CHAPTER 7: MIDDLE WILLAMETTE SUBBASIN

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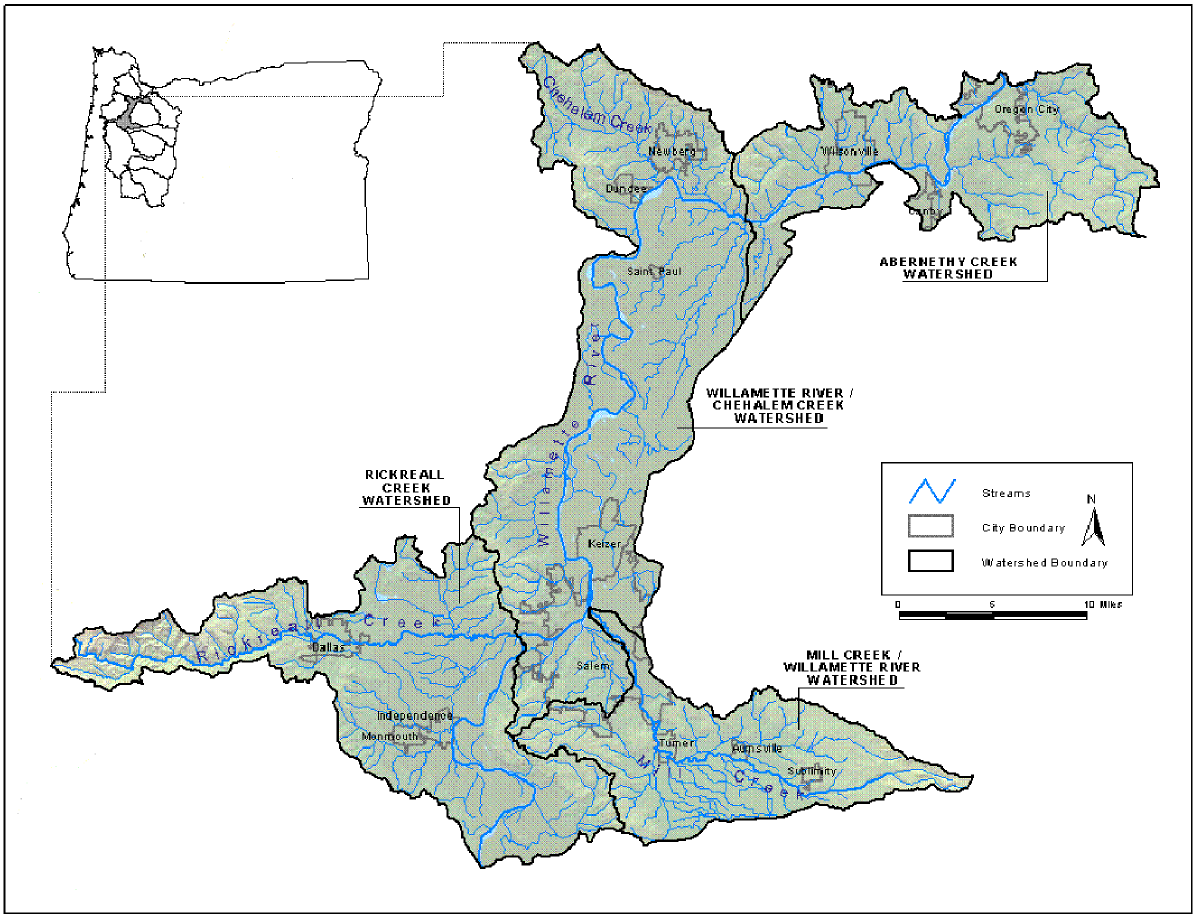
WATER QUALITY SUMMARY

Reason for action

The Middle Willamette Subbasin (Map 7.1) 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, toxics, and dissolved oxygen. Total Maximum Daily Loads (TMDLs) for temperature and bacteria were developed based on information for these parameters. Wasteload allocations are developed for individual facilities (point sources) that discharge these pollutants. In the case of the temperature, load allocations for nonpoint sources are developed for each geomorphic unit and apply to all sectors in the subbasin.

Map 7.1 The Middle Willamette Subbasin.



This chapter only includes TMDLs for rivers and streams in the Middle Willamette Subbasin. These subbasin rivers and streams are tributary to the Willamette River. For the mainstem Willamette River TMDLs see Chapter 2 for Bacteria, Chapter 4 for Temperature, and Chapter 3 for Mercury (addresses the entire Willamette Basin). All other subbasin TMDLs are included in Chapters 5 – 13.

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[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 7.1.

Table 7. 1 Name and location of listed Middle Willamette Subbasin waterbodies.

Waterbody Name	Listed River Miles	Parameter	Season	TMDL
Abernethy Creek	0 to 15.5	Temperature	Summer	Chapter 7
Bashaw Creek	0 to 4.8	Fecal Coliform	Year Around	Chapter 7
Champoeg Creek	0 to 7.5	Dieldrin	Year Around	No
Clark Creek	0 to 1.9	E Coli	Year Around	Chapter 7
Gibson Gulch	0 to 2.8	Dissolved Oxygen	October 1 - May 31	No
Glenn Creek	0 to 7	Dissolved Oxygen	October 1 - May 31	No
Mill Creek	0 to 25.7	Fecal Coliform	Year Around	Chapter 7
Patterson Creek	0 to 7.2	Temperature	Summer	Chapter 7
Pringle Creek	0 to 6.2	Copper	Year Around	No
		Dieldrin	Year Around	No
		E Coli	Year Around	Chapter 7
		Lead	Year Around	No
		Temperature	Summer	Chapter 7
		Zinc	Year Around	No
Rickreall Creek	0 to 24.9	Temperature	Summer	Delayed
Winslow Gulch	0 to 2.5	Dissolved Oxygen	October 1 - May 31	No

Water Quality Parameters Addressed

The following Middle Willamette Subbasin 303(d) parameters are addressed by a TMDL:

- Temperature
- Bacteria
- 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 TMDL analysis for this TMDL for some of the newly listed parameters. These parameters will be addressed in subsequent TMDL efforts. Parameters that are specifically excluded from this TMDL study are:

- Temperature for Rickreall Creek

The Environmental Quality Commission, based upon information provided by the Oregon Department of Fish and Wildlife, determined that Rickreall Creek was not salmon habitat and designated its use as "cool water." However, the cool water temperature criterion was not approved by USEPA, thus no temperature criterion currently exists for Rickreall Creek and a TMDL can not be completed at this time. Until a temperature TMDL is developed for Rickreall Creek riparian and bank restoration measures developed to address stream temperature concerns in the Middle Willamette Subbasin will reduce Rickreall Creek temperatures.

- Dissolved Oxygen

The dissolved oxygen (DO) listings for Gibson Gulch, Glenn Creek, and Winslow Gulch will not be addressed in this TMDL. These waterbodies were listed in 2002, which did not allow sufficient time to collect data needed for TMDL analysis. Until TMDLs for dissolved oxygen are developed for these streams riparian protection and restoration measures developed to address stream temperature concerns in the basin will benefit dissolved oxygen levels.

- Dieldrin

The dieldrin listings for Pringle Creek and Champoeg Creek will not be addressed in this TMDL, however a discussion paper on the current condition of dieldrin in Salem area streams and the toxicity of dieldrin is provided at the end of this chapter. Currently, insufficient data are available to complete an accurate dieldrin source assessment and to allocate load reductions with confidence. Additional in-stream dieldrin sampling reflecting seasonal and temporal variability for a period of at least one year would provide for a source assessment and possible development of load allocations in the future. In the interim ODEQ recommends the control of upland soil erosion to prevent sediment runoff to streams, increasing stream bank stability, and protecting and restoring system potential vegetation in riparian buffer zones.

- Copper / Lead / Zinc

The copper, lead, and zinc listings for Pringle Creek will not be addressed in this TMDL study. These parameters were listed in 2002, which did not allow sufficient time to collect data needed for TMDL analysis. In the interim ODEQ recommends additional metals data collection in the watershed to better define current conditions and source assessment. Best management practices implemented in the Pringle Creek Watershed to address temperature and bacteria concerns will also improve stream quality for these and other parameters likely to be associated with watershed runoff events.

In 1994, ODEQ established a TMDL for ammonia and Biological Oxygen Demand (BOD) in Rickreall Creek. These TMDLs were not reviewed or changed as part of this TMDL. The allocations established in 1994 continue to remain in effect.

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.

