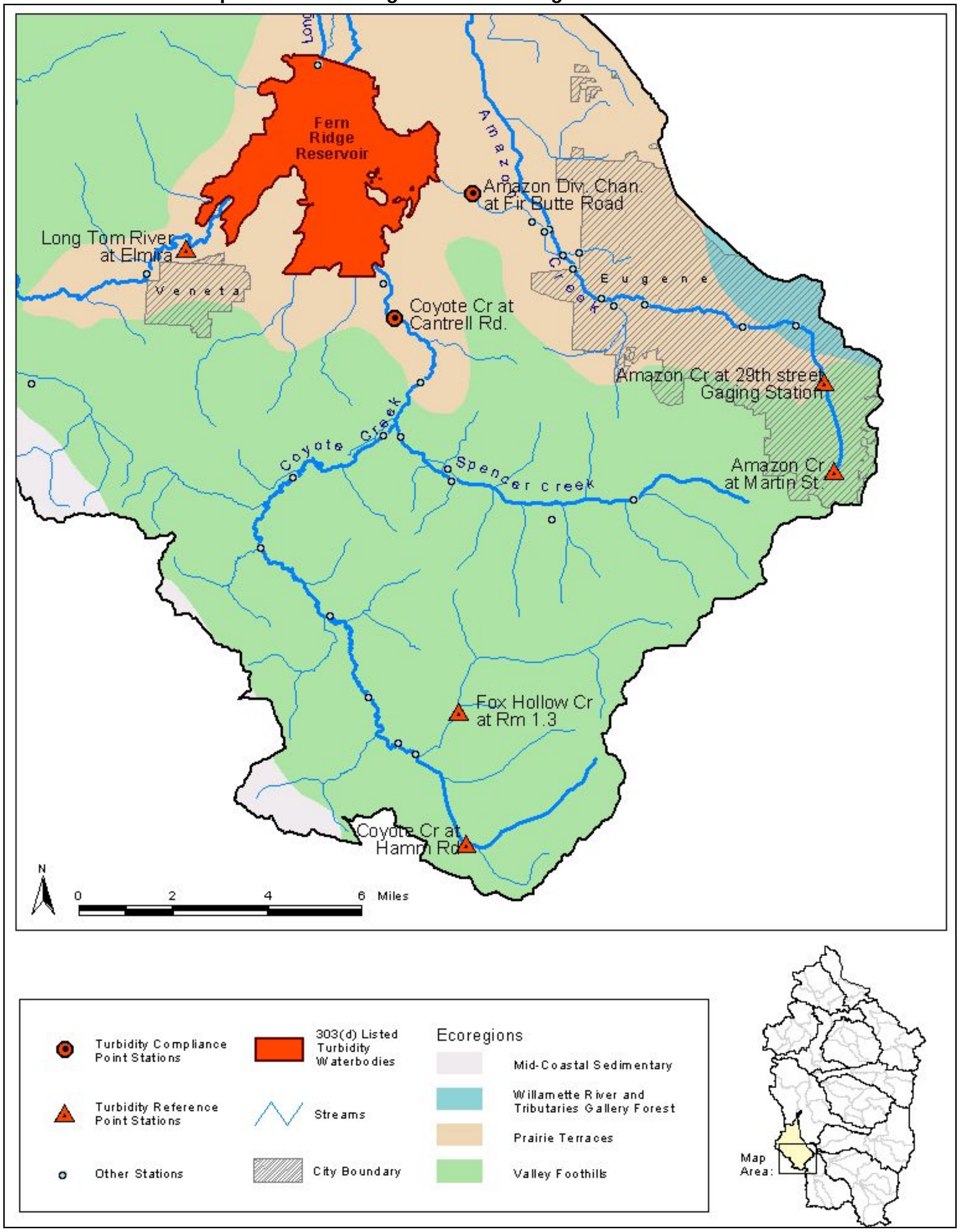


Figure 10.113 Long Tom River Reference Site

While physical characteristics of the Upper Long Tom River watershed may differ from those in the Amazon and Coyote Creek watersheds, this station is impacted by runoff from the same ecoregions as Amazon and Coyote Creeks (Map 10.29).

Map 10.29 Ecoregions for the Long Tom Watershed



In order to derive targets for the mouths of Amazon and Coyote Creeks, the regression lines for the upper Amazon and Coyote Creek reference sites were averaged with the regression line for the Long Tom River reference site. This is discussed in more detail below.

Additional Aquatic Life Beneficial Use Based Targets

While the upper reaches of Coyote Creek represent conditions more representative of natural potential than the lower reaches, they are still subject to anthropogenic impacts due to agricultural practices that may adversely impact aquatic life in those reaches. A review was performed to determine appropriate upper limits for turbidity for Amazon and Coyote Creeks. This was used to cap upper allowable turbidity levels for the streams. In addition, since the available dataset for turbidity for these reaches is quite sparse, additional reductions were specified in order to provide a margin-of-safety to compensate for uncertainty.

ODEQ Turbidity Standard Review

A review of literature was recently performed by ODEQ in order to derive more accurate aquatic life based turbidity limits for lakes and streams. This section presents some findings of this review (ODEQ, 2005).

Turbidity effects on plants and animals in aquatic systems are directly related to reductions in light transmittance through the water column from suspended particles. Direct turbidity effects to animals are mostly visibility-related, causing behavioral changes with respect to maneuverability, feeding, predation, or escape. Other types of responses include fish growth or abundance, density or richness in macro invertebrate populations, and algal or periphyton productivity related to photosynthetic potential. Endpoints used by the U.S. Environmental Protection Agency (USEPA) in deriving numerical water quality criteria, are generally ones which affect growth, survival or reproduction (Bash et al., 2001).

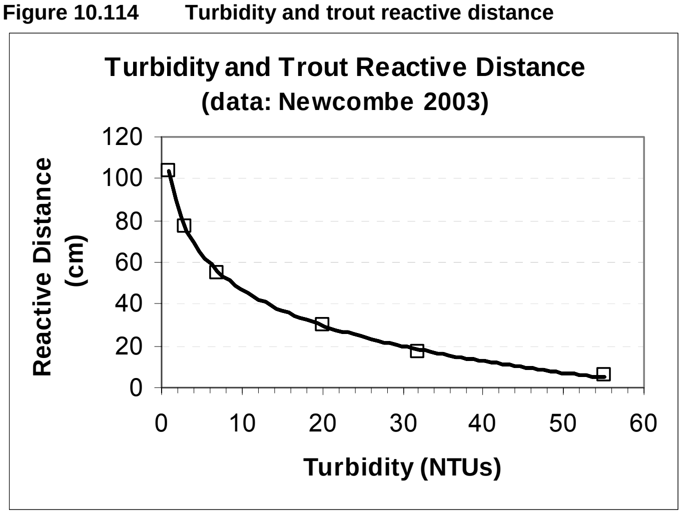
Table 10.67 lists the beneficial uses affected by turbidity and their potential adverse effects, along with measured endpoints from laboratory and field studies.

Table 10. 67 Endpoints measured to determine adverse effects to beneficial uses (ODEQ 2005)

Beneficial Uses		Endpoints	Adverse effects to:
Aquatic life	Fish and other aquatic animals	Reactive distance, avoidance, feeding behavior, feeding and predation rates, and growth rate	Growth, survival,reproduction, and ecological integrity
	Invertebrates	Species density and species richness	
	Plants/other	Whole-stream respiration, photosynthesis or productivity Percent cover Growth rate Cell density	
Water supply and aesthetics		Aesthetic acceptability and treatability	Aesthetic qualityand treatment cost
Water contact recreation, fishing, boating, and aesthetics		Visual recognition and aesthetic acceptability	Hazard identificationand safety and aesthetic quality

Direct turbidity effects to fish are mostly visibility-related (ODEQ 2005). Impacts on visibility cause behavioral changes to maneuverability and migration, feeding, predation and escape, and may influence fish behavior by reducing the ability of fish to see and capture prey. Several authors suggest that reactive distance, the distance at which fish visually recognize and respond to a particular prey item, is a key variable in fish predator-prey interactions (Newcombe, 2003). Reactive distance has a strong effect on prey encounter rates according to Gerritsen and Strickler (1977). Based on available data pooled from Brook, Lake, and rainbow trout, Newcombe (2003) developed a relationship between turbidity and reactive distance (Figure 10.114). As shown, reactive distance approaches zero at high turbidity levels.

Figure 10.114 Turbidity and trout reactive distance



Newcombe (2003) developed an empirical model which relates potential fish impairment to turbidity levels. Results of the model are summarized in Table 10.68. The model suggests that the impact of turbidity on fish is related to both intensity and duration. Short-term exposure of less than 1 hr of turbidity as high as 38 NTU may cause only slight impairment to clear water fish, while long term exposure to as low as 3 NTU may have severe effects.

Table 10. 68 Adverse turbidity level effects on clear water fish with respect to duration of exposure. (ODEQ 2005)

Duration	Turbidity Levels at or above which adverse effects are estimated to occur to clear water fish (NTUs) (data from Newcombe 2003)		
	Slight impairment (behavioral effects)	Severe effects (to growth and habitat)	Severe impairment (habitat alienation)
1 hour	38	160	
2 hours	28	120	
3 hours	23	100	
8 hours	15	65	710
1 day	10	39	440
5 days	5	19	215
3 weeks	3	10	115
>10 months		3	35

Overall, the data indicates that absolute turbidity levels of less than 3 NTUs, with occasional increases above 3 NTUs, should be protective of the most sensitive beneficial use endpoints. As the duration of a turbid event increases, the magnitude of the turbidity should be decreased, in order for clear water species to achieve their full survival capability. The data indicates that 2 - 4 NTUs as long-term absolute turbidity levels should be protective of aquatic life, as well as other other beneficial uses. For short periods of time, on the order of 1 and 3 hours, turbidity levels could be increased up to 38 and 23 NTUs, respectively, before the first indications of fish impairment would occur, with significant growth and habitat impairments occurring with increases of up to 160 and 100 NTUs respectively.

Biological Integrity Based Targets

In March of 1997, winter storm turbidity was measured at 27 first through third order streams in the coast ecoregion of Oregon, including a tributary to Coyote Creek, and the data was compared to biological integrity scores for the same streams (Mulvey and Hamel, 1998). Three storm events were monitored using both continuous turbidity monitoring equipment and discrete grab samples. Biological integrity was evaluated using the macroinvertebrate assemblages of pool and riffle habitat and vertebrate surveys. Results indicated that the integrity of all three portions of the stream biota correlated with winter storm turbidity. Streams with higher winter storm turbidity tended to have lower biological integrity scores. The data was used to estimate acceptable upper levels for turbidity.

Figures 10.115 to 10.117 compare maximum datasonde measured storm turbidities with scores for vertebrate, riffle macroinvertebrate, and pool macroinvertebrate indicators of stream biotic condition (Mulvey and Hamel, 1998). As shown, all three indicators of biotic condition decline with increasing storm event turbidity, indicating that high turbidites adversely impact biological integrity. As shown, adverse impacts were observed on vertebrates and riffle macroinvertebrates when maximum turbidities exceeded 40 NTU and on pool macroinvertebrates when maximum turbidities exceeded 20 NTU. This supports limiting maximum turbidity levels to the 20 to 40 NTU range.

Figure 10.115 Vertebrate biological integrity based scores vs. Maximum turbidity

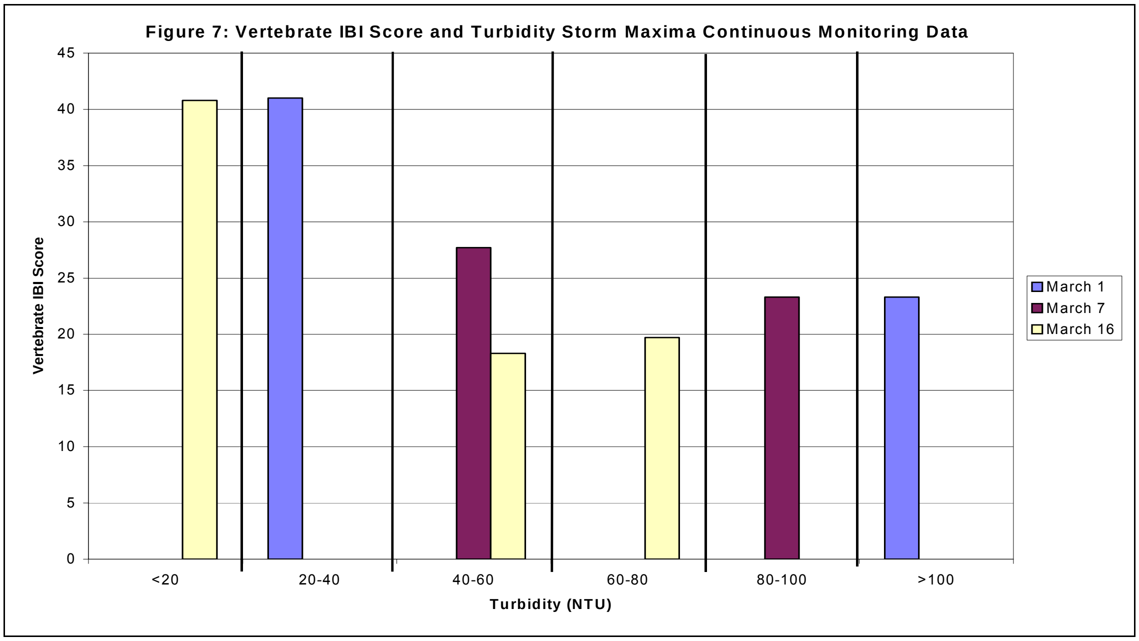


Figure 10.116 Riffle macroinvertebrate biological integrity based scores vs. Maximum turbidity