- City of Salem
- Environmental Health Department, Marion County
- U.S. Geological Survey, Oregon District
- Oregon Water Resources Department
- Greater Salem-Keizer Area Watershed Councils

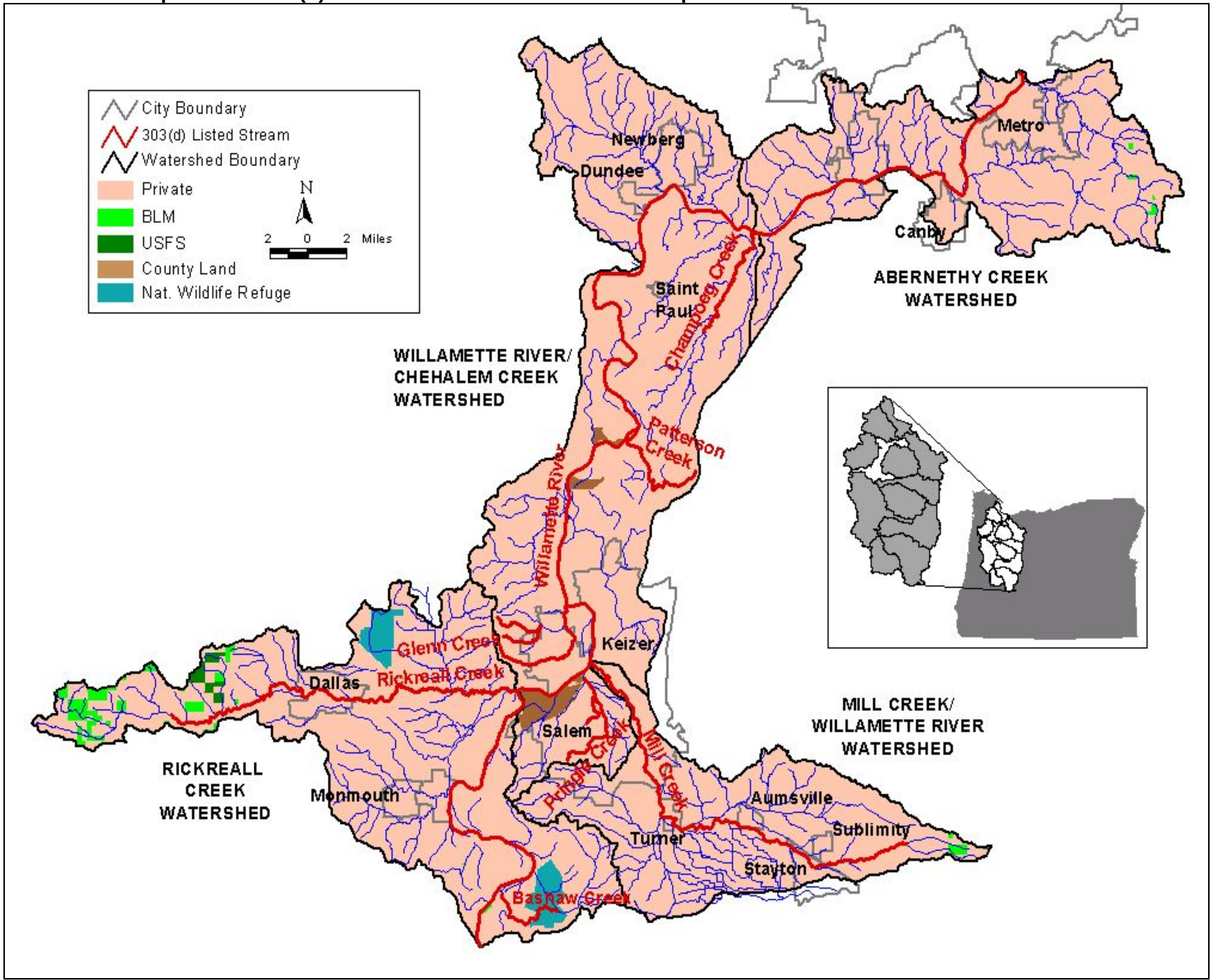
SUBBASIN OVERVIEW

The Middle Willamette Subbasin, Hydrologic Unit Code (HUC) 17090007, includes the Willamette River from Willamette Falls at river mile (RM) 26.6 to RM 108, near the Santiam River, with four 5th-field HUC watersheds that drain to the Willamette River. It is located in the northwest portion of the Willamette Basin and drains parts of the Cascade foothills from the east and the Coast Range from the west. The Willamette River longitudinally divides the subbasin with several medium to large tributaries and many smaller tributaries throughout its length. The 698 square miles (446,718 acres) of the subbasin have been divided among the following four watersheds:

- Abernethy Creek Watershed
- Mill Creek Watershed
- Rickreall Creek Watershed
- Willamette River tributaries / Chehalem Creek Watershed

The political jurisdictions within the subbasin include portions of Marion, Polk, Yamhill, Clackamas, and Washington Counties. There are fifteen incorporated cities: Stayton, Turner, Oregon City, Wilsonville, Newberg, Canby, Dundee, Donald, Saint Paul, Keizer, Salem, Dallas, Independence, Monmouth, Aumsville, Sublimity, and a portion of West Linn. The subbasin is almost entirely in private land ownership. Land uses are primarily agriculture, forestry, and urban. However there are small, scattered areas of public land managed by the Bureau of Land Management (BLM) and the State of Oregon (Map 7.2).

Map 7.2 303(d) Listed Streams and Land Ownership in the Middle Willamette Subbasin.



Watershed Descriptions

Abernethy Creek Watershed

The Abernethy Creek Watershed drains a 135 square mile (86,399 acres) area of low gradient, rolling hills typical of the west slope Cascade Range. Oregon City, in the southern portion of the Portland Metropolitan area, and the City of Canby are the only incorporated municipalities within the watershed. There are three major tributaries in this watershed that contribute to Willamette River flow: Beaver Creek, Parrott Creek, and Abernethy Creek.

The watershed is predominantly in private ownership. Agricultural land use is the most common land use; accounting for 52% of the area. Forestry accounts for 31% of the land area, and consists primarily of privately owned forested land parcels. Urban areas cover most of the remaining 15% of the land area.

There are six confined animal feeding operations (CAFOs) in the Abernethy Creek Watershed (ODA, March 2003). Of these six CAFOS, five are dairies with herd sizes ranging from 31 to 660 animals, and one is a swine lot with 1,400 animals. Five of these facilities are located west of the Willamette River.

There is one individual National Pollutant Discharge Elimination System (NPDES) permit holder that discharges to the Abernethy Creek Watershed. Clackamas River Water, a private water purveyor, is testing an Aquifer Storage and Recovery system that stores water in an aquifer during high flows for use during low flow and emergency times. Some of this stored water is discharged directly to Abernethy Creek with limitations specified in a minor industrial NPDES permit.

Mill Creek Watershed

The Mill Creek Watershed is 111 square miles (71,039 acres) of mostly privately owned land and includes the incorporated cities of Sublimity, Stayton, Aumsville, Turner, and Salem. Mill Creek flows into the Willamette River at RM 83.5. The cities of Salem and Stayton receive their drinking water from the Lower North Santiam River. Salem also stores drinking water in Franzen Reservoir, located on Mill Creek at RM 10.5.

Mill Creek has two major tributaries that contribute to its flow; Beaver Creek and McKinney Creek. Mill Creek also receives water from the North Santiam River at two in-flow diversion points operated by the Santiam Water Control District (SWCD). In addition the SWCD has another point of diversion from Mill Creek just south of Kubler Blvd that discharges into the Middle Pringle / East Pringle Creek system. The first in-flow is a year round diversion of North Santiam River water through Salem Ditch in Stayton. The second in-flow is seasonal and diverts North Santiam River water into Mill Creek through Perrin Lateral Canal and McKinney Main Line Canal. This seasonal diversion is open from May 1 to September 31, with an extended flow season occurring from March 1 to October 31 based on demand from the City of Salem.

Mill Creek has two out-flow diversions to supplement the flows in Pringle Creek. The two diversions, Shelton Ditch (Mill Creek RM 3.5) and Mill Race (Mill Creek RM 2.3), are operational year round and are man-made channels constructed to minimize the effects of flooding in Salem (Hemesath and Nunez, 2002). Mill Race was originally constructed as the water supply for Mission Mill and the Boise Cascade pulp and paper mill.

Mill Creek has one real-time flow gage (Oregon Water Resources Department gage #14192000) in Salem at Capital Street, RM 1.1. The real-time data is available on-line at http://odwr.e-monitoring.net/ .

Mill Creek Watershed land use is approximately 75% agricultural use, 13% forestry use, and 12% urban use. While the watershed is dominated by agricultural land use upstream of the city of Turner there is very little area between Turner and Salem that is not urbanized. The City of Salem currently has a Phase I municipal separate storm sewer system (MS4). The MS4 permits are based in part on urbanized areas as defined by the U.S. Bureau of Census. Marion and Polk counties hold MS4 Phase II permits.

There are ten CAFOs in the Mill Creek Watershed (ODA, March 2003), including eight dairies, one feed lot, and one swine lot. Dairy herds range in size from 100 to 5000 animals, while the feedlot and swine operation have 200 and 315 animals, respectively.

There are four individual NPDES permits in the Mill Creek Watershed including one domestic sewage permit for the Aumsville Sewage Treatment Plant that discharges to Beaver Creek. There are also 24 general NPDES permits in the watershed
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Rickreall Creek Watershed

The Rickreall Creek Watershed drains a 183 square mile (117,119 acres) area of the Willamette Valley and the Coast Range. The watershed has three major tributaries that contribute to the Willamette River flow; Rickreall Creek, Ash Creek, and Bashaw Creek. Dallas and Monmouth are the only incorporated municipalities within the watershed. The City of Dallas obtains its drinking water from Rickreall Creek and Aaron Mercer Reservoir. The Ankeny National Wildlife Refuge and Baskett Slough National Wildlife Refuge are located in the lower watershed. There is also scattered public land managed by the US Forest Service and the Bureau of Land Management, primarily in the upland forested areas of the watershed.

Agriculture accounts for approximately 61% of land use in the watershed, with forestry land use accounting for 33% of use, and 5% for rural residential use. Rickreall Creek drains the Coast Range forested upland. This is primarily privately owned forest land, and flows into Aaron Mercer Reservoir at RM 25. Downstream of the reservoir, the creek flows through a mix of agriculture and urban land uses.

The flow in Rickreall Creek is controlled by Aaron Mercer Reservoir, near the headwaters of the creek. The dam provides water storage in the winter and augments flow in Rickreall Creek in the summer and fall (Mattson, K. and, Gallagher, A., 2001). During the dry weather low flow period, the City of Dallas adjusts the release from Mercer Reservoir to, at a minimum, match flows entering the reservoir. This practice ensures that flows in the individual streams entering the reservoir in excess of the city's water right are passed through below the city's water intake. During extreme low flow periods when the flow into the reservoir is less than the city's in-stream water right, it has been the city's practice to use water stored in the reservoir to maintain minimum flows (1.5-2.5 cfs) below the water intake.

There are four individual NPDES permits in the watershed. Three are domestic sewage permits and one is an industrial discharge permit. The three domestic sewage permits are issued to the City of Dallas, which discharges treated effluent year-round to Rickreall Creek at RM 10.5, and the cities of Independence and Monmouth, which discharge directly to the Willamette River. The City of Dallas also has an industrial individual NPDES permit for discharging process wastewater to Rickreall Creek during the winter. Wastewater is used for irrigating hybrid poplar trees during the spring, summer and early fall months.

There are three CAFOs in the watershed (ODA, March 2003) which are one dairy, one feedlot, and one unidentified operation. The number of animals in these operations ranged from 125 to 800.

There are no real-time flow gages on the tributaries to the Willamette River in the Rickreall Creek Watershed.

Willamette River/Chehalem Creek Watershed

The Willamette River/Chehalem Creek Watershed drains 244 square miles (156,159 acres) of the low gradient Willamette Valley. Newberg, Dundee, Saint Paul, and the northern portion of the Keizer/Salem area are the only incorporated municipalities within the watershed. There are several tributaries in the watershed that contribute to Willamette River flow. These include Gibson Creek, Glenn Creek, Pringle Creek, Patterson Creek, Claggett Creek, Chehalem Creek, and Champoeg Creek.

The watershed is mostly in private ownership. Agricultural land use accounts for the majority of use at approximately 74% of the watershed. Privately owned forested land is 14% of land use while urban land use is approximately 10% of use in the watershed.

There are 27 CAFOs in the watershed (ODA, March 2003). There are: 18 dairies, ranging in size from about 50 to 3300 animals; three swine lots with up to 145 animals; two feed lots with up to 320 animals; one horse lot with 19 animals; one poultry facility with 44,000 birds; and two unidentified lots.

There are five individual NPDES permits in the watershed; three are domestic sewage permits, although all discharge directly to the Willamette River. Domestic major permits have been issued to the cities of Salem and Newberg sewage treatment plants. A minor domestic individual NPDES permit is issued to the City of

Dundee Sewage Treatment Plant. There is one industrial individual NPDES permit issued in the watershed to Virginia Paper Manufacturing, which discharges directly to the Willamette River.

There are no real-time flow gages on the tributaries to the Willamette River in this watershed.

MIDDLE WILLAMETTE TEMPERATURE TMDL

The temperature TMDL for the Middle Willamette Subbasin includes tributaries to the Willamette River within HUC 17090007. As per Oregon Administrative Rule (OAR) 340-042-0040 required components of a TMDL are listed in Table 7.2.

Table 7. 2 Middle Willamette Subbasin Temperature TMDL Components.

Name and location of 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 Middle Willamette Subbasin, HUCs 170900701, 170900702, 170900703, and 170900704.
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 Middle Willamette Subbasin.
Target Criteria Identification **OAR 340-042-0040(4)(c)** ***CWA §303(d)(1)*** **OAR 340-041-0028(4)(a)** **OAR 340-041-0028(4)(c)** **OAR 340-041-0028(4)(d)** ***OAR* 340-041-0028(8)** **OAR 340-041-0028(9)** **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. Biologically-based numeric criteria applicable to the Middle Willamette subbasin include: 13.0°C: during times and at locations of salmon and steelhead spawning through fry emergence. 18.0°C: during times and at locations of salmon and trout rearing and migration. 20.0°C: during times and at locations of salmon and steelhead migration in identified migration corridors. 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.
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 standards. The WQMP is designed to complement the detailed plans and analyses provided in specific implementation plans. See Chapter 14.
Standards 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)

There are four stream segments in the Middle Willamette Subbasin that are listed on the 303(d) list for exceeding water temperature criteria: Patterson Creek, Pringle Creek, Rickreall Creek, and the Willamette River from RM 26.6 to RM 108 as shown on Map 7.3. The mainstem Willamette River segment is addressed in Chapter 4 of this document.

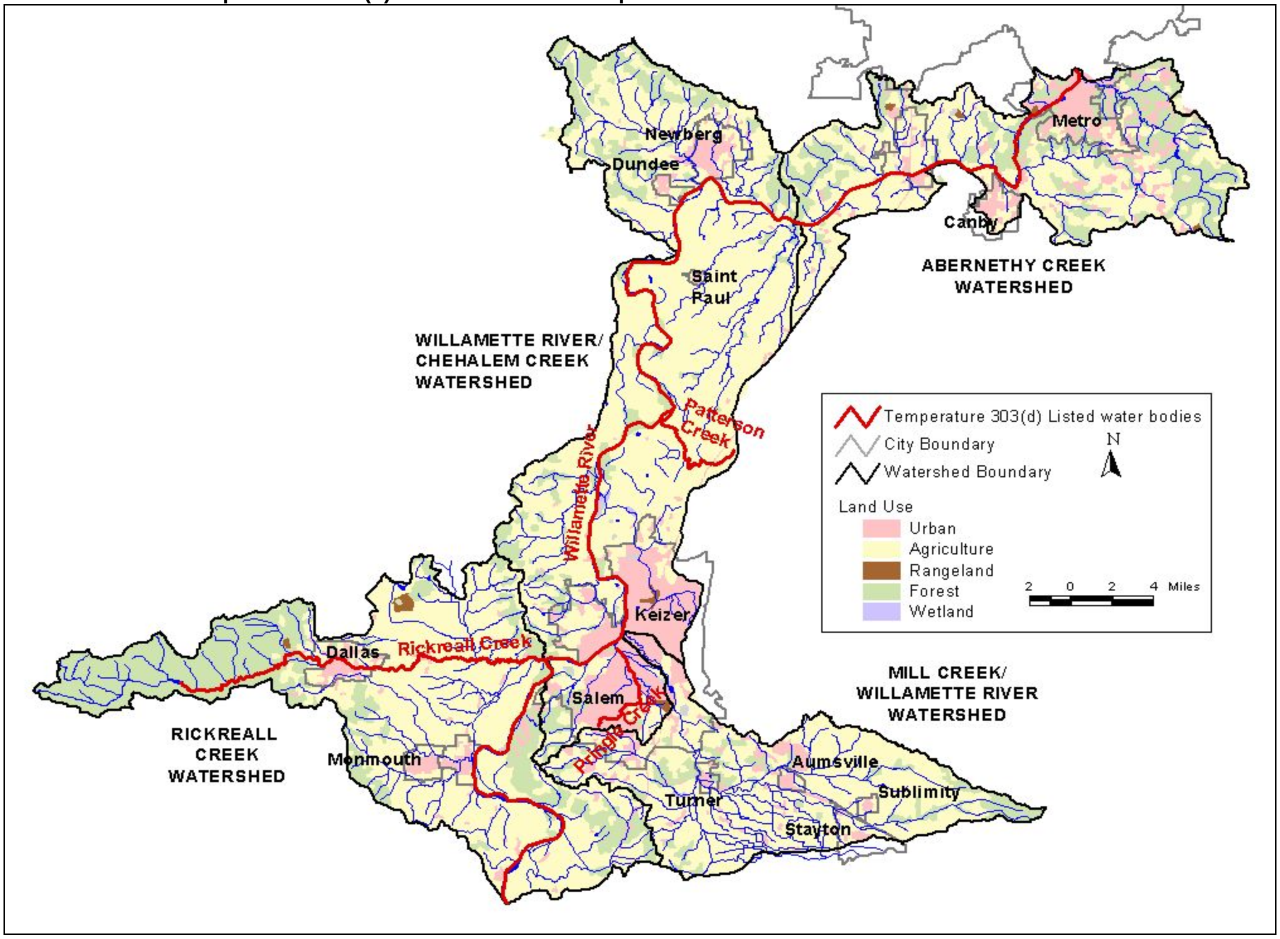
Patterson, Pringle, and Rickreall creek segments were listed under the previous temperature standard because they exceeded the temperature criterion of 17.8°C (64.0°F) for salmonid migration and rearing (Table 7.3). However, in December 2003 the new temperature standard was adopted by the Environmental 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 Patterson and Pringle Creeks indicate that these streams exceed the recently adopted numeric criterion.