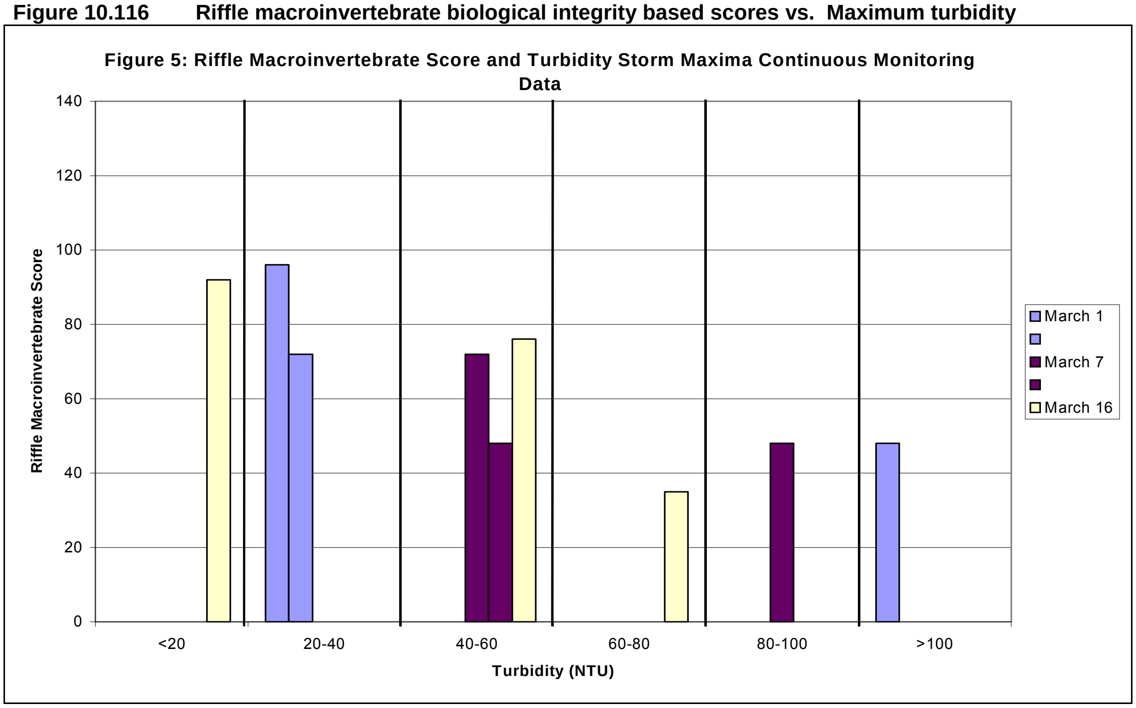
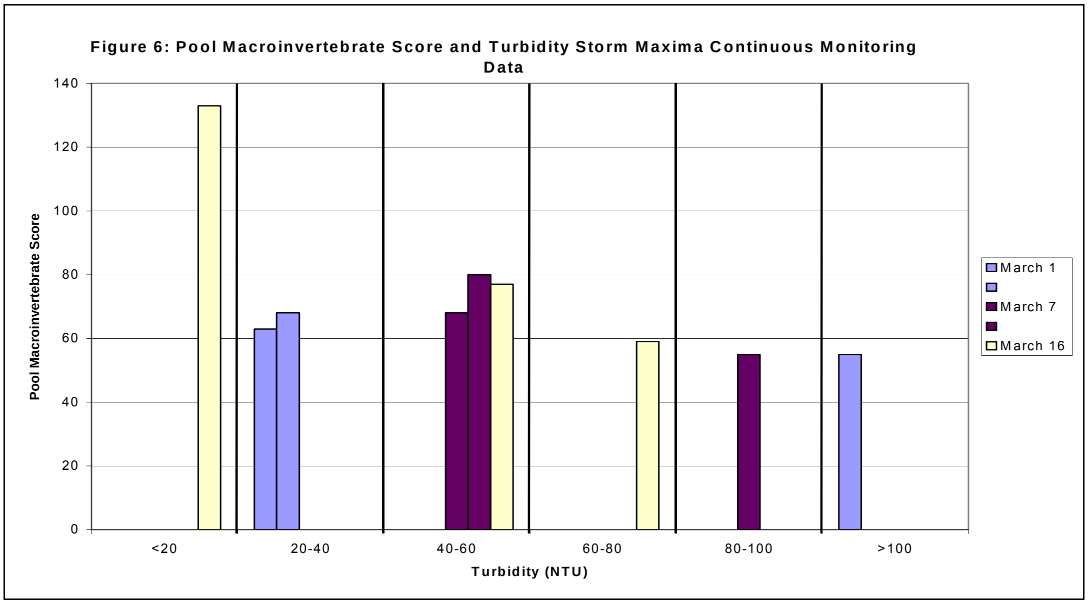


Figure 10.117 Pool macroinvertebrate biological integrity based scores vs. Maximum turbidity



Umatilla Sediment TMDL Turbidity Targets

The Umatilla Sediment TMDL specified an amount of suspended solids load reduction necessary to achieve turbidity levels that are protective of salmonid feeding and respiration for the Umatilla River in northeastern Oregon (ODEQ 2001). The TMDL implemented the turbidity standard by explicitly targeting turbidity and the sedimentation standard by reducing the amount of suspended material available for settling.

The Umatilla TMDL states that *"Umatilla Basin fisheries managers determined through basin-specific knowledge and literature review that 30 NTU instream turbidity (not to exceed a 48-hour duration) is protective of aquatic species and will not be detrimental to residential biological communities." "This target is applicable basin-wide and year-round."* The TMDL allows the 30 NTU target to be exceeded, as long as the duration of the exceedance does not last more than 48 hours (Butcher, 2004).

In order to express the water column sediment TMDL in terms of mass load, regressions were calculated to evaluate the association between total suspended solids (TSS) and turbidity. The TMDL applies to the 14 watersheds comprising the Umatilla Basin. The regression analyses were done for all watersheds where data was available. The TSS correlative to 30 NTU turbidity was calculated as the TMDL target concentration for those watersheds. TSS correlatives to 30 NTU ranged from 70 to 110 mg/L, with a basinwide mean of 80 mg/L.

Selected Aquatic Life Beneficial Use Based Targets for Amazon and Coyote Creeks

Based on the information presented above, turbidity levels greater than 30-40 NTU would probably result in adverse impacts to aquatic life. Therefore, the maximum allowable turbidity level for this TMDL has been set to 35 NTU.

Turbidity Numeric Targets

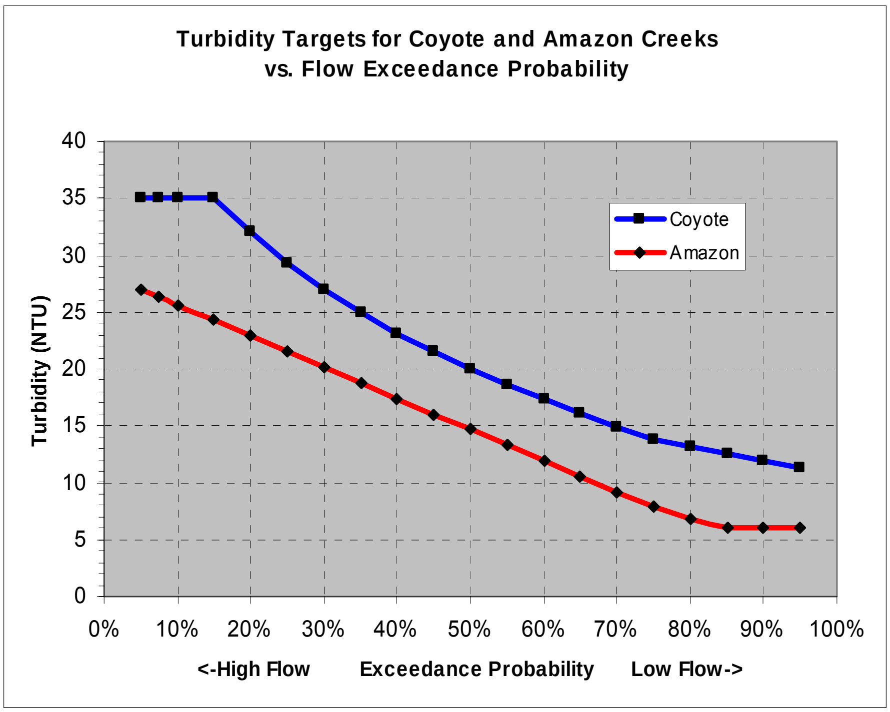
In order to derive turbidity targets for Coyote Creek, the regression line for the upper Coyote Creek reference site (Equation 1) was averaged with the regression line for the Long Tom River reference site (Equation 3), with maximum turbidities capped at 35 NTU. Similarly, to derive targets for Amazon Creek, the regression line for the upper Amazon Creek reference site (Equation 2) was averaged with the regression line for the Long Tom River reference site (Equation 3).

$$Turbidity = -21.563\ln(EP) + 16.50 \quad \text{(Coyote Creek, Eq. 1)}$$
$$Turbidity = -40.004(EP) + 40.74 \quad \text{(Amazon Creek, Eq. 2)}$$
$$Turbidity = -14.905(EP) + 16.04 \quad \text{(Long Tom R, Eq. 3)}$$

where:
EP is Flow Exceedance Probability (% greater than)
Turbidity is turbidity in NTU

Resultant flow based targets for Amazon and Coyote Creeks are shown in Figure 10.118.

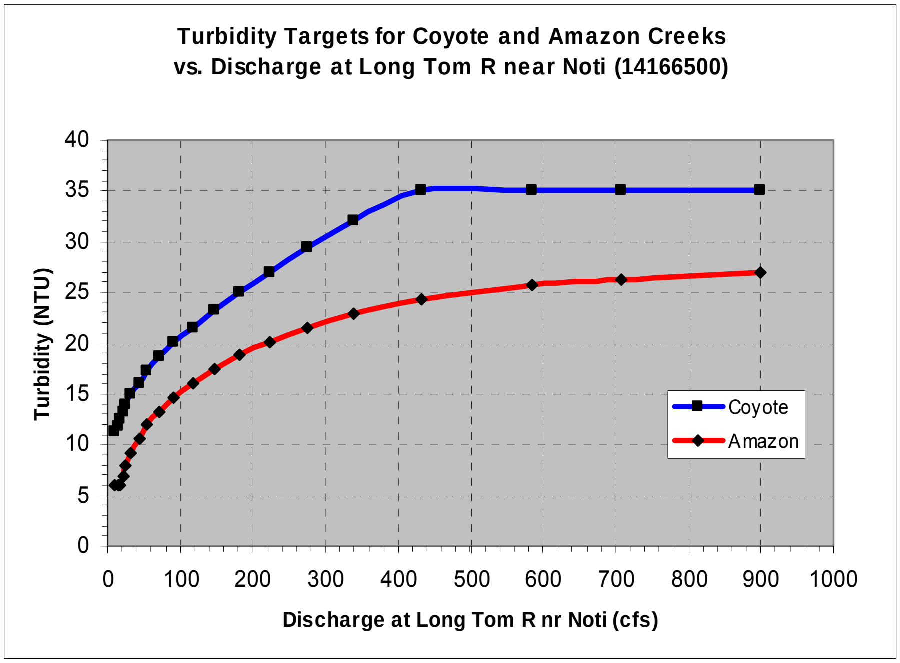
Figure 10.118 Turbidity targets vs. flow exceedance probability



There are currently no discharge gages active on Amazon or Coyote Creeks. The closest active gage is on the Long Tom River near Noti (USGS Gage No. 14166500). Historic gages on Amazon and Coyote Creeks were used to develop relationships with this upper Long Tom River gage (this is described in more detail in section below entitled **Flow Exceedance Probability Methodology**). From October through May, monthly average Coyote Creek discharge rates range from 48% to 97% of the Long Tom River at Noti discharge, while Amazon Creek discharge rates range from 9% to 18% of the Long Tom discharge (Table 10.69). The historic flow relationships allow turbidity targets for Amazon and Coyote Creeks to be estimated based on flow at the active Long Tom River gage. Therefore, turbidity targets are also shown vs. discharge at Long Tom River near Noti (see Figure 10.119).

Using Figure 10.119, the degree of compliance with the TMDL can be determined. For example, when Long Tom River flow is 500 cfs, turbidities should not exceed 35 NTU in Coyote Creek or 25 NTU in Amazon Creek. Note that while Amazon and Coyote watersheds are generally influenced by the same storm events as the upper Long Tom River watershed, responses in the watersheds will vary due to localized variations in storm characteristics. Therefore, monitoring of turbidity should be performed over a period of time and regressions performed to develop curves to compare to the Figure 10.119 curves.

Figure 10.119 Turbidity targets vs. discharge at Long Tom R near Noti



Data review

Flow Patterns in Amazon and Coyote Creeks

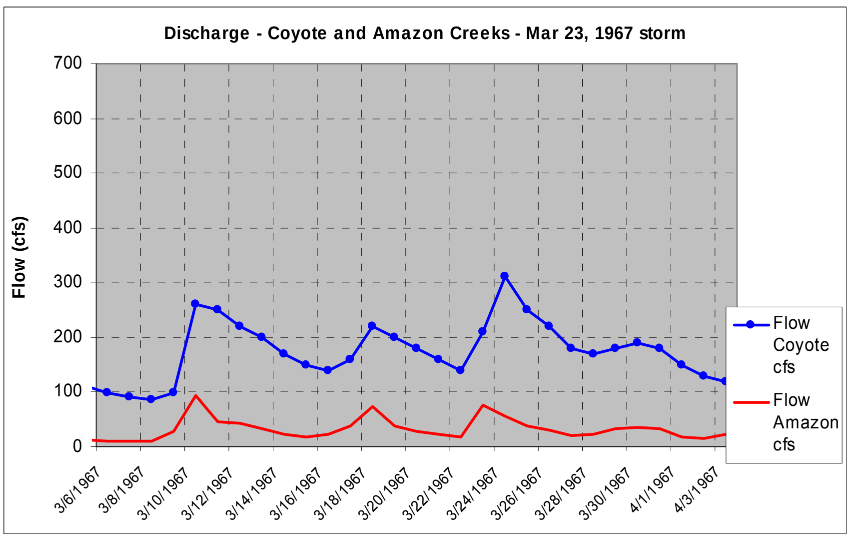
Coyote Creek has a drainage area about four times as large as the portion of the Amazon Creek watershed that is diverted to Fern Ridge Reservoir. Accordingly, flows are higher in Coyote Creek and proportionally higher loads of solids are provided to Fern Ridge Reservoir by Coyote than Amazon (Table 10.69). An example of stream discharge response for an early spring storm is presented in Figure 10.120. As shown, Coyote Creek flow rates are several times greater than Amazon. In addition, the Amazon Creek flows return quicker to base flow conditions following a storm, due to the smaller size of the watershed and the greater percentage of the watershed that is impervious due to urbanization.

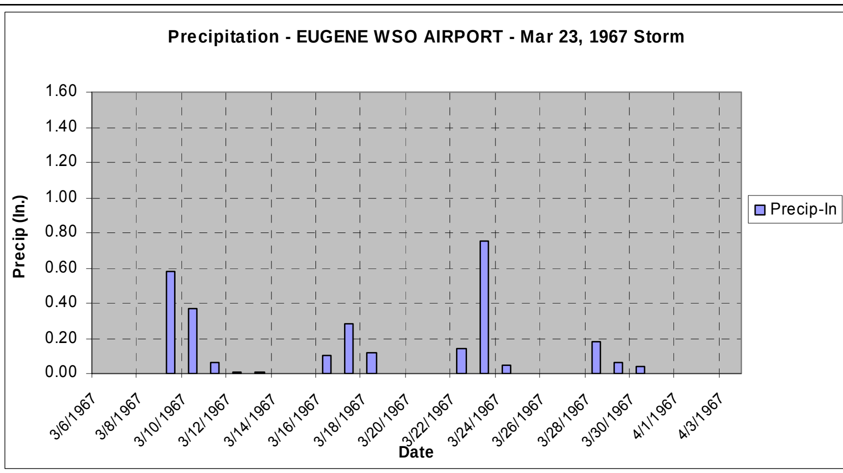
Discharge response to storms varies considerably. In the winter, large stream discharges can result from a single day 1 to 2 inch storm event. In the summer and fall, very little discharge may result from such a storm. This is partly due to antecedent moisture content. When soil is dry, a much higher percentage of rainfall will be absorbed than when soil is wet. In addition, in the summer, much of the resultant flow may be diverted to irrigation. Also, there may be significant in-stream storage available in the summer due to pools created by natural and man-made dams.

Table 10. 69 Stream flow rates

	Monthly Mean Stream Flow Rates			Ratios		
Month	USGS 14169500 Amazon Creek near Eugene	USGS 14166500 Long Tom River near Noti	USGS 14167000 Coyote Creek near Crow	Coyote to Long Tom	Amazon to Long Tom	Amazon to Coyote
	cfs	cfs	cfs			
Jan	71.7	584	505	86%	12%	14%
Feb	57.5	556	441	79%	10%	13%
Mar	48.3	409	303	74%	12%	16%
Apr	21.7	248	151	61%	9%	14%
May	11.8	127	62	49%	9%	19%
Jun	2.38	65.8	16.6	25%	4%	14%
Jul	1.11	30.6	3.7	12%	4%	30%
Aug	0.81	16.8	0.84	5%	5%	96%
Sep	1.66	17.4	1.14	7%	10%	146%
Oct	4.6	39.5	18.9	48%	12%	24%
Nov	28.2	204	163	80%	14%	17%
Dec	85.9	471	459	97%	18%	19%

Figure 10.120 Example stream discharge response to precipitation event





Flow Exceedance Probability Methodology

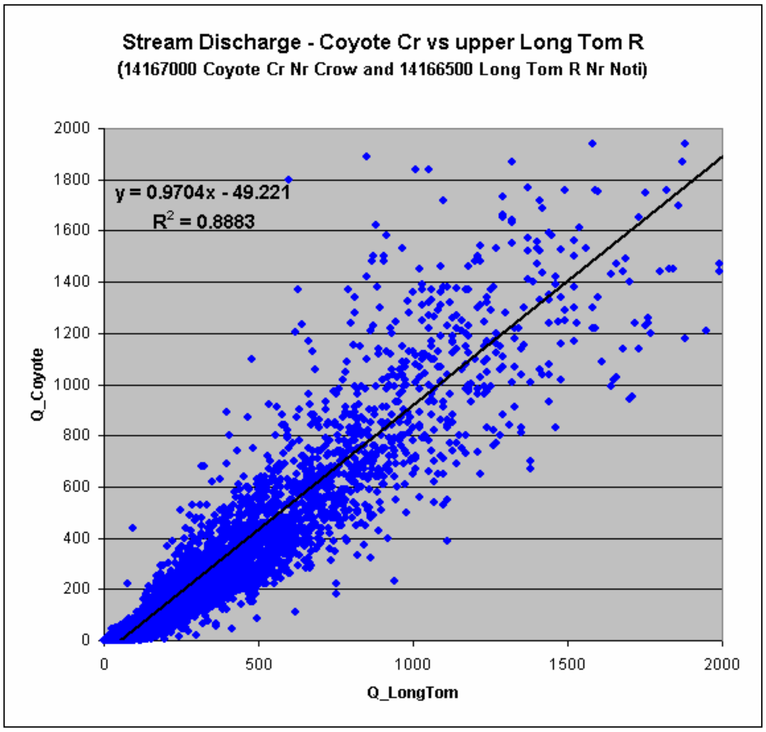
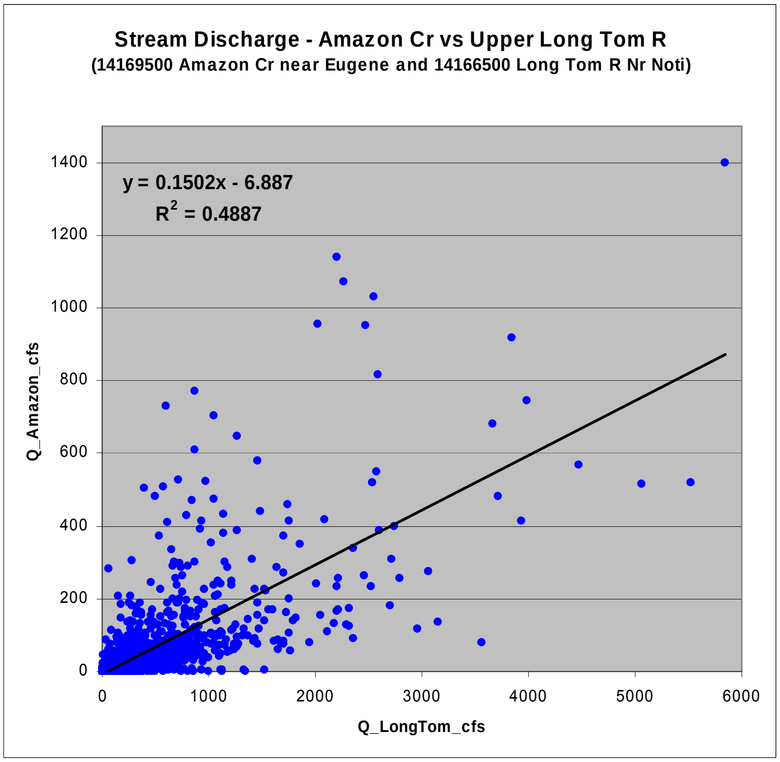


Figure 10.121 Correlation of Coyote Creek and Long Tom River flow rates

Due to the lack of active discharge gages on Amazon and Coyote Creeks, flow rates from the Long Tom River near Noti gage (USGS No. 14166500) were used for flow exceedance probabilities (EP). As shown in Figure 10.121, flow in Coyote Creek correlates well with flow in Long Tom River (r^2=0.8883). This shows that it is appropriate to use EP from the upper Long Tom River to estimate the EP in Coyote Creek. The correlation between flow rates in Amazon Creek and Long Tom River (Figure 10.122) is not as good (r^2=0.4887). This weaker correlation is probably because the Amazon watershed is located further from the upper Long Tom than is the Coyote watershed. The greater urbanization of the Amazon watershed may also contribute to the difference. Nonetheless, lacking better gages in the subbasin, the EP for Amazon Creek was also based on the upper Long Tom River EP.

The methodology for deriving flow rates and corresponding exceedance probabilities for Coyote Creek is described in detail in Appendix A: Bacteria Appendix.

Figure 10.122 Correlation of Amazon Creek and Long Tom River flow rates



Correlations of Turbidity to Suspended Solids

Turbidity is caused by suspended solids. Therefore, it's helpful to express turbidity in terms of suspended solids. A review of coast ecoregion stream data collected by ODEQ, including data on a Coyote Creek tributary and the Long Tom River, shows that turbidity in Fern Ridge's ecoregion correlates well with suspended solids (see Figure 10.123). Based on this data, TSS as a function of turbidity is expressed by Equation 4.

$$Turbidity = 0.7149(TSS) + 4.1714$$

or

$$TSS = 1.40(Turbidity) - 5.84 \qquad \text{(eq. 4)}$$

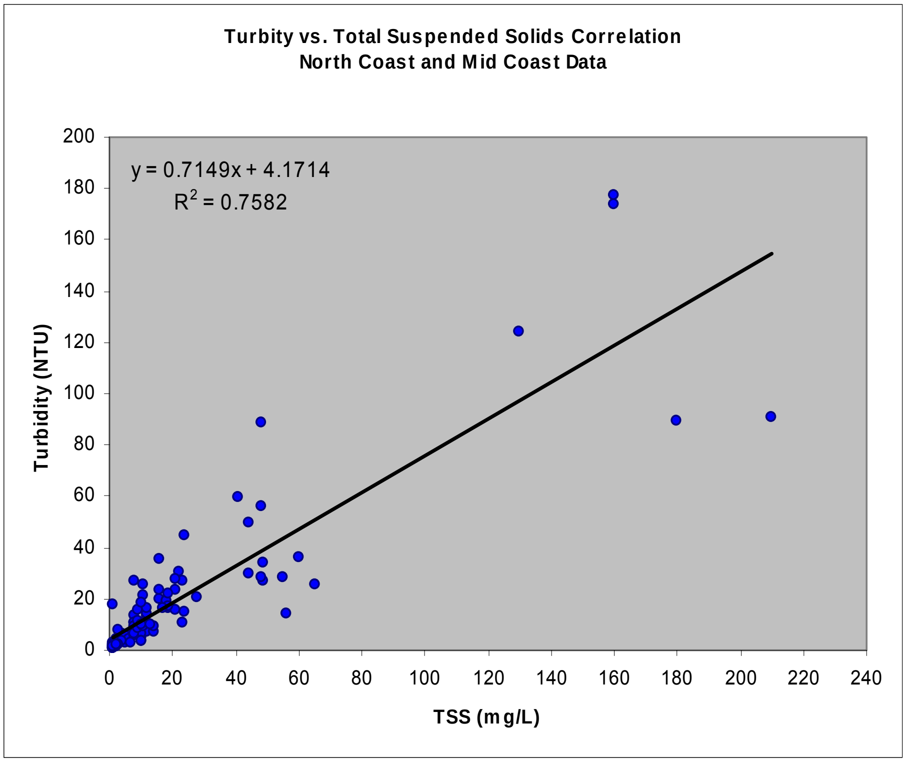
$$where:$$

$$TSS = \text{total suspended solids, mg/L}$$

$$Turbidity = \text{turbidity, NTU}$$

Based on Equation 4, a turbidity range of 30 to 40 NTU would correspond to a TSS range of 36 to 50 mg/L. It's interesting to compare this to the Umatilla Subbasin in Northeastern Oregon, where a turbidity of 30 NTU was found to correspond to a TSS of 80 mg/L. This comparison shows that turbidity is affected by more than just the gross suspended solids concentration. It is also affected by the nature of solids present. During high flows, total suspended solids may be dominated by large inorganic sediments, while at low flows, smaller inorganic particles may be present. In addition, algal growth during the summer may result in turbidities unrelated to runoff.

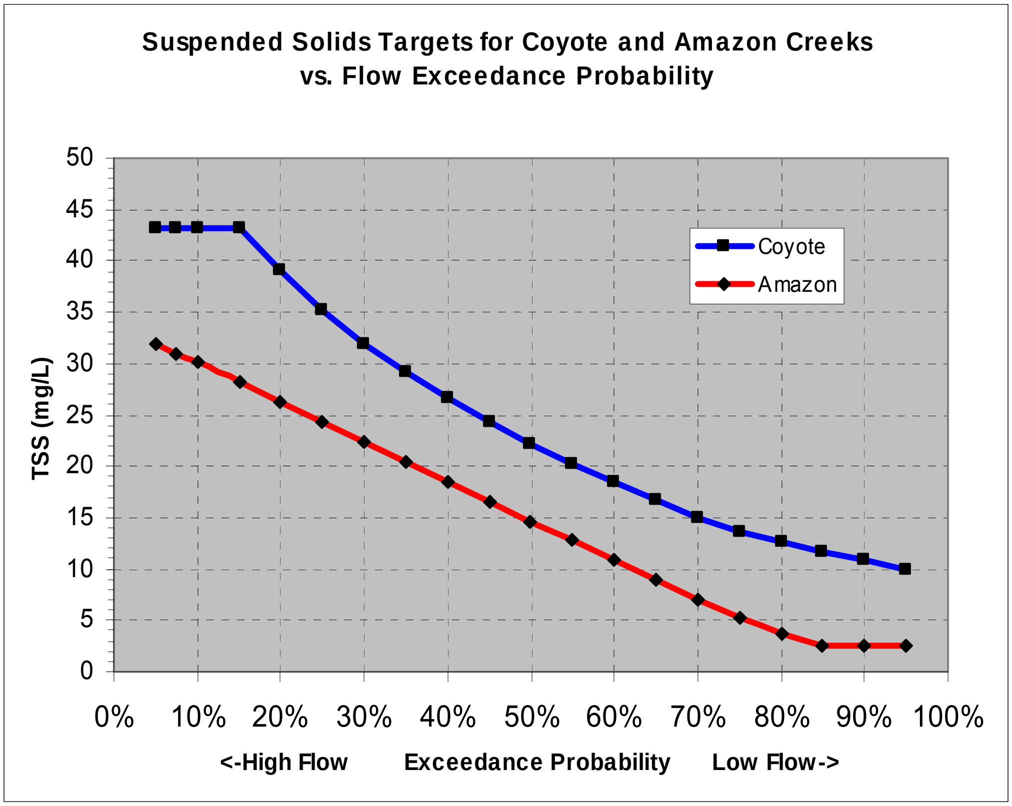
Figure 10.123 Suspended Solids vs. Turbidity Correlation - Coast Ecoregion (Mulvey and Hamel, 1998)


Turbity vs. Total Suspended Solids Correlation
North Coast and Mid Coast Data
y = 0.7149x + 4.1714
R^2 = 0.7582
Turbidity (NTU)
TSS (mg/L)
0
20
40
60
80
100
120
140
160
180
200
220
240

Numeric Targets – Suspended Solids

Equation 4, the relationship between TSS and turbidity, was used to convert the turbidity targets (Figure 10.123) to total suspended solids targets. These are shown in Figure 10.124.

Figure 10.124 Suspended solids targets vs. flow exceedance probability



Required Turbidity Reductions

Required turbidity reductions have been calculated using two datasets: a U.S. Army Corps of Engineers (USACE) dataset collected from 1996 through 1999 and an ODEQ dataset collected mostly from 2001 and 2002. The results were then averaged to estimate required reductions.

Reductions Needed Based on USACE Data

Turbidity and suspended solids data collected by USACE during 1996 through 1999 has been used to determine turbidity reductions required to meet water quality standards. These reductions were estimated by comparing observed turbidities at the most downstream Amazon and Coyote Creek stations (Table 10.70`Coyote Station CC-2 and Amazon Station AA-2, just u/s of Fern Ridge Reservoir) to the turbidity targets presented previously (Figure 10.118).

Table 10. 70 USACE Stations located near stream mouths

Stations	Location
AA-1	Lake station in vicinity of Amazon Diversion Channel inflow
AA-2	Most d/s station in Amazon Diversion Channel
CC-1	Lake station in vicinity of Coyote Creek inflow
CC-2	Most d/s station in Coyote Creek
LT-3	Lake station in vicinity of Long Tom R inflow
LT-4	Most d/s station in Long Tom R (u/s of Lake)

Turbidity reductions required for Coyote Creek, based on the USACE data, range from 20 to 30% for high to median flow conditions, and diminish to zero for low flow conditions (Figure 10.125). For Amazon Creek, reductions for high flow conditions are similar to Coyote, but for low flow conditions significantly greater reductions in turbidity are needed. However, since no impacts on Fern Ridge Reservoir due to these streams have been identified during low flow periods, no percent reductions will be required for low flow conditions of flow EP greater than 60%. Turbidity reductions for various flow categories are summarized in Table 10.71.