Rickreall Creek was identified as exceeding the rearing criterion from its confluence with the Willamette upstream to RM 24.9.

Table 7. 3 Middle Willamette Subbasin 303(d) temperature listed stream segments.

Waterbody Name	Listed River Miles	Parameter	Listing Criterion	Season
Patterson Creek	0 to 7.2	Temperature	Rearing: 17.8 C	Summer
Pringle Creek	0 to 6.2	Temperature	Rearing: 17.8 C	Summer
Rickreall Creek	0 to 24.9	Temperature	Rearing: 17.8 C	Summer

Map 7.3 303(d) listed streams for temperature in the Middle 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 Middle 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 Middle 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.

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. This level is 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 7.4 summarizes the modes of cold water fish mortality.

Table 7. 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)

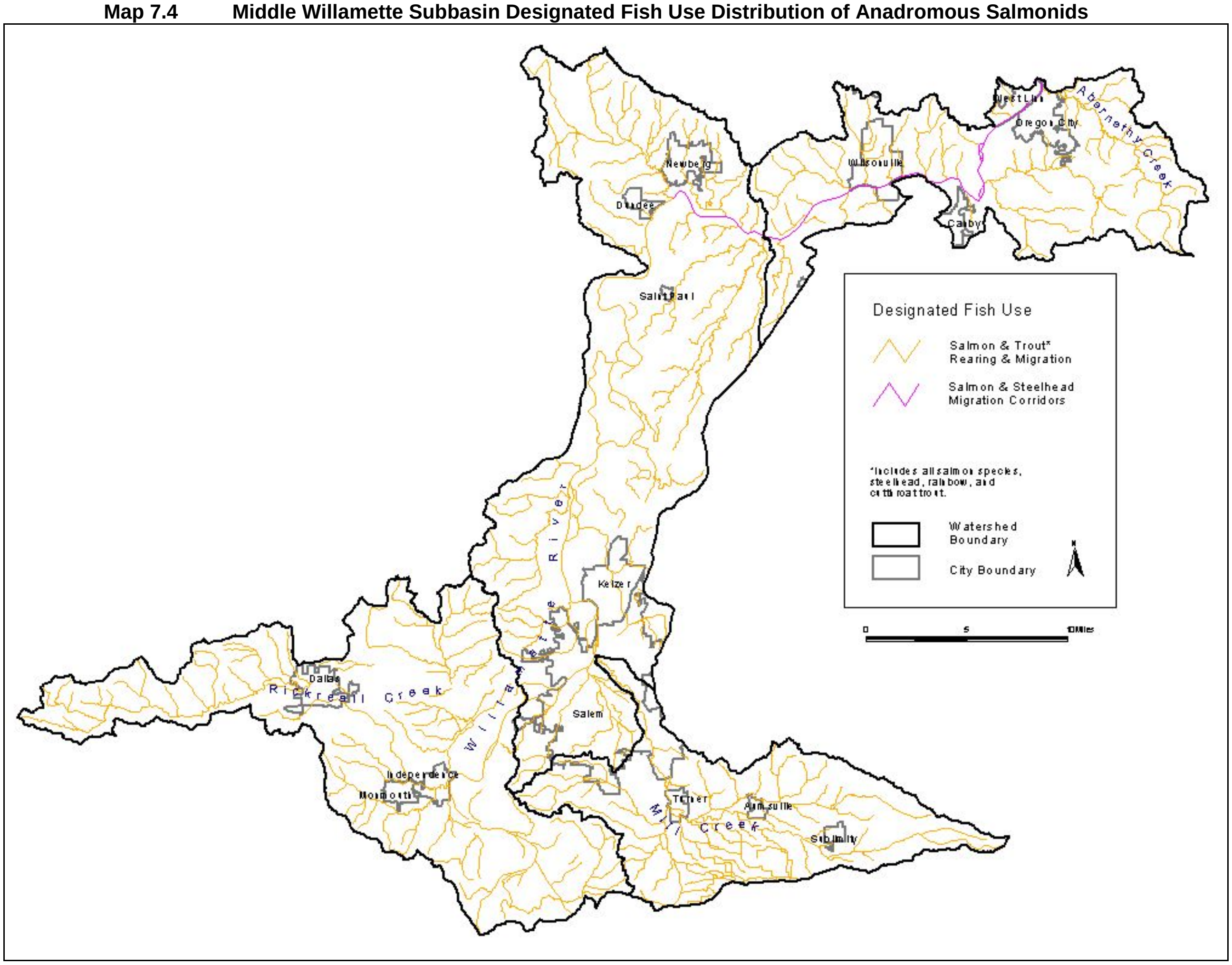
Oregon's water quality criteria for temperature are designed to protect beneficial uses, such as cold-water salmon and trout species, based on specific salmonid life stages. The temperature standard includes both narrative and numeric criteria. Table 7.5 lists the temperature criteria that are applicable to the Middle Willamette Subbasin. Maps 7.4 and 7.5 illustrate designated subbasin fish use and salmonid spawning use. The maps indicate where salmonid spawning through fry emergence criterion, salmonid rearing and migration criterion, and salmonid migration corridor 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 7. 5 Oregon's Biologically Based Temperature Criteria.

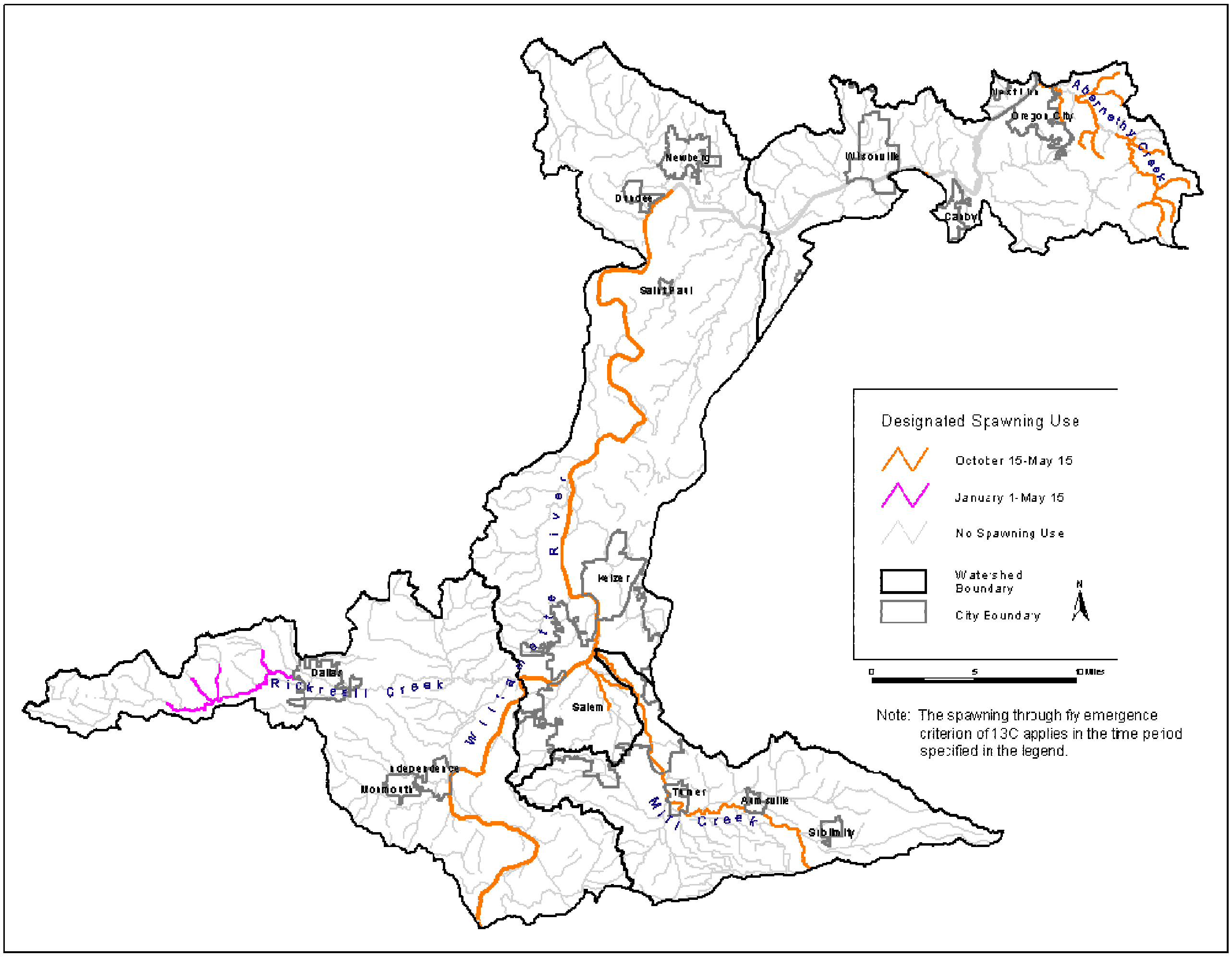
Beneficial Use	Temperature Criteria
Salmon and Steelhead Spawning	∗13.0°C (55.4°F)
Salmon and Trout Rearing and Migration	∗18.0 °C (64.4 °F)
Salmon and Steelhead Migration Corridors	∗20.0 °C (68.0 °F)