Table 10. 71 Turbidity percent reductions needed based on USACE data

Flow category range of flows (% greater than)	Flow category	Required percent reductions in Turbidity
<10	Coyote High Flow	30%
10-40	Coyote Transitional Moist Conditions	23%
40-60	Coyote Median Flow Conditions	17%
>60	Coyote Low Flow Conditions	NA
<10	Amazon High Flow	27%
10-40	Amazon Transitional Moist Conditions	30%
40-60	Amazon Median Flow Conditions	41%
>60	Amazon Low Flow Conditions	NA

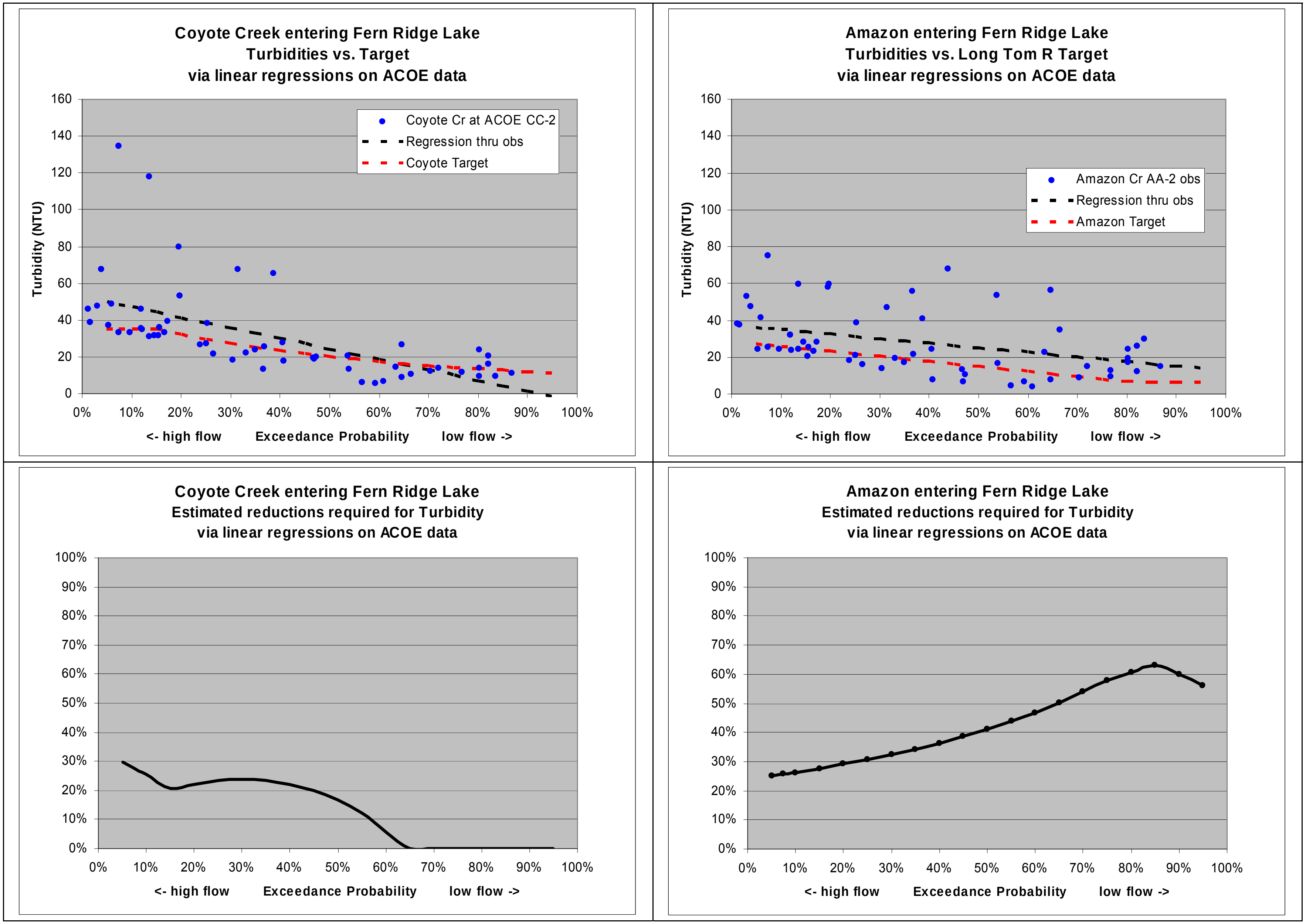


Figure 10.125 Turbidity reductions required based on USACE data

Reductions Needed Based on ODEQ Data

A dataset collected by the ODEQ was also used to determine turbidity reductions required to meet water quality standards. In a similar manner as with USACE data, these reductions were estimated by comparing observed turbidities at the most downstream Amazon and Coyote Creek stations (Coyote Cr at Cantrell Rd and Amazon Diversion Channel at Fir Butte Road, just u/s of Fern Ridge Reservoir) to the turbidity targets described previously.

The ODEQ dataset is considerably smaller than the USACE dataset. However, it has the advantage of being of known high quality, since it was collected in accordance with ODEQ quality assurance procedures and given an A+ (highest grade) quality assurance rating by ODEQ's laboratory. In addition, data was collected in the upper reaches of Amazon and Coyote Creek, which provides for intra-watershed reference sites. The bulk of this data was collected during 2001 and 2002 for purposes of developing TMDLs. Stations used for the load allocations are shown in Table 10.72 (see also Map 10.29).

Table 10. 72 ODEQ stations for load allocations

Lasar No.	Station Name	Miles u/s from Reservoir	Location
29707	Amazon Cr at Martin St.	12.7	Upstream
25624	Amazon Cr at 29th street	10.9	Upstream
25617	Amazon Diversion Channel at Fir Butte Road	0.8	Near mouth
28549	Coyote Cr at Hamm Rd	20.9	Upstream
12290	Fox Hollow Cr At Rm 1.3 (Trib to Coyote)	21.5	Upstream
10150	Coyote Cr at Cantrell Rd.	1.5	Near mouth

The data set is quite sparse, which partially explains the relatively high correlation coefficients for the trend lines (Figures 10.126 and 10.127). However, the plots do give a general indication of the reductions in turbidity needed for the system. The trend line equations are used to determine the percent reductions needed for Amazon and Coyote Creeks for turbidity and solids.

As with the USACE data, ODEQ observed turbidities near the mouth of Coyote Creek are higher than near the mouth of Amazon Creek during high flow conditions, but less during low flow conditions. This shows that Coyote Creek turbidities are more sensitive to runoff than Amazon Creek.

Figure 10.126 Turbidity - Coyote Creek near mouth – ODEQ

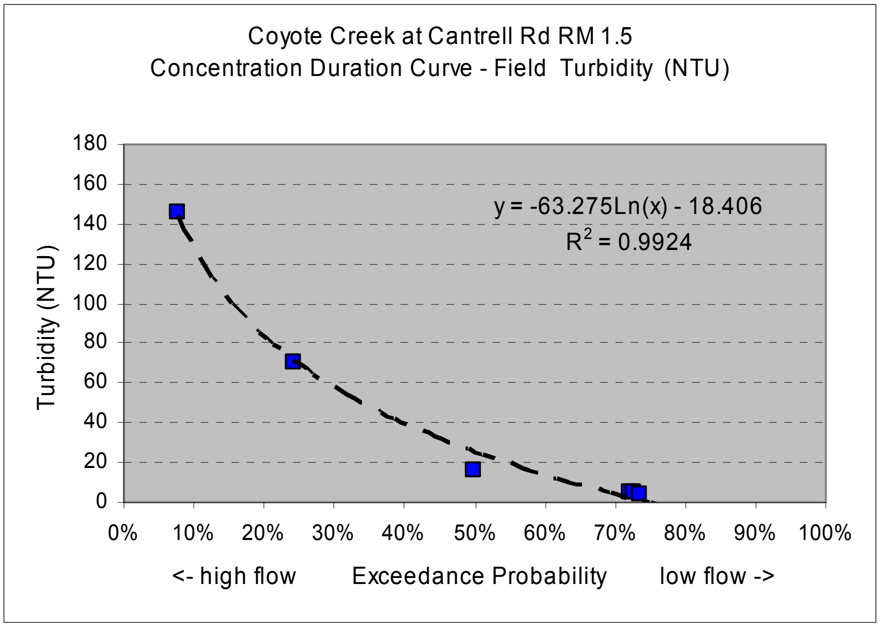
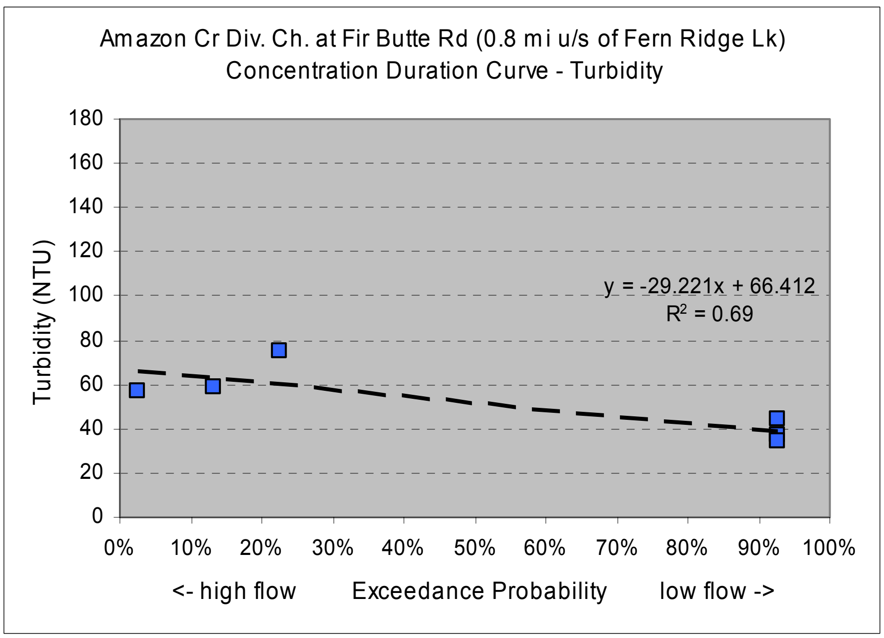


Figure 10.127 Turbidity - Amazon Creek near mouth - ODEQ



Turbidity reductions required for Coyote Creek, based on the ODEQ data, range from 40 to 80% for high to median flow conditions, and diminish to zero for low flow conditions (see Figure 10.128). For Amazon Creek, reductions for high flow conditions are similar to Coyote, but for low flow conditions significantly greater reductions in turbidity are needed. However, since no impacts on Fern Ridge Reservoir due to these streams have been identified during low flow periods, no percent reductions will be required for low flow conditions of flow EP greater than 60%. Turbidity reductions for various flow categories are summarized in Table 10.73.

Table 10. 73 Turbidity percent reductions needed based on ODEQ data

Flow category range of flows (% greater than)	Flow category	Required percent reduction in Turbidity
<10	Coyote High Flow	79%
10-40	Coyote Wet Conditions	58%
40-60	Coyote Transition Conditions	21%
>60	Coyote Dry and Low Flow Conditions	NA
<10	Amazon High Flow	58%
10-40	Amazon Wet Conditions	64%
40-60	Amazon Transition Conditions	72%
>60	Amazon Dry and Low Flow Conditions	NA

Suspended solids data was also collected by ODEQ. This was compared to target suspended solids calculated using Equation 4, which correlates suspended solids to turbidity. The required percent reductions in suspended solids for the streams are presented in Figure 10.129. Since suspended solids are largely conservative (do not decay), the percent in-stream suspended solids reductions equate to overall required reductions in loading to the stream from upland and in-stream erosion sources. As shown, the percent reductions required for TSS are similar to those required for turbidity (Figure 10.128).

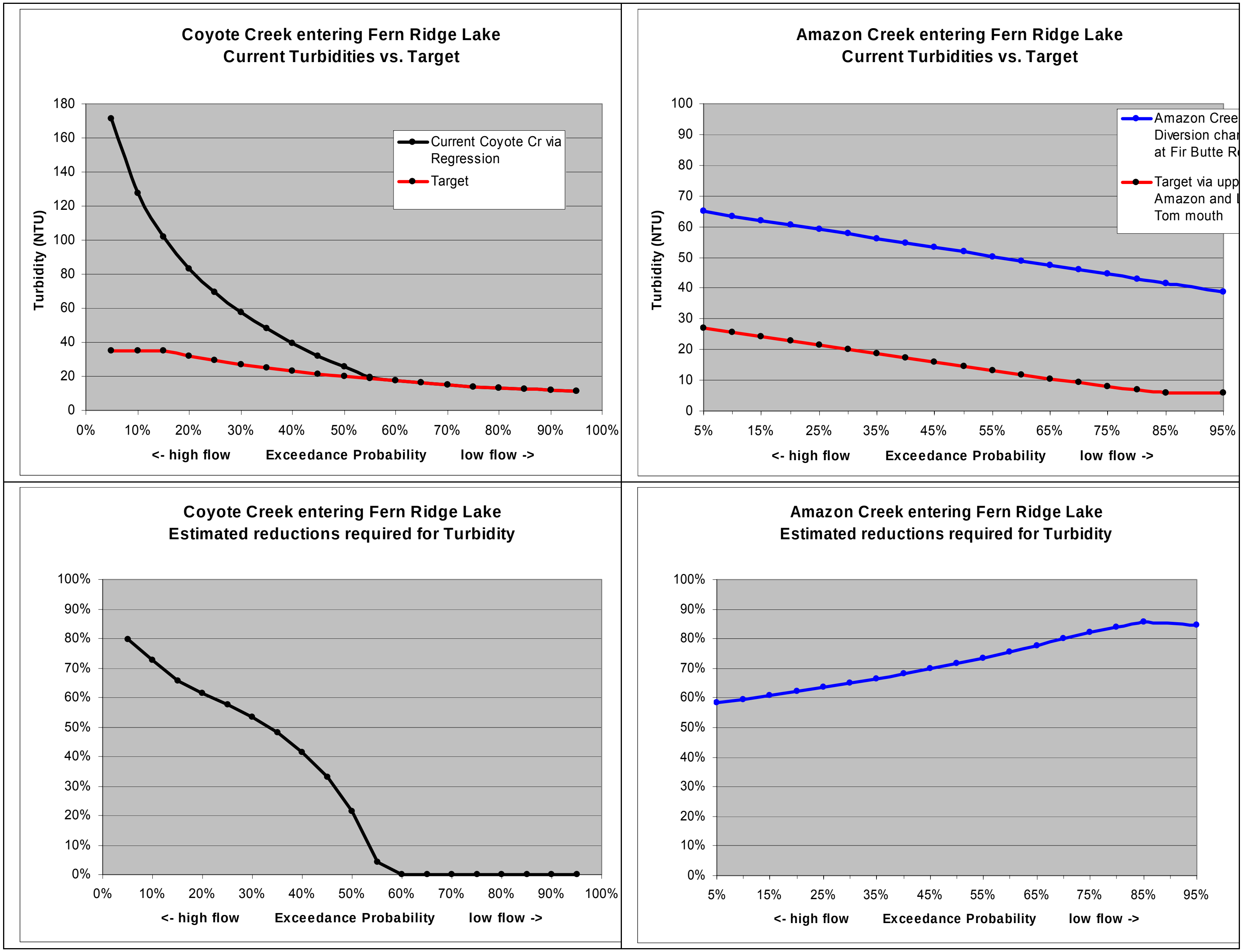


Figure 10.128 Turbidity reductions required based on ODEQ data

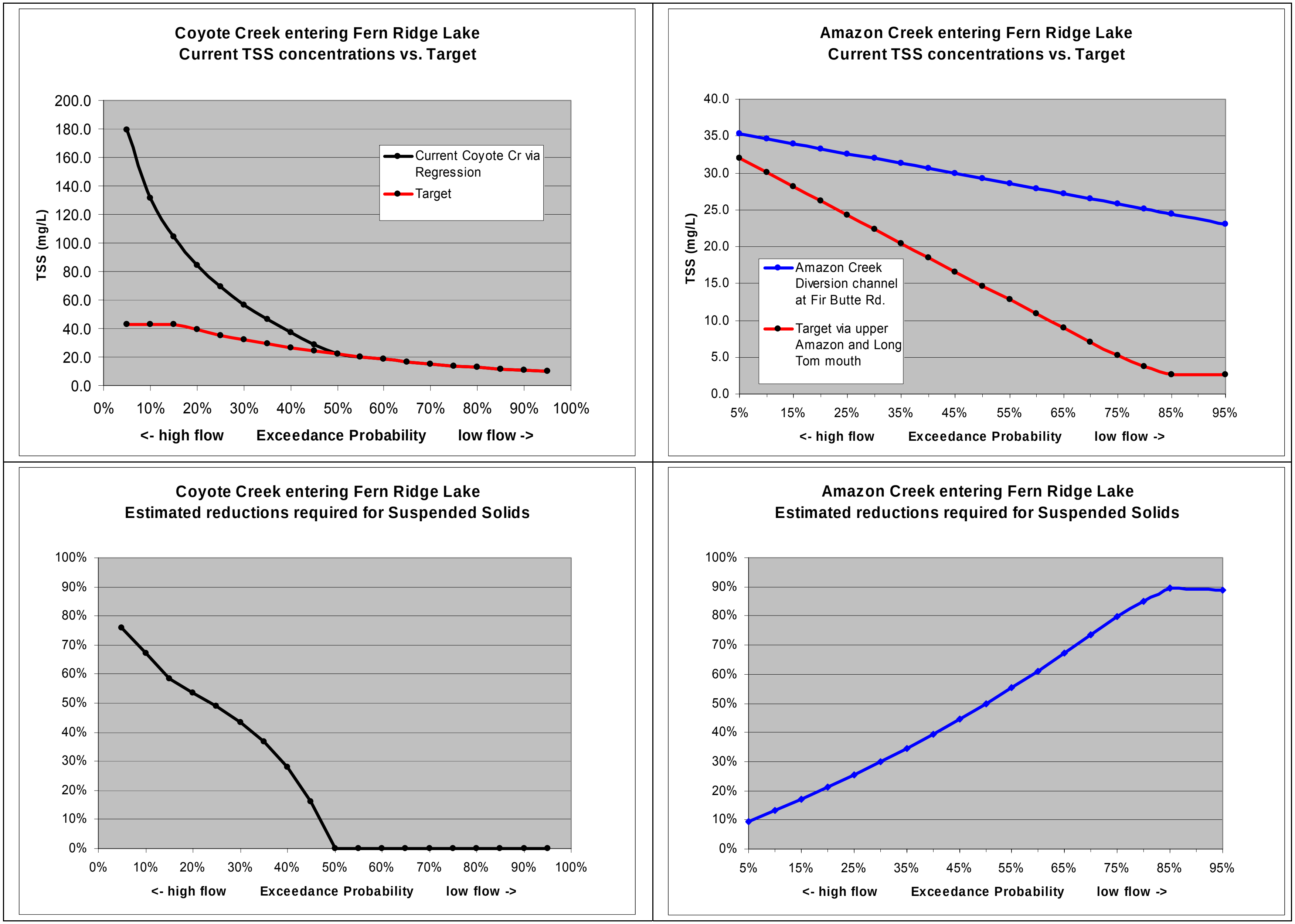


Figure 10.129 Suspended solids reductions required based on ODEQ data

Required Turbidity Percent Reductions

The required turbidity reductions calculated using the two datasets have been averaged to derive the required percent reductions (see Table 10.74). Included also are the estimated flow ranges for each flow category for each stream and the upper Long Tom River.

Table 10. 74 Required percent reductions in turbidity based on average of USACE and ODEQ data

Flow category range of flows (% greater than)	Long Tom R near Noti range of flows (cfs)	Stream range of flows (cfs)	Flow category	Average required percent reduction in turbidity
<10	>584	>448	Coyote High Flow	55%
10-40	148-584	63-448	Coyote Wet Conditions	41%
40-60	55-148	11-63	Coyote Transition Conditions	19%
>60	<55	<11	Coyote Dry and Low Flow Conditions	NA
<10	>584	>75	Amazon High Flow	43%
10-40	148-584	10.5-75	Amazon Wet Conditions	47%
40-60	55-148	1.9-10.5	Amazon Transition Conditions	57%
>60	<55	<1.9	Amazon Dry and Low Flow Conditions	NA

Loading Capacity

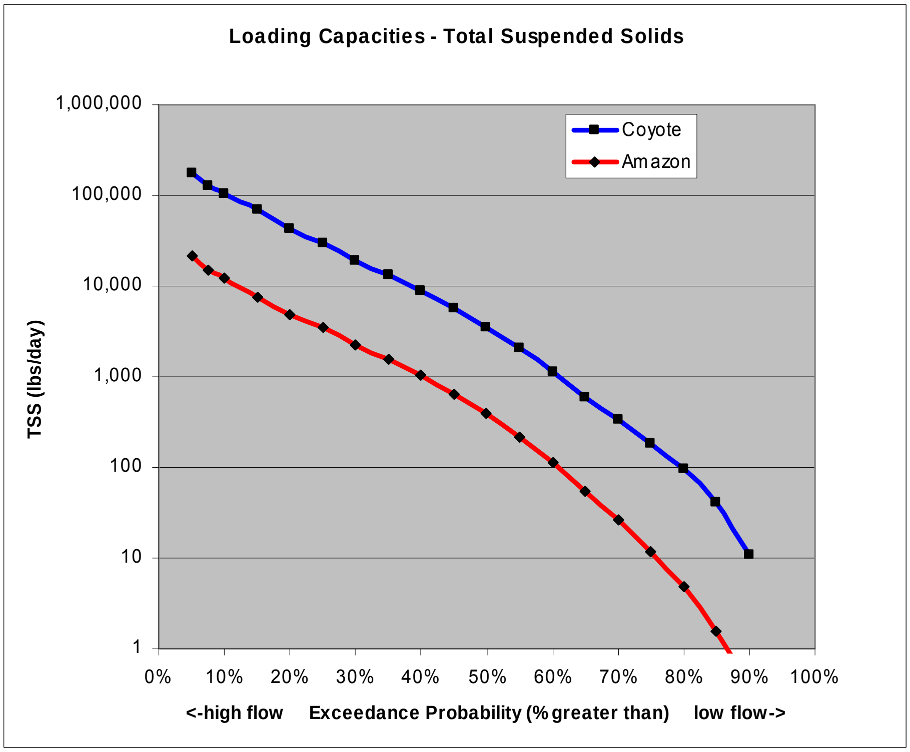
The loading capacity is the amount of a pollutant that a waterbody can receive and still meet water quality standards. This section presents the loading capacity for turbidity causing suspended solids for the two watersheds.

A stream's loading capacity will be greater than its in-stream load if the pollutant is not conservative (i.e. it decays), settles and becomes buried, or otherwise leaves the water column. For this analysis, suspended solids have been treated as a conservative pollutant. This should be a valid assumption because most of the solids which enter Fern Ridge Reservoir and cause turbidity problems are inorganic suspended solids which do not decay. Some of these solids will settle in the stream, however, most will be resuspended during storm events and be transported to the lake. Therefore, most of the load of suspended solids which enter the stream should be reflected in in-stream concentrations and the loading capacity can be based on observed in-stream suspended solids concentrations.

Suspended solids targets (Figure 10.124) were multiplied by flow to derive loading capacities for turbidity-causing suspended solids for the streams in terms of pounds per day of suspended solids (Figure 10.130). Flows for Coyote Creek were estimated by relating historic flow in Coyote Creek to flow in Long Tom River (see Appendix A: Bacteria for additional information on this methodology). For Amazon Creek, flows are based on the average ratio of monthly average Amazon Creek discharge to Coyote Creek discharge from October through June of 16.8% (Table 10.69).

Loading capacities are presented in Figure 10.130. Note that the Amazon Creek loading capacity is an order of magnitude lower than Coyote Creek's due to the lower flow in Amazon Creek as well as its lower turbidity targets.

Figure 10.130 Loading Capacities for Total Suspended Solids



Flows have been divided into five categories consistent with methodologies used for other TMDLs (see Appendix A: Bacteria). Loading capacities for each stream for mid-point exceedance probabilities of 5% (<10%), 25% (10 to 40%), 50% (40 to 60%), 75% (60 to 90%), and 95% (90 to 100%) are summarized in Table 10.75.

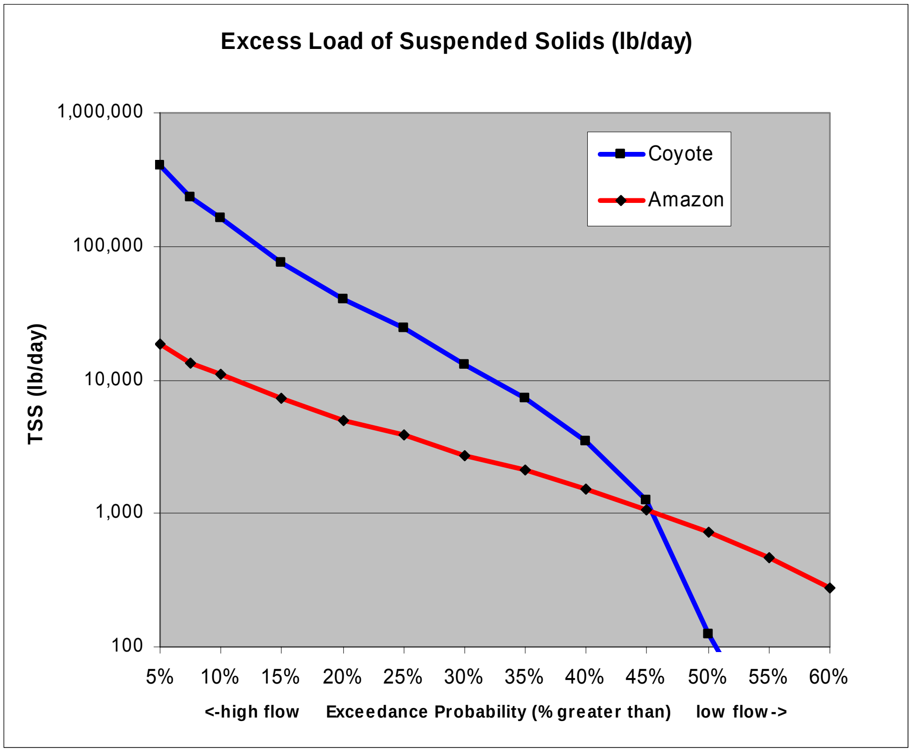
Table 10. 75 Loading Capacities and Targets for flow categories

Flow category range of flows	Reference River Discharge (cfs)	Turbidity Targets (NTU)		Total Suspended Solids Targets (mg/L)		Suspended Solids Loading Capacity (lbs/day)		Suspended Solids Loading Capacity (kg/day)	
(% greater than)	Long Tom R near Noti (14166500) (cfs)	Coyote	Amazon	Coyote	Amazon	Coyote	Amazon	Coyote	Amazon
<10	900	35.0	27.0	43.2	32.0	176,352	21,955	79,978	9,957
10-40	274	29.4	21.5	35.3	24.3	30,011	3,474	13,610	1,576
40-60	92	20.0	14.7	22.2	14.7	3,518	391	1,595	177
60-90	25	13.9	7.9	13.6	5.2	185	12	84	5
>90	9	11.3	6.0	10.0	2.6	0	0	0	0

Excess Load

Excess load is the difference between the actual pollutant load in a waterbody and the loading capacity of that waterbody (OAR 340-042-0040). Excess loads for the streams were estimated based on the differences between observed ODEQ and USACE turbidities near the streams' mouths and the streams' target turbidities. For the analysis, the regressions through ODEQ data (Figures 10.111 and 10.112) were averaged with the regressions through USACE data (Figure 10.125). The averages were then compared to the turbidity targets (Figure 10.118). Resultant excess turbidities were converted to suspended solids load using the correlation between TSS and turbidity (Equation 4) and estimated stream flow rates. The resultant excess load estimates for the streams are as shown in Figure 10.131.

Figure 10.131 Excess loads of suspended solids



As shown, excess loads in Coyote Creek are quite large during high flow events, but decrease to zero during low flow periods. Excess loads in Amazon Creek, on the other hand, do not decrease to zero during low flow periods because target turbidities are exceeded in Amazon Creek under all flow conditions (however, as discussed previously, load allocations are not needed for low flow periods because the streams' impacts on the Reservoir are negligible during such periods).

Linkages with other TMDLs

In order to derive land use based load allocations that match the loading capacities, it is helpful to review other TMDLS that have been developed for the Fern Ridge Reservoir Watershed. Implementation of these TMDLs will result in reduction in suspended solids loads to Amazon and Coyote Creeks and Fern Ridge Reservoir, in addition to the other pollutant loads for which the TMDLs are targeted.

Loads of turbidity causing solids to the streams come from two general categories: in-channel loads due to bank erosion, and upland loads due to surface runoff. TMDLs developed for other pollutants will reduce loads from both categories. TMDLs to address high temperatures and low dissolved oxygen levels in the streams specify minimum vegetative shade targets for the streams that will improve bank stability and reduce in-channel erosion to background levels. TMDLs to address high bacteria concentrations and low DO concentrations in the stream specify reductions in bacteria, organic matter, and nutrients from upland sources. Reductions in bacteria, organic matter, and nutrients from upland sources will result in similar reductions in suspended solids loads. Compliance with these TMDLs should result in compliance with the turbidity standard.

Upland Loads – Linkage with Upper Long Tom Watershed Bacteria TMDL

Correlation of Turbidity and Solids with Bacteria

The Upper Long Tom Watershed Bacteria TMDL specifies load allocations for bacteria for Amazon and Coyote Creeks. A review of data shows that turbidity and suspended solids correlate well with bacteria in Coyote Creek (see Figure 10.132 and Figure 10.133). This indicates that the reductions in bacteria specified in the Bacteria TMDL should result in similar reductions in suspended solids and turbidity.