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

Map 7.4 Middle Willamette Subbasin Designated Fish Use Distribution of Anadromous Salmonids



Map 7.5 Middle Willamette Subbasin Designated Spawning Use Distribution of Anadromous Salmonids



The narrative criteria that apply to the Middle 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 (0.5 Fahrenheit) above the applicable criteria after complete mixing in the water body, and at the point of maximum impact.

The lower 10.4 miles of Rickreall Creek has been designated as cool-water habitat by ODFW. However, USEPA has not approved the cool water species temperature criteria for the Willamette basin. Thus, the reach from RM 0 to 10.4 has no habitat use designation. This narrative limits the cumulative anthropogenic heating of surface waters to no more than 0.3 ^{o}C (0.5 ^{o}F) above ambient temperature in waters that only support cool water species.

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 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 amount of solar radiation reaching the stream surface.

Riparian vegetation also influences channel morphology. Vegetation supports stream banks during erosive, high flow events and 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. Dam 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. Also, higher volumes correspond to greater stream velocities and shorter 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 down stream temperatures as the heat held by the impounded water is also 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 may be selectively withdrawn at various depths.

Reservoirs are located on both Rickreall Creek and Mill Creek. Mercer Reservoir is an earthen dam with a storage capacity of 47.9 million cubic feet located at RM 25 on Rickreall Creek. During the summer the water released from Mercer Reservoir is used to maintain a minimum stream flow in Rickreall Creek downstream of the City of Dallas. Dallas uses much of the flow for municipal purposes. Franzen Reservoir is a storage reservoir within Salem’s municipal water system. It is covered under the city’s MS4 permit.

Point Sources of Heat

Point source discharges play a limited role in stream heating in the streams of the Middle Willamette Subbasin. There are 27 individual National Pollutant Discharge Elimination System (NPDES) permitted sources in the Middle Willamette Subbasin, 20 discharge directly into the mainstem Willamette River and will be discussed in Chapter 4. The remaining seven individual NPDES point sources include two year-round discharges with a likelihood of increasing heat loading to their receiving streams, Map 7.6 and Table 7.6.

The City of Dallas Sewage Treatment Plant (STP) discharges to Rickreall Creek and the Oregon State Penitentiary discharges treated groundwater to Mill Creek. The four other individual NPDES point sources, Clackamas River Well #1, Aumsville STP, Walling Sand And Gravel, and Industrial Poplar are not considered likely contributors to temperature criteria exceedances because of the timing and characteristics of their discharges. The Norpac Plant #1 in Stayton has discharged wastewater to a pond that was later land applied, and the boiler blow down and non-contact water was discharged to Mill Creek. Currently, the Norpac permit process is currently on hold, however the permit remains open. In addition there are 228 general NPDES permits in the subbasin, mostly consisting of storm water discharges. These also are not considered to have reasonable potential to contribute to exceedances of numeric temperature criteria.

Map 7.6 Middle Willamette Subbasin NPDES Permit Locations. April, 2003.

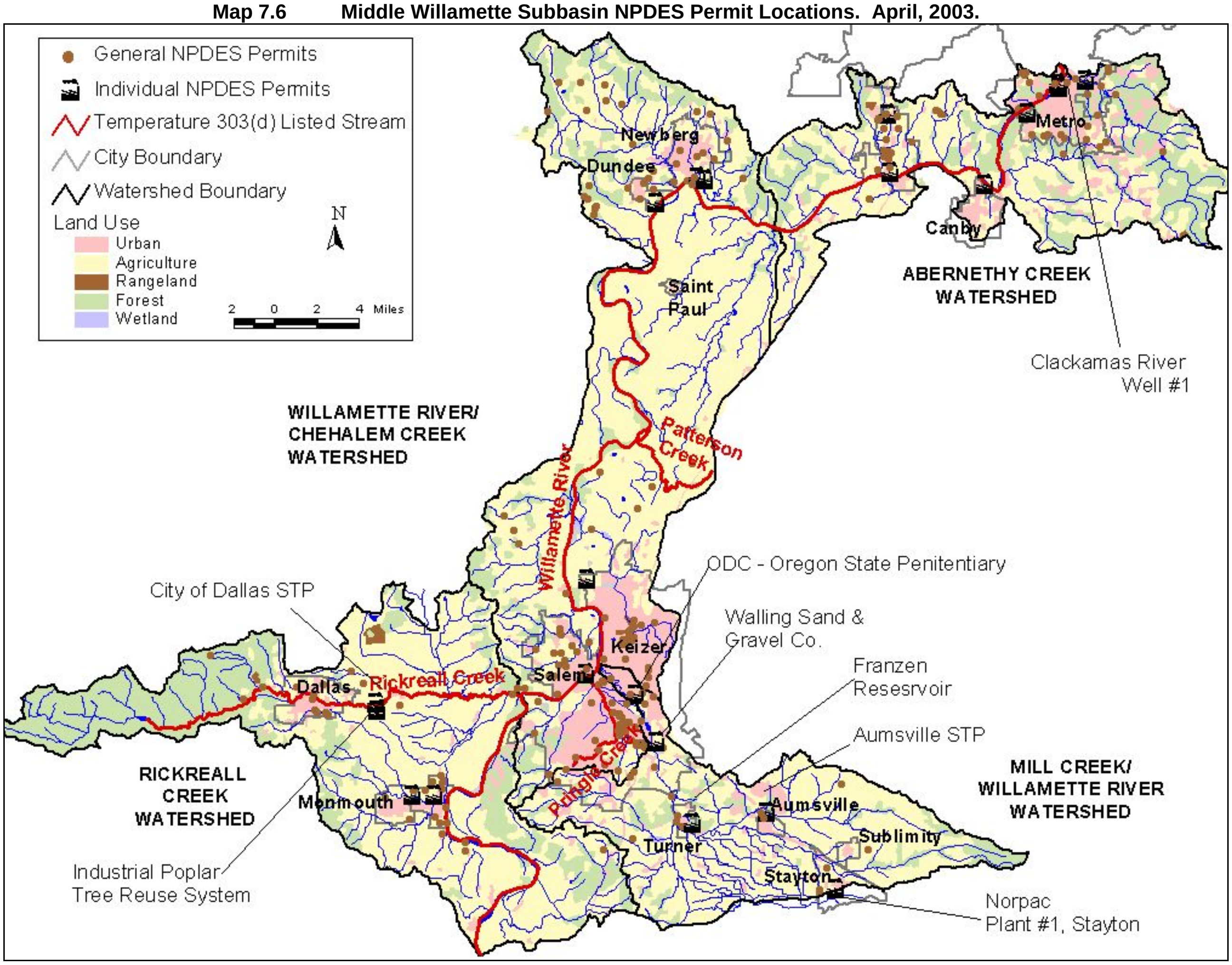


Table 7. 6 Individual NPDES facilities in the Middle Willamette Subbasin that do not discharge to the Willamette River. April, 2003.