Figure 10.132 Turbidity vs. Bacteria - Coyote Creek - ODEQ data

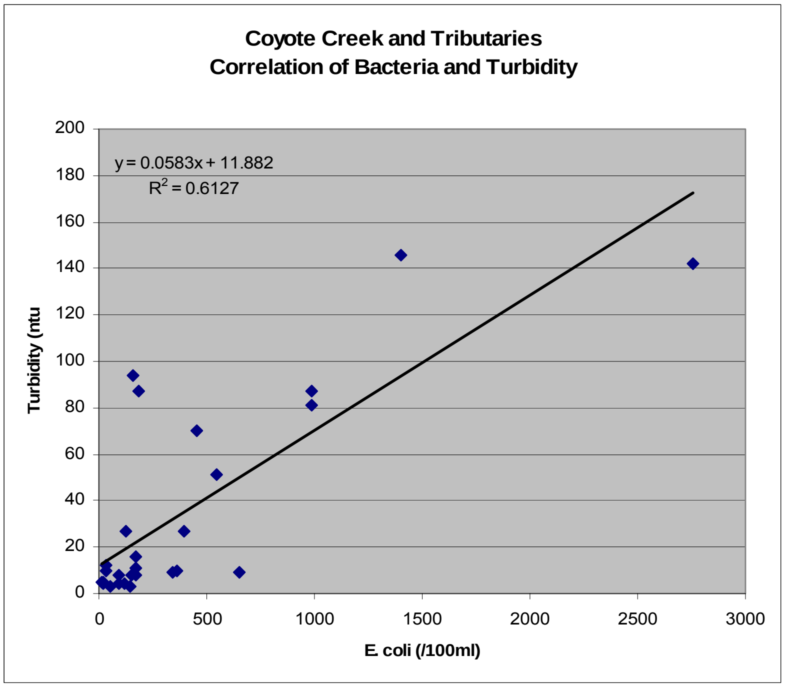
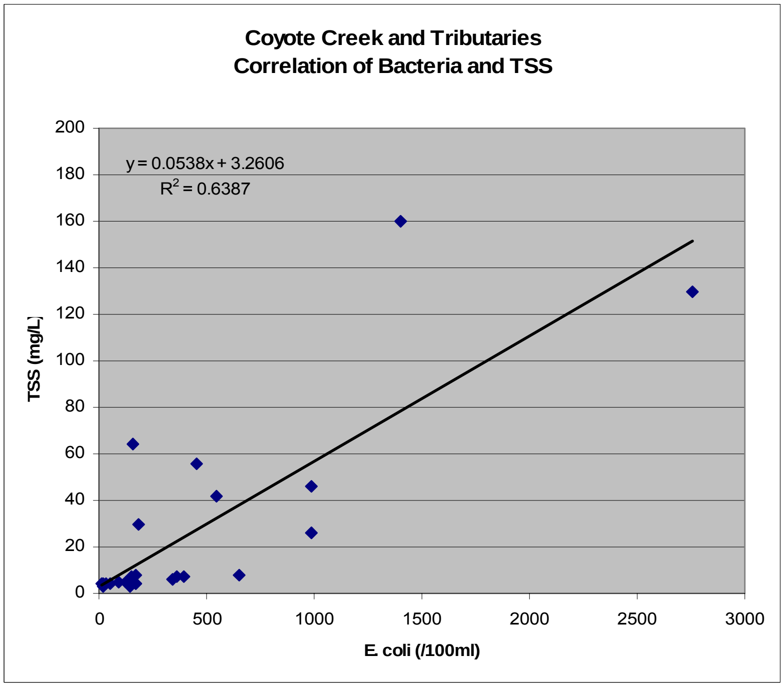


Figure 10.133 Solids vs. Bacteria - Coyote Creek - ODEQ data



Interestingly, in predominately urban Amazon Creek, as opposed to rural Coyote Creek, turbidity and suspended solids do not correlate nearly as well with bacteria (see Figure 10.134 and Figure 10.135). However, it still appears likely that efforts to reduce bacteria loads associated with overland flow should result in reductions in turbidity.

Figure 10.134 Turbidity vs. Bacteria - Amazon Creek - ODEQ data

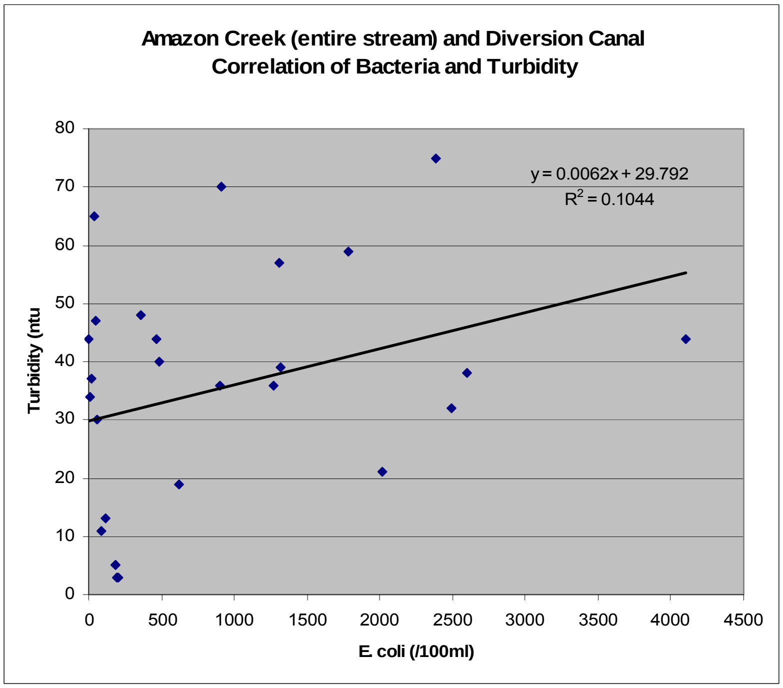
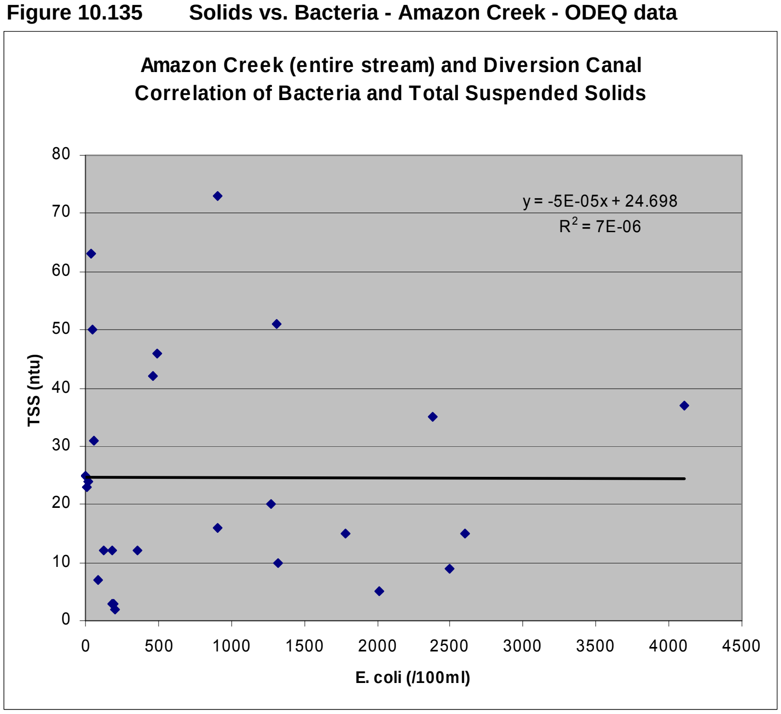


Figure 10.135 Solids vs. Bacteria - Amazon Creek - ODEQ data

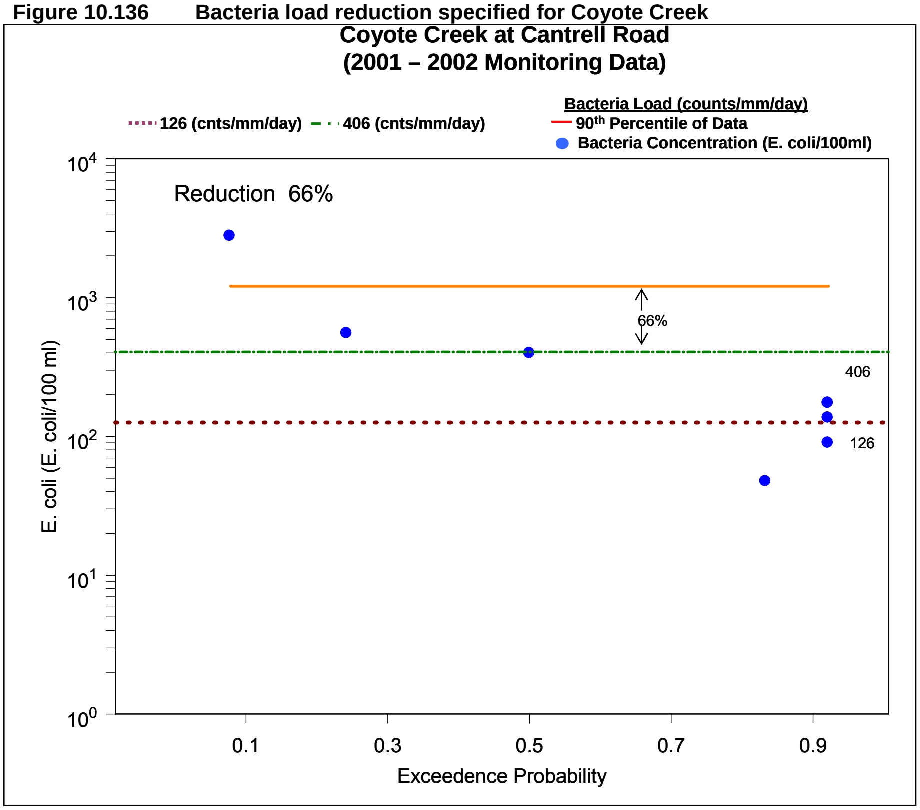


Coyote Creek Bacteria Load Allocations

The Upper Willamette Subbasin Bacteria TMDL specifies bacteria load allocations for Amazon and Coyote Creek watersheds. Similar percent reductions in solids and turbidity should occur in response to the bacteria load reductions.

The Bacteria TMDL specifies a concentration based reduction. The reduction is based on the percentile, in this case the 90th percentile, which will reduce concentrations to the 406 standard (Figure 10.136).

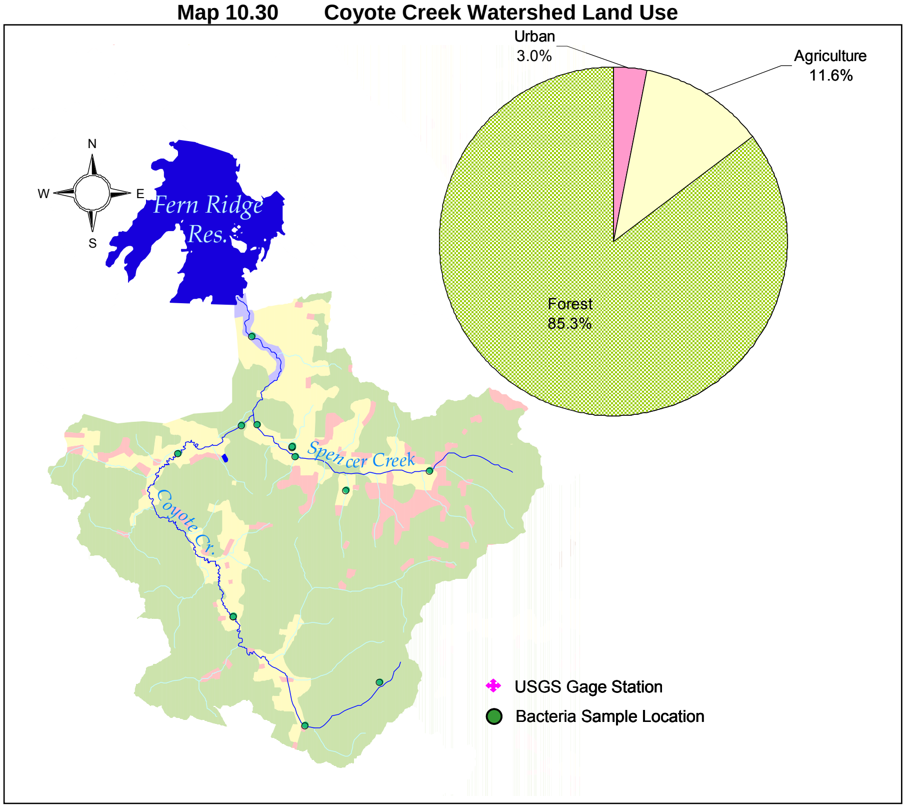
Figure 10.136 Bacteria load reduction specified for Coyote Creek



Points that plot above the 406 line represent deviations from the water quality standard. Those plotting below the line represent compliance with water quality criteria. The red line represents the 90th percentile of samples. As with high turbidities, bacteria standard exceedances occur at high flows regimes. The value in the dry flows contains samples below the 406 standard. As designated in Figure 10.136, the 90th percentile reduction for the system to meet the 406 standard is 66%.

The primary land use in the valley bottom, where a majority of violations occur is agriculture (Map 10.30). Agriculture appears to be the major contributor to the bacteria load observed in the waterbody. The upland areas of the watershed are forestland with bacteria levels meeting standards based on available data. For this reason, reductions calculated for Coyote Creek have been assigned to agricultural and urban land uses.

Map 10.30 Coyote Creek Watershed Land Use



For the Coyote Creek Watershed, exceedances of the bacteria standard take place during high flow events. It is likely that the loading is due to runoff related sources such as agricultural overland runoff, urban stormwater, sanitary sewer overflows or combined sewer overflows. Conversely bacteria concentrations are usually less during low flow periods. Data indicate that violations of the water quality standard at low flows are less likely to occur in this watershed. Applicable bacteria reductions are summarized in Table 10.76.

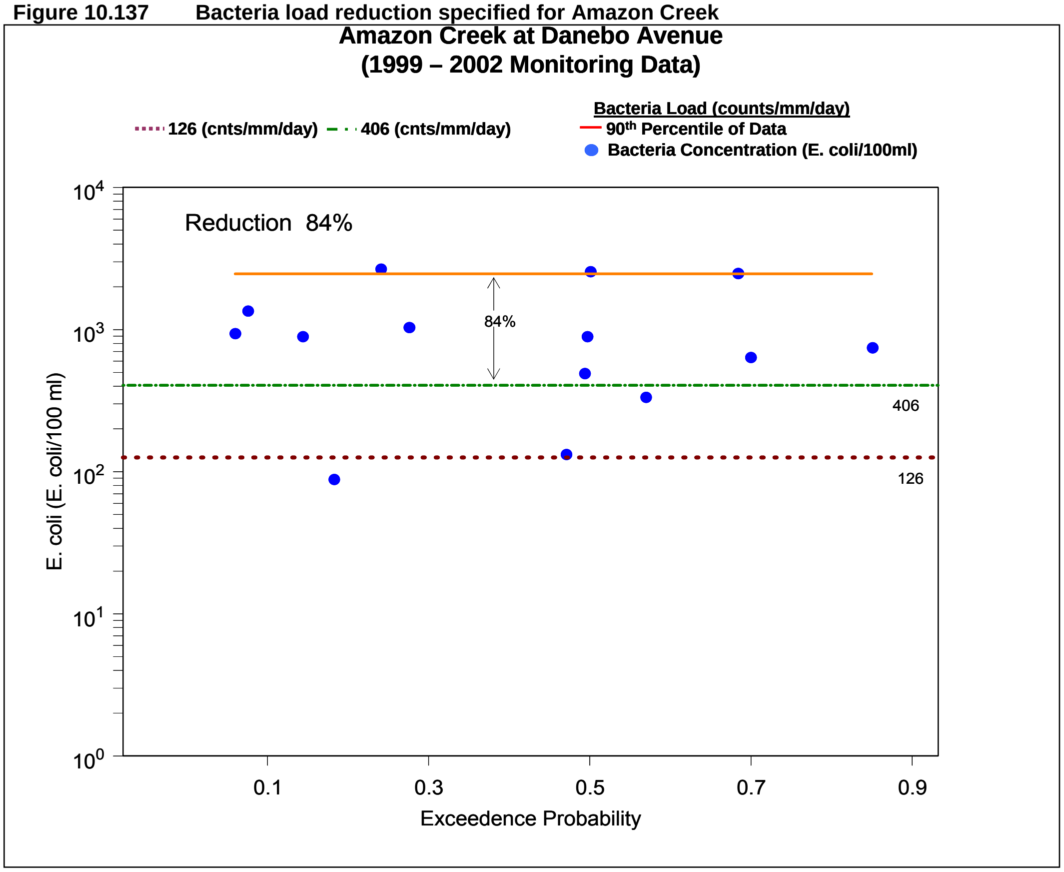
Table 10. 76 Land use based bacteria reductions required for the Coyote Creek Watershed

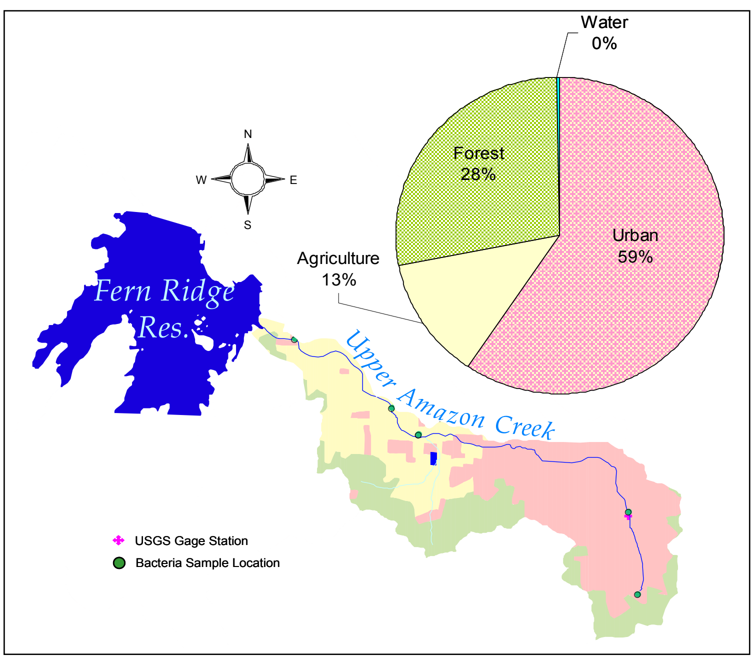
Land Use Categories	Coverage Percentage	Percent Reduction Specified
Urban	3%	66%
Agriculture	12 %	66%
Range	0%	0%
Forest	85%	0%

Amazon Creek Bacteria Load Allocations

As with Coyote Creek, a concentration based bacteria reduction is applied to Upper Amazon Creek. The reduction is based on the 90th percentile that will reduce concentrations to the 406 standard (see Figure 10.137).

Figure 10.137 Bacteria load reduction specified for Amazon Creek





Map 10.31 Upper Amazon Creek Watershed Land Use

Points that plot above the 406 line represent deviations from the water quality standard. Those plotting below the line represent compliance with water quality criteria. The red line represents the 90th percentile of samples. Exceedances of the 406 standards occur at all flows regimes. As designated in the concentration plot above, the 90th percentile reduction for the system to meet the 406 standard is 84%.

Urban development is the primary land use upstream of the principle sampling site (Danebo Avenue). The upland areas of the watershed are forest land, which are unlikely to be significant sources of bacteria. Upper Amazon Creek bacteria percent reductions of 84% have been assigned to urban land use (Table 10.77). Agricultural land use is downstream of the Danebo Avenue sampling site. The agricultural land use within the Upper Amazon Creek watershed is assigned a 58% reduction in bacteria loading as per the Upper Willamette Subbasin percent reduction calculated specifically for agricultural land use within the subbasin.

For the Upper Amazon Creek Watershed, exceedances take place during all flow events. It is likely that the loading is due to sources such as urban overland runoff, urban stormwater, sanitary sewer overflows or combined sewer overflows. Conversely bacteria concentrations occurring during low flow periods are from sources that may include warm-blooded animals in streams, direct discharge of waste to streams, failing septic tanks, waste water treatment plants and improper discharge of sewage. Applicable bacteria reductions are summarized in Table 10.77.

Table 10. 77 Land Use Based Bacteria Reductions for the Amazon Creek Watershed

Land Use Categories	Coverage Percentage	Percent Reduction Specified
Urban	59%	84%
Agriculture	13%	58%
Range	0%	0%
Forest	28%	0%

Upland Loads – Linkage with Upper Willamette DO TMDL

The Upper Willamette DO TMDL specifies load allocations for oxygen demanding pollutants, such as organic matter, that contribute to biochemical oxygen demand (BOD) and sediment oxygen demand (SOD); ammonia, which contributes to BOD and can cause toxicity; and nutrients, which contribute to excessive algal growth. The DO TMDL specifies required percent reductions for these pollutants for Amazon Creek and Amazon Diversion Channel and Coyote Creek.

Correlation of Solids and Turbidity with Oxygen Demanding Pollutants

A review of Amazon Creek data shows that suspended solids and turbidity correlate with BOD and chemical oxygen demand (COD) (Figure 10.138 and 10.139). This indicates that reductions in loads specified in the DO TMDL should result in similar reductions in both suspended solids and turbidity.

For Coyote Creek, similar correlations could not be developed because no BOD or COD data is available for days with elevated suspended solids concentrations.

Figure 10.138 TSS vs. BOD and COD - Amazon Creek - ODEQ data

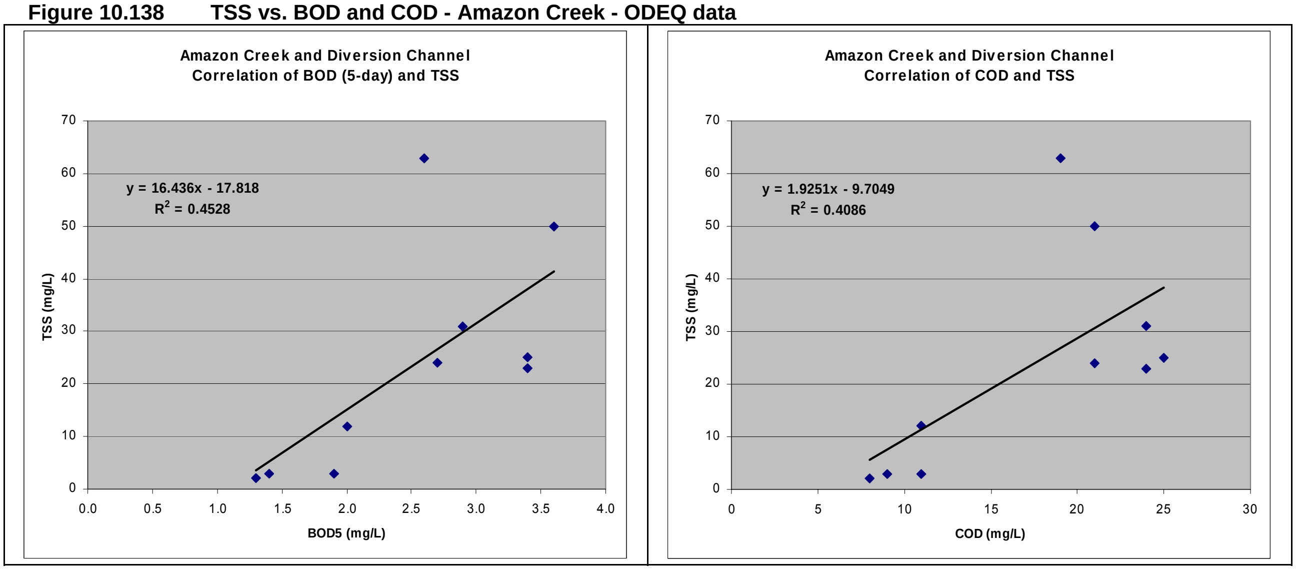
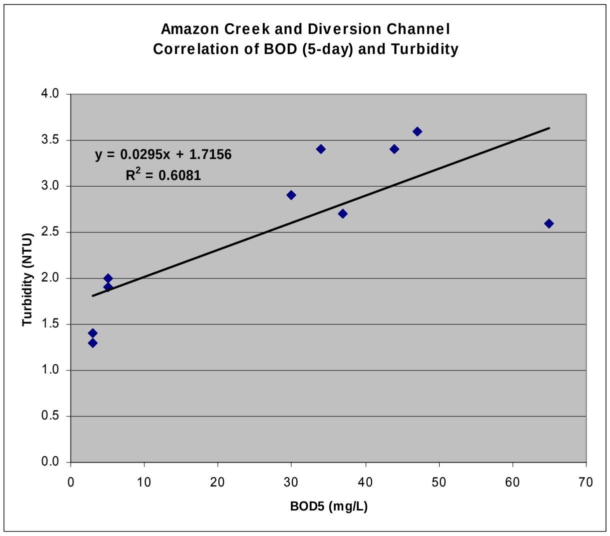
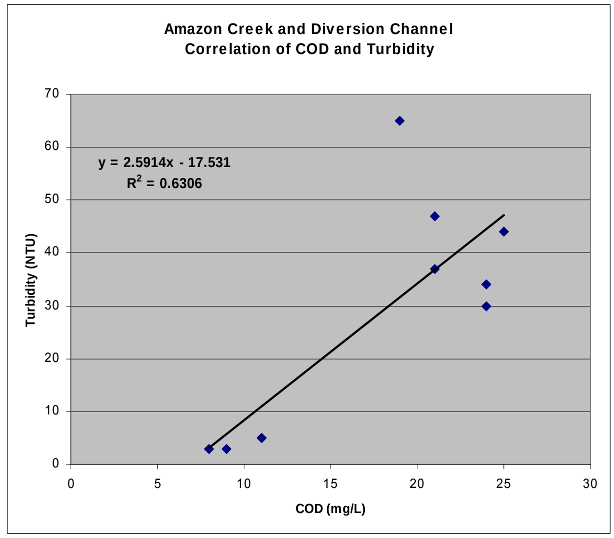


Figure 10.139 Turbidity vs. BOD and COD- Amazon Creek - ODEQ data





Coyote Creek Load Allocations to Address DO Concerns

The Upper Willamette DO TMDL specifies load reductions for Coyote Creek for BOD, nutrients and volatile suspended solids (Table 10.78). Similar reductions in solids and turbidity should occur in response to the BOD and volatile suspended solids (VSS) load reductions.

Table 10. 78 Load Reductions for BOD, nutrients and VSS specified in Coyote Creek DO TMDL

Land Use Categories	Coverage Percentage	Percent Reduction Specified
Urban	3%	20%
Agriculture	12%	20%
Forest	85%	0%

Amazon Creek Load Allocations to Address DO Concerns

The Upper Willamette DO TMDL specifies load reductions for Amazon Creek and Diversion Channel for BOD, nutrients and volatile suspended solids (Table 10.79). Similar reductions in solids and turbidity should occur in response to the BOD and VSS load reductions.

Table 10. 79 Load Reductions for BOD, nutrients and VSS specified in Amazon Creek DO TMDL

Land Use Categories	Coverage Percentage	Percent Reduction Specified
Urban	59%	40%
Agriculture	13%	40%
Forest	28%	0%

In-Stream Loads – Linkage with Temperature TMDLs

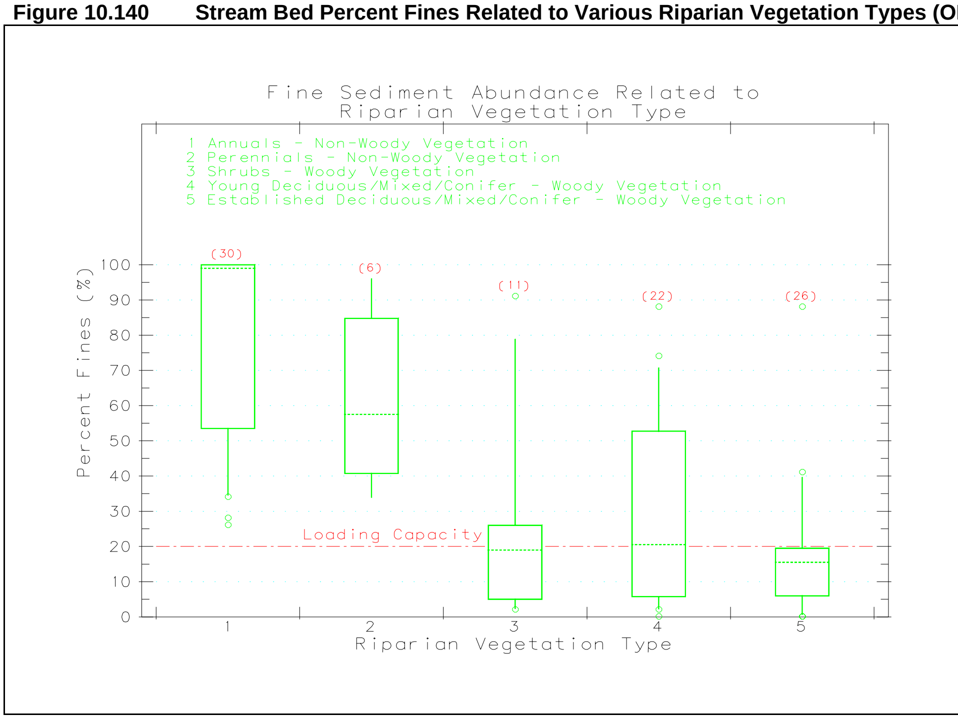
The Upper Willamette Subbasin Temperature TMDL addresses high temperatures by providing load allocations for the surrogate measure “percent effective shade.” Streams addressed by this TMDL include Amazon and Coyote Creeks, as well as the Long Tom River. Since factors that affect water temperature are interrelated, the surrogate measure (percent effective shade) relies on restoring/protecting riparian woody vegetation to increase stream surface shade levels, reduce stream bank erosion, stabilize channels, reduce the near-stream disturbance zone width, and reduce the surface area of the stream exposed to radiant processes. Implementation of the Temperature TMDL should reduce erosion of stream banks to natural levels to be expected in the absence of anthropogenic activities.

Surrogates used in the Upper Willamette Subbasin Temperature TMDL include:

1. Site-specific shade targets;
2. Shade curves for areas that were not specifically modeled;
3. Channel widths.

Sediment discharged into streams from excessive bank erosion can settle and adversely impact fish redds and benthic organisms. The percentage of stream bed covered in fines can be quantified as a percent streambed fines. Studies performed by the Oregon Department of Fish and Wildlife (ODFW) show that streams with banks protected by woody vegetation, necessary to meet the effective shade target specified in the Temperature TMDL, have significantly lower percent streambed fines than those without woody vegetation (Figure 10.140).