Facility Name	Permit Type	Permit Description	Receiving Stream	River Mile	Type of Discharge	Season of Discharge
CLACKAMAS RIVER WELL #1	NPDES-IW-O	Industrial Wastewater; NPDES non-process wastewater NEC; Aquifer Storage and Retrieval (ASR)	Abernethy Creek	1.1	Stored Potable Water	Occasional Year Round
Aumsville STP	NPDES-DOM-Db	Sewage Disposal; NPDES less than 1 MGD with lagoons	Beaver Creek	2.5	Wastewater	F-W-S
WALLING SAND & GRAVEL CO.	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Mill Creek	0.0	Aggregate Process Water	F-W-S
ODC - OREGON STATE PENITENTIARY	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Mill Creek	2.5	Treated Groundwater Cleanup	Year Round
INDUSTRIAL POPLAR TREE REUSE SYSTERM	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Rickreall Creek	10.0	Percolated Wastewater Groundwater Discharge	F-W-S
Dallas STP	NPDES-DOM-C1a	Sewage Disposal; NPDES 5 MGD or more, less than 10 MGD	Rickreall Creek	10.5	Wastewater	Year Round
Norpac - Plant #1, Stayton	NPDES-IW-O	Industrial Wastewater; NPDES non-process wastewater NEC	Mill Creek	18.5	Wastewater	permit currently on hold

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

Clackamas River Water, a private water purveyor, discharges small volumes of water from an aquifer storage and retrieval well that stores treated water during high flows for retrieval during low-flow (summer) periods. Aumsville STP, and Walling Sand and Gravel discharge during the fall-winter-spring period and are not a heat source during the critical low flow period. The Dallas STP has a wastewater reuse system (in addition to its direct discharge to Rickreall Creek) that irrigates poplar trees without discharge to surface waters. The poplar irrigation demonstration is limited in duration. These sources discharge principally during runoff events and are not believed to be significant sources of stream heating.

The City of Dallas STP discharges to Rickreall Creek year round. The current facility design capacity is 2.67 cubic feet per second (cfs) dry weather average daily flow and 18.62 cfs wet weather peak instantaneous flow. In 1997 the City of Dallas applied for an exemption from the State's temperature standard for the STP. This exemption was granted by the Environmental Quality Commission (EQC) stating the following stipulations:

- The discharger will implement all reasonable management practices to mitigate stream warming;
- The discharge will not significantly affect the beneficial uses;

The EQC granted the city the exemption based on the environmental cost of meeting the temperature standard (that is the technology required) outweighed the impact of the higher temperature.

Studies at the time indicated that the lower reaches of Rickreall Creek did not have the water quality or habitat quality to support use of the creek by salmonid species during the low flow summer period. Although steelhead and cutthroat trout spawn and rear in the upper watershed, Oregon Department of Fish and Wildlife advised ODEQ that the lower reaches of Rickreall Creek should be considered a cool water fishery rather than a cold water fishery, however EPA has not approved Oregon's cool water temperature criteria.

As part of the temperature standard exemption and permitting process the Dallas STP is undergoing facility upgrades. After the city completed major plant upgrades and expansion in 2001 most of the raw sewage overflows to Rickreall Creek were eliminated. Facility improvements will be phased in. The city will be developing and implementing alternatives to address heavy metals and ammonia associated with industrial discharge to the Dallas STP (diversion of industrial waste to poplars is one of a number of alternatives under evaluation). Then the city will be involved in developing and implementing alternatives (determined based on performance of the poplar application) that will result in the discharge complying with all water quality standards. The alternatives under consideration may or may not include filters.

Temperature TMDL Approach Summary

Middle 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 ODEQ 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. 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 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 Middle 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 are based on 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 Middle 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. 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(38) 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.

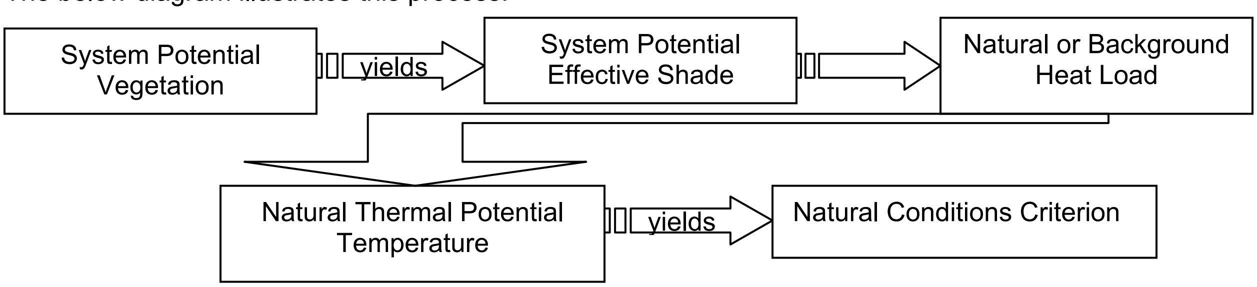
- OAR 340-041-0002(39) states:
  "*Natural Thermal Potential" means the determination of the thermal profile of a water body using best available methods of analysis and the best available information on the site potential riparian vegetation, stream geomorphology, stream flows and other measures to reflect natural conditions.*

Middle 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, see Appendix C. 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.

The below diagram illustrates this process:



Stream temperature analysis discussed in this chapter is limited to stream systems in the Middle 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 Middle 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 7.1). Summer stream temperature data collected by local agencies and watershed councils indicates that the 18.0ºC (64.4ºF) migration and rearing criterion was exceeded in Rickreall, Mill, Patterson, and Pringle creeks (Figure 7.1). Temperatures in Pringle Creek were commonly in the 23.0°-24.0°C (73.4°-75.2°F) range during summer.

Figure 7.1 Temperature Profiles at Rickreall, Mill, Patterson, and Pringle Creeks in the Middle Willamette Subbasin typically exceed the Rearing and Migration Criterion of 18.0ºC starting in June.

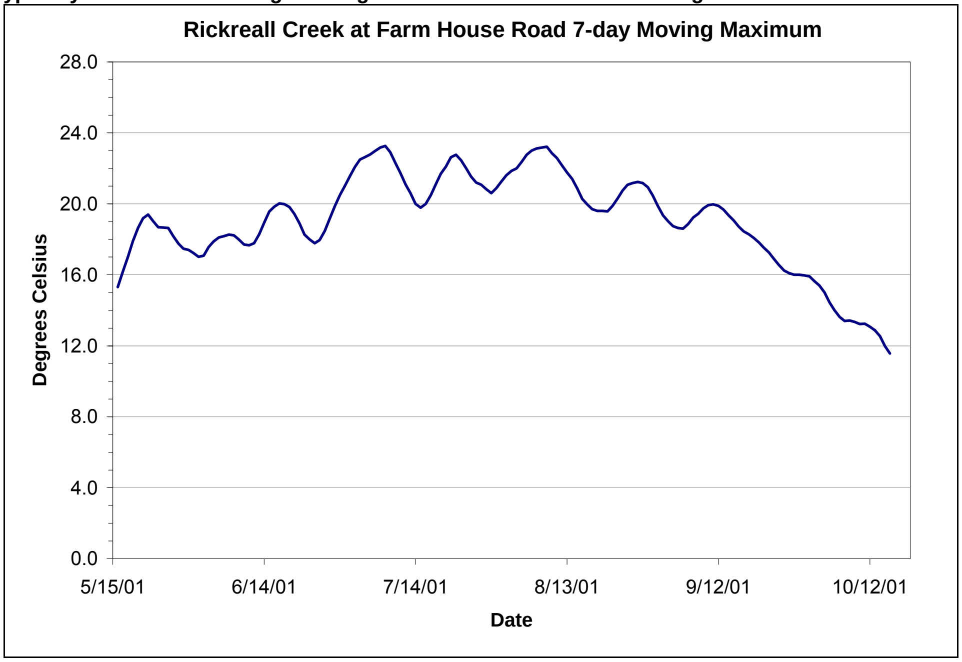
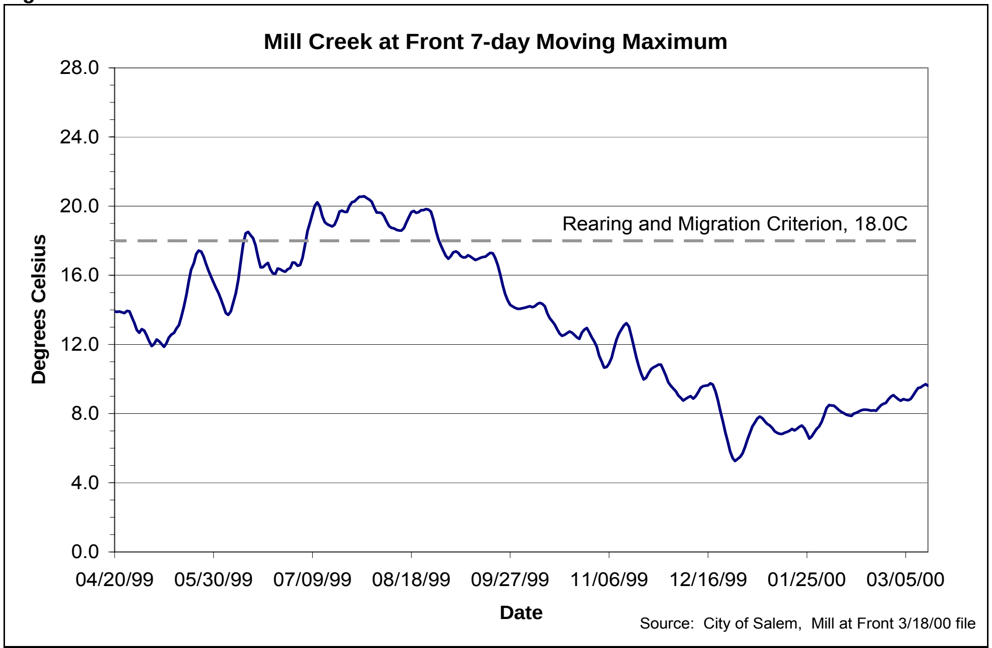


Figure 7.1 continued



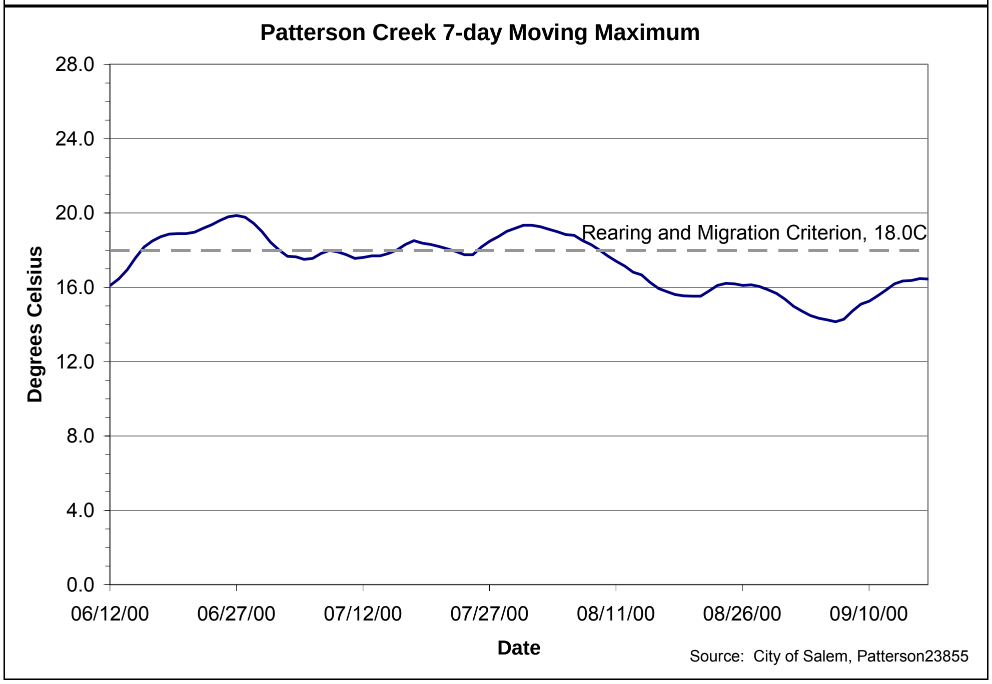
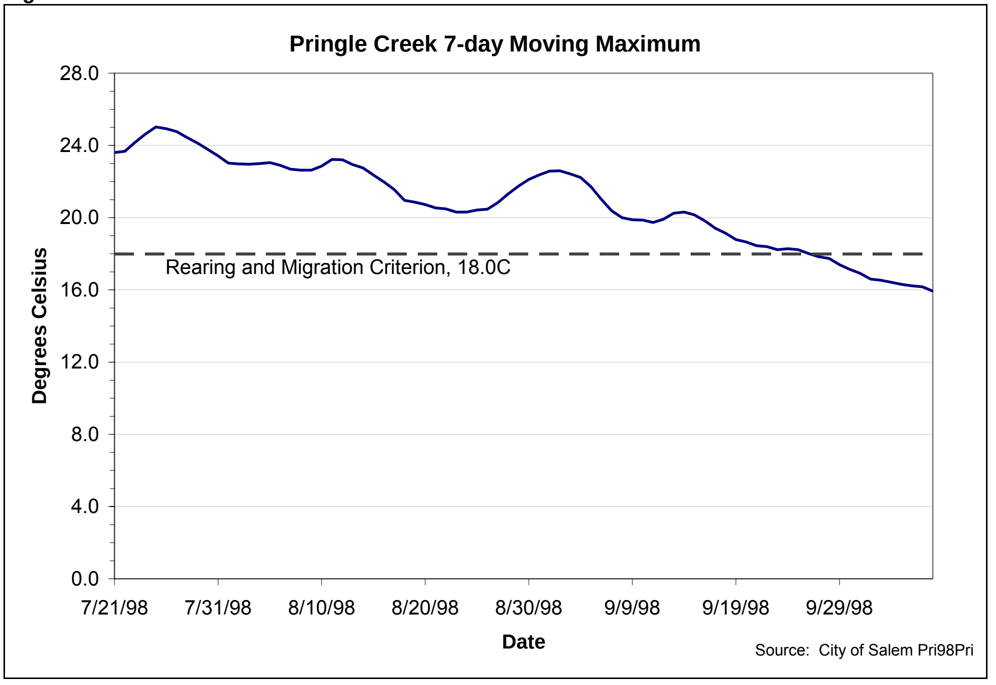


Figure 7.1 continued



Rickreall Creek Watershed

The Rickreall Creek Watershed Assessment (Mattson and Gallagher, 2001) states that riparian areas were wider than today prior to human settlement in the low lying areas of the drainage. Currently these riparian forests of Lower Rickreall Creek are routinely less than 100 feet wide. The assessment report also indicates that losses in riparian vegetation appear to have slowed since the 1930s.

In 2002 ODEQ staff collected information on the condition of channel and riparian corridors at three sites along Rickreall Creek below Mercer reservoir. Shade measurements at these sites ranged from very high levels exceeding 90%, to levels less than 50% effective shade, Table 7.7. These measurements provide an indication of existing riparian vegetation and shade characteristics, Figure 7.2.

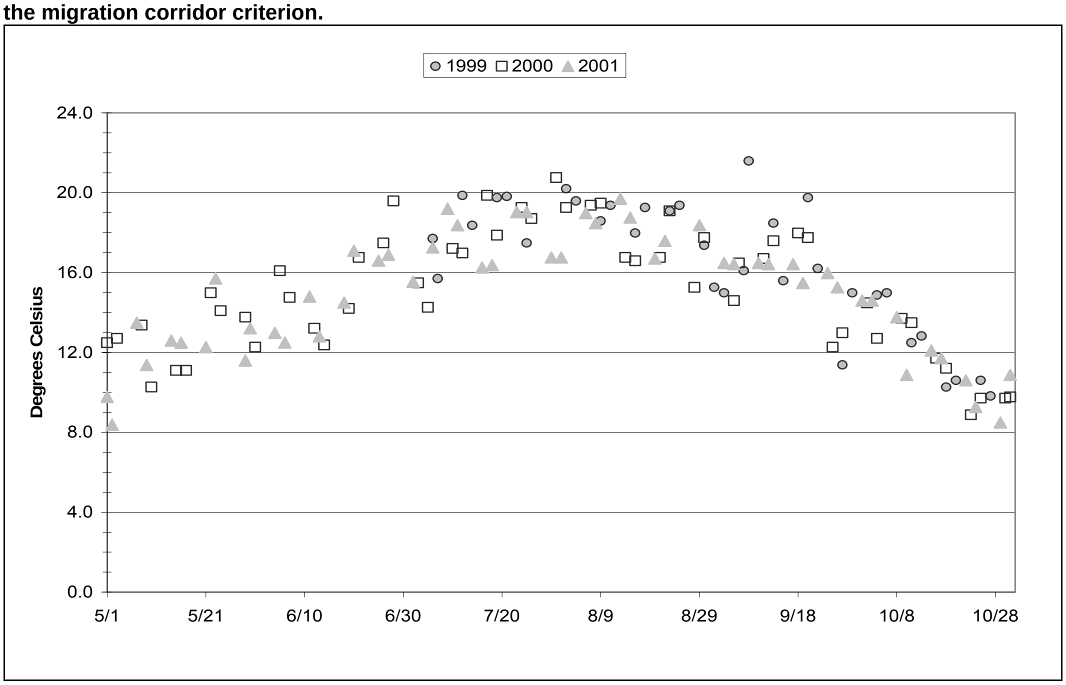
Table 7. 7 Rickreall Creek Riparian Condition Data (DEQ 2002). Blank data cells indicate no data was available.

Site Name	LASAR Number	Active Channel Width (Feet)	Wetted Channel Width (Feet)	Left Buffer Width (Feet)	Right Buffer Width (Feet)	Solar Pathfinder Effective Shade
Rickreall Creek at Ellendale	11191	34	24	100	>150	96%
Rickreall Creek at levens (Dallas)	11105	47	32	50	20	82%
Rickreall Creek at Bowersville Rd (Dallas)	11156	42				44%

Figure 7.2 Rickreall Creek at Levens Rd (left), at Bowersville Rd (right), and Left Bank across from Dallas STP (bottom), ODEQ July, 2002.