Figure 10.140 Stream Bed Percent Fines Related to Various Riparian Vegetation Types (ODEQ, 2000)



For the Upper Grande Ronde TMDL (approved by USEPA May, 2000), the observed ODFW data indicated that when an established deciduous/mixed/conifer riparian community exists, the loading capacity of 20% streambed fines was attained (ODEQ, 2000). While no streambed percent fines target has been established for Amazon and Coyote Creeks, the presence of woody vegetation at levels necessary to meet the shade targets in the temperature TMDLs should ensure that erosion of stream banks will not exceed natural levels. Note that Coyote Creek, which is mostly a natural channel, is more susceptible to bank erosion than Amazon Creek and Diversion Channel, which is largely channelized and armored with riprap and cement.

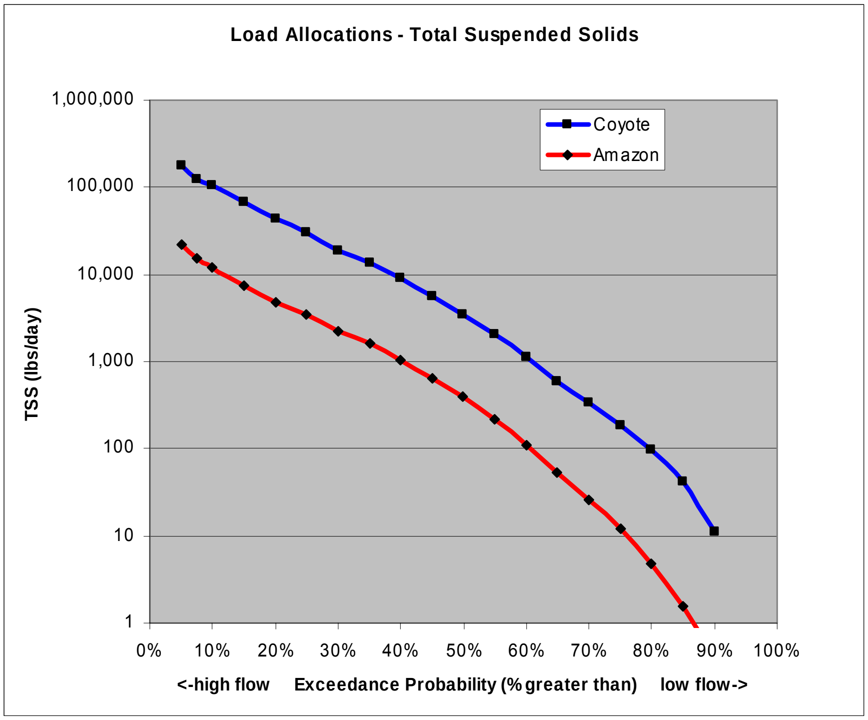
Shade target surrogate measures provided for in the Upper Willamette Temperature TMDL provide for the establishment of a deciduous/mixed/conifer riparian community. This same surrogate measure can be utilized to achieve the load allocations in the turbidity TMDL. The shade target surrogate measure promotes riparian conditions that will increase near-stream (stream bank) area resistance to erosive energy (shear stress) and may reduce local shear stress levels. Specifically, the restoration/protection of riparian areas called for in the temperature TMDL will serve to reduce stream bank erosion by increasing stream bank stability via rooting strength and near-stream roughness. This will result in elimination of excessive solids loads due to stream bank erosion. Since the surrogate measure specified in the Temperature TMDL is necessary to eliminate the excessive discharge of turbidity causing sediments into the streams, it is also specified as a required measure by this Turbidity TMDL

Load Allocations for Suspended Solids

Load Allocations for Suspended Solids as Functions of Flow

Load allocations for nonpoint sources of suspended solids for each of the watersheds have been set equal to the loading capacities of the streams (Figure 10.141).

Figure 10.141 Load Allocations for Total Suspended Solids



Percent Reductions in Suspended Solids Required to Meet Load Allocations

In order to meet these load allocations, percent reductions in suspended solids are specified for each of the principle land use categories: urban, agriculture, and forest. These are shown in Figure 10.142 and 10.143.

The percent reductions were calculated by averaging the percent reductions indicated by the two datasets, the USACE dataset and the ODEQ dataset, as described previously (Table 10.74).

For Coyote Creek (Figure 10.142), the load reductions have been applied to the dominant land use category, agriculture. Since available data was insufficient to differentiate between contributions of loads from urban areas vs. agricultural areas, the same percent reductions have been applied to both categories, even though urban land use is a relatively minor land use category for the Coyote Creek Watershed

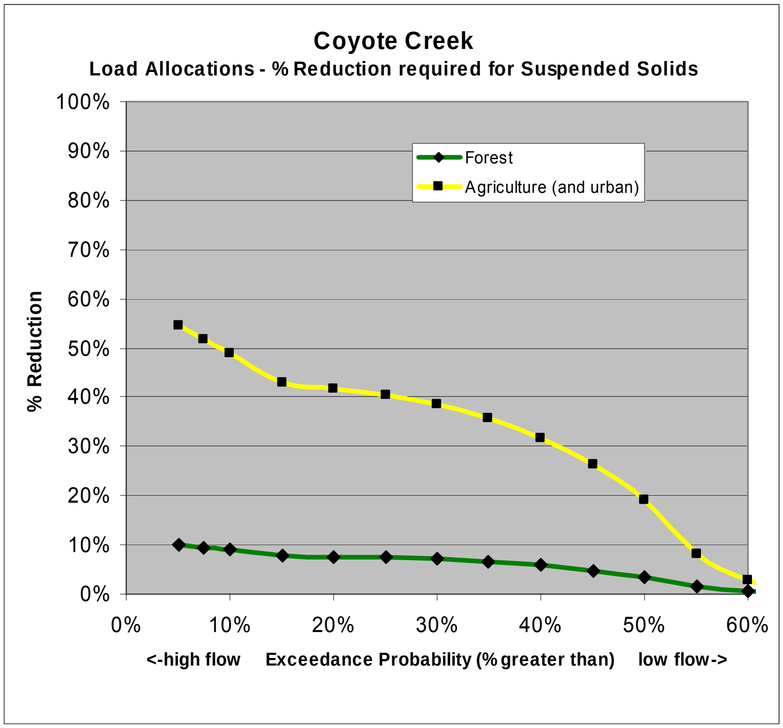
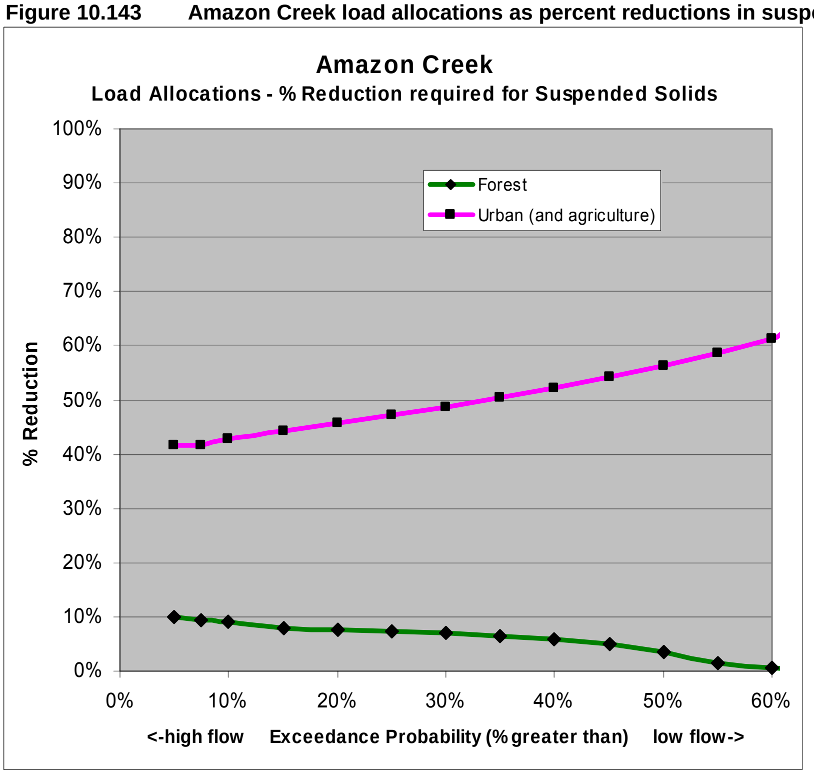


Figure 10.142 Coyote Creek load allocations as percent reductions in suspended solids

Required load reductions for these land use categories range from a maximum 55% percent reduction at high flows to a zero reduction at low flows. In order to provide for a margin-of-safety, percent reductions have also been applied to forestry. A maximum 10% reduction is specified for forestry at high flows. This is reduced to a zero reduction at low flows.

Figure 10.143 Amazon Creek load allocations as percent reductions in suspended solids



For Amazon Creek and Diversion Channel (Figure 10.143), the load reductions have been applied to the dominant land use category, urban. As with Coyote Creek, available data was insufficient to differentiate between contributions of loads from urban areas vs. agricultural areas. Therefore, the same percent reductions have been applied to both categories. Required load reductions for urban and agriculture average about 50%, (41% to 61%) for high to median flow conditions. For low flow conditions (EP > 60%), no reductions are needed. As for Coyote, percent reductions have also been applied to forestry in order to provide for a margin-of-safety. A maximum 10% reduction is specified for forestry at high flows. This is reduced to a zero reduction at low flows.

The specified percent reductions are summarized in Table 10.80.

Table 10. 80 Load allocations as percent reductions in suspended solids loads

Flow category range of flows (% greater than)		EP	Coyote			Amazon		
			Forest	Agriculture	Urban	Forest	Agriculture	Urban
<10	High Flows	5%	10.0%	54.6%	54.6%	10.0%	41.7%	41.7%
10-40	Transitional High	25%	7.4%	40.5%	40.5%	7.4%	47.2%	47.2%
40-60	Median	50%	3.5%	19.0%	19.0%	3.5%	56.4%	56.4%
60-90	Transitional Low	75%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
>90	Low Flow	95%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Percent of watershed in each land use category:			85%	12%	3%	28%	13%	59%

Implementation of TMDLs developed for the Upper Willamette to address other concerns, including bacteria, dissolved oxygen, and temperature, should result in the load allocations for turbidity being met.

For the Amazon watershed, the required reductions in solids loads are similar to the 40% reduction in BOD specified in the DO TMDL and less than the 84% reduction in bacteria specified in the bacteria TMDL. For the Coyote watershed, the required reductions in solids loads are less than the 66% reduction in bacteria specified in the bacteria TMDL, although they exceed the 20% reduction in BOD specified in the DO TMDL. Since turbidity correlates with solids, bacteria, and BOD, it is likely that actions taken to meet the DO and bacteria TMDLs will result in the specified reductions in suspended solids loads being met in both Amazon and Coyote.

Significant reduction in loads should also be achieved by implementation of the Upper Willamette Subbasin Temperature TMDL. For both streams, the Temperature TMDL provides load allocations for the surrogate measure "percent effective shade." Implementation of this TMDL should result in reductions in loads of suspended solids to the streams by protecting and restoring riparian woody vegetation and reducing erosion of stream banks.

Confined animal feeding operations are not allowed to discharge wastes from specific areas covered by the general NPDES permit. Therefore, for BOD and nutrients, CAFOs are allocated loads of zero from regulated portions of operations.

No other point sources appear likely to discharge significant quantities of suspended solids. If any point sources are found to discharge such pollutants in quantities likely to result in turbidity impacts, wasteload allocations will be developed to address the discharges.

Measures for Addressing Internal Recycling of solids

Reductions in solids loads from Amazon and Coyote Creeks will reduce storm event-related turbidity levels in the streams and in Fern Ridge Reservoir. This will result in a reduction in solids which settle near the confluences of the stream and are available for resuspension during the summer. However, solids already present in the lake will continue to be resuspended. In the summer, "turbidity is the combined result of fine clays in permanent colloidal suspension, larger clays and silt which are present in varying quantities due to settling and resuspension, and moderate levels of planktonic growth (LCOG, 1983)." The LCOG, 1983 report recommended that the following actions be considered for reducing summer turbidity levels:

- Chemical treatment to improve solids settling,
- Reservoir dredging to remove clays and increase depth,
- Vegetative management by introducing aquatic plants to bind sediment and dampen waves,
- Construction of dikes and islands to restrict circulation of turbid water,
- Change bottom composition by applying a thin layer of sand over the clay bottom,
- Summer flow augmentation into the lake to reduce low Summer water levels,
- Control of bottom foraging fish,
- Boating restrictions.

In response to turbidity and other water quality issues in Fern Ridge Reservoir, USACE has implemented a number of management measures designed to address internal recycling of solids. These investments include: the development of sub-impoundments within the emergent zone; shoreline erosion control and bank stabilization projects; and the sanding and overall improvements of designated swimming areas. USACE has invested significant resources to develop impoundments in the management area since the early 1980’s. For example, 300-350 acres within the emergent zone of the Fisher Butte Management Unit have been developed by USACE and ODFW as a wet soil management impoundment area. The rationale for these impoundments is to restore degraded wetland plant communities pursuant to achieving identified resource stewardship and wildlife management program objectives. An added benefit of these improvements, however, may be to promote the settling of fine grain sediments and to develop vegetation which will help address sedimentation and turbidity. USACE plans to continue such management measures in the future under continuing natural resource stewardship programs and restoration authorities.

There have also been significant restrictions on boating traffic on over 3,000 acres of Project waters at Fern Ridge with the primary objective of reducing adverse impacts to nesting waterfowl and other wildlife within the emergent vegetation zone in addition to other sensitive wildlife management areas south of Highway 126 and along riparian stream corridors of the Long Tom tributary. Additional benefits of these restrictions may also be a reduction in bank erosion and turbidity that results from wakes and disturbances caused by boating activity in these areas.

The internal recycling of solids in Fern Ridge Reservoir can be attributed to a variety of sources including wind and wave action and recreational traffic as noted in the LCOG report from 1983. The past and future management measure developed and implemented by USACE, in conjunction with activities outlined in this TMDL to reduce the runoff-related loads of solids from the tributaries, will help reduce turbidity levels within Fern Ridge Reservoir.

Margins of Safety

TMDLs must include a margin of safety to account for any lack of knowledge concerning the relationship between load allocations and water quality. Such margins of safety can be explicit or implicit. This TMDL provides for implicit margins of safety, as follows:

1. The turbidity standard allows no more than a ten percent cumulative increase in natural stream turbidities as measured relative to a control point. For control points, this TMDL targets natural stream turbidities, measured at appropriate reference sites. The TMDL targets the reference site turbidities, rather than reference turbidities plus ten percent. Hence, the TMDL provides for an implicit ten percent margin of safety.
2. The TMDL provides for a margin of safety by capping maximum turbidities at levels necessary to protect aquatic species, even if reference site turbidities exceed these levels.
3. A station on the upper Long Tom River was used as a reference site in addition to upper Amazon and Coyote Creek stations. Turbidity and suspended solids concentrations at this location were consistently less than measured at the Amazon and Coyote Creek stations, which provides for a margin of safety over simply using reference sites on Amazon and Coyote Creeks.

Seasonal Variation

TMDLs must address seasonal variability. This TMDL addresses seasonal variability by providing load allocations for all seasons and flow conditions.

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