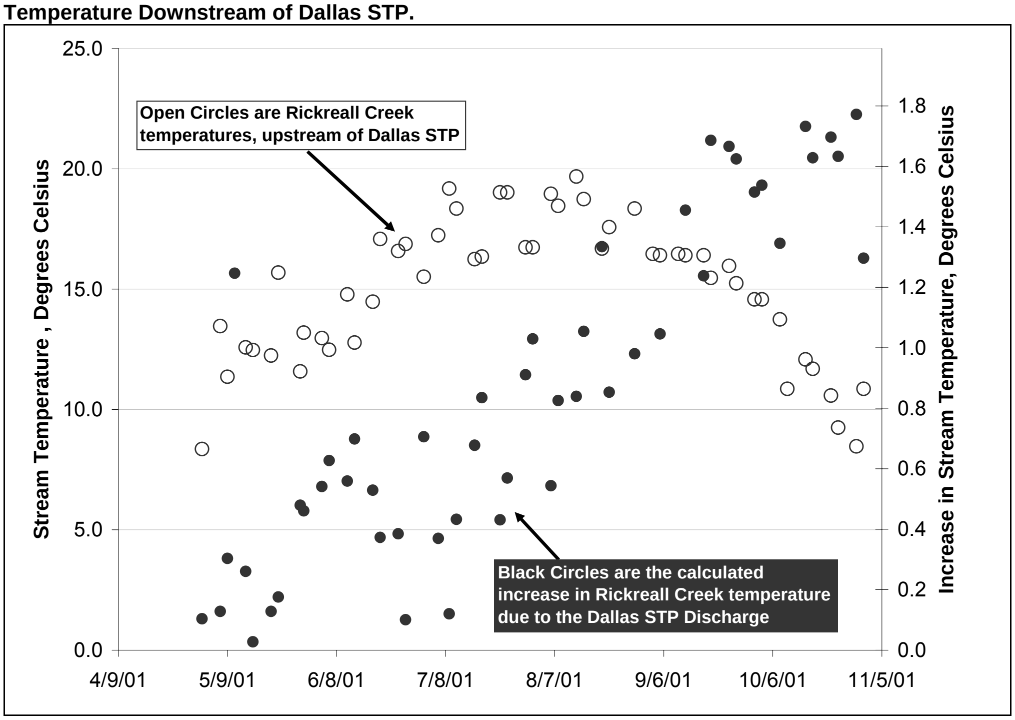
The 1993 Rickreall Creek Water Quality Report states that Rickreall Creek "shows typical afternoon temperatures exceeding 20^{o}C (68^{o}F) for several months during the summer" (ODEQ 1993). Temperature data collected in 1999, 2000, and 2001 indicate that stream temperature improvements have occurred in Rickreall Creek, downstream of Mercer Reservoir (RM 25) and upstream of the City of Dallas STP, rarely exceeded the migration corridor criterion (68°F, 20°C), Figure 7.3. Long term monitoring upstream of the Dallas STP indicates that stream temperatures during 1999, 2000, and 2001 were not from unusually cold or warm years. However, Rickreall Creek temperatures remain elevated downstream of the STP near the mouth at Farm House Road, stream temperatures are above the migration corridor criterion (68°F, 20°C), Figure 7.1.

Figure 7.3 Rickreall Creek Summertime Daily Stream Temperatures, Upstream of Dallas STP, are typically below 20°C, the migration corridor criterion.



Summer temperatures in Rickreall Creek typically begin to cool in September, however effluent discharge temperatures from Dallas STP increase downstream Rickreall Creek temperatures up to 1.8ºC (3.2ºF) even in November when upstream temperatures are 9ºC (48.2ºF), Figure 7.4.

Figure 7.4 Rickreall Creek Summer Stream Temperatures Upstream of Dallas STP, and Increase in Stream Temperature Downstream of Dallas STP.



Pringle Creek Watershed

The 2002 Pringle Creek watershed assessment, completed for the Greater Salem-Keizer Area Watershed Councils, provided a shade index for several Salem area streams, Table 7.8. The assessment relied on interpretation of aerial photographs taken in the 10 years prior to the assessment. While not the exact methodology that ODEQ uses to derive effective shade values, the index provides an indication of streamside vegetation condition and distribution along Pringle Creek. Stream shading index categories are included in the table below.

Table 7. 8 Shade Index for Salem Area Streams (Hemesath, and Nunez; 2002).

Indicator	Shade	Category
Stream surface not visible, Slightly visible, or visible in patches	>70%	High
Stream surface visible, but banks not visible	40-70%	Medium
Stream surface visible, banks visible or visible at times	<40%	Low

Approximately 27 stream miles within the Pringle Creek Watershed were assessed and categorized for shade, Table 7.9. Over 50% of Pringle Creek or its tributaries were included in the low shade category. About one quarter of the stream miles in Pringle Creek drainage were assessed as high shade. Shade levels in Pringle Creek were below average compared with some of its tributary streams categorized using the same assessment procedures, Table 7.9 and Figure 7.5. ODEQ staff also collected channel and riparian information in Pringle Creek in 2002. Shade levels ranged from over 90% at Madrona Road and Church Street sites to almost zero at Shelton Ditch, Table 7.10.

Table 7. 9 Percent of Stream Miles Categorized into Low, Medium and High Shade Cover (Hemesath, et.al; 2002).

Creek Name	Shade			Unclassified (%)	Stream Miles Classified	Total open stream miles
	High (%)	Medium (%)	Low (%)			
Pringle	28	16	52	4	27	28
Glenn-Gibson	55	10	25	10	28	31
Claggett	25	13	43	19	21	26
Mill	28	11	16	45	174	316

Table 7. 10 Pringle Creek Watershed Riparian Condition Data (ODEQ, 2002).

Site Name	LASAR Number	Active Channel Width (Feet)	Wetted Channel Width (Feet)	Wetted Depth (Feet)	Left Buffer Width (Feet)	Right Buffer Width (Feet)	Shade (%)
Pringle Creek at Pringle Road	28736	10	7	0.4	30	23	80
Clark Creek at Ratcliff	28965	5	2.5	0.3	7	15	36
Pringle Creek at Madrona Road	28967	17	5	0.5	20	35	92
Pringle Creek above Clark Cr.	28966		14	0.6	90	90	87
Pringle Creek at Church Street	10655	18	17	0.8	20	>100	91
Shelton Ditch at Church Street	28737	60	57	1.7	25	40	2

Figure 7.5 Representative Images of Sites in the Pringle Creek Watershed: Pringle Creek, LASAR # 28734 , ODEQ April, 2002 (left); Clark Creek at Ratcliff, ODEQ July, 2002 (right); Shelton Ditch at Church Street, LASAR # 28737, ODEQ July, 2002 (bottom).

Patterson Creek

The Patterson Creek drainage basin is 3.6 square miles (2,296 acres) of mostly agricultural land. ODEQ biomonitoring staff assessed a 525 feet (160 meter) length of Patterson Creek on July 31, 2000. This stream site was approximately 8 miles south west of Woodburn in Marion County. This site on Patterson Creek (Figure 7.6) was randomly selected as part of the Oregon Plan for Salmon and Watersheds regional stream condition assessment monitoring. The photo in Figure 7.6 shows complete coverage of Patterson Creek's surface water by a mix of macrophytes and algae. The site was among a larger set of stations selected to represent smaller streams throughout western Oregon and not as an evaluation of Patterson Creek. The data collected at Patterson Creek included stream habitat and riparian measurements, biological samples, water chemistry sampling and continuous water temperature. With the exception of temperature and water chemistry, all measurements are reach averages collected at regularly spaced transects along the survey reach.

The creek provides irrigation water for the surrounding agricultural lands, to include retention structures. The riparian vegetation in Patterson Creek is dominated by tall grass and blackberry, specifically non-native species including reed canary grass and Himalayan blackberry, with some bald cypress and bamboo. Riparian canopy is present along 14% of the reach with an average canopy density of 7.5% and height of a minimum 16.4 feet (5 meters). Larger canopy trees defined as having a diameter at breast height (dbh)of a minimum 1 foot (0.3 m dbh) were scarce, comprising less than 3% of the reach. Stream channel effective shade was 52% at mid channel and 88% at the stream banks, measured with a spherical densitometer. The stream channel in the survey reach had a mean width of 11 feet (3.3 meters) and mean depth of 1.5 feet (45 centimeters). The in-stream habitat is identified as 100% pools, including two deep, human made-pools or wetlands. The stream substrate is 65% sand or smaller (< 2mm diameter).

Figure 7.6 Patterson Creek, LASAR # 23855, ODEQ July, 2000. The photo shows complete coverage of stream surface with a mix macrophytes and algae.

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 standards. 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 (0.5°F) 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 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 standards 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 Middle 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 water bodies other than the Willamette River in the Middle Willamette Subbasin. Point sources that discharge directly to the Willamette River have been considered as part of Chapter 4.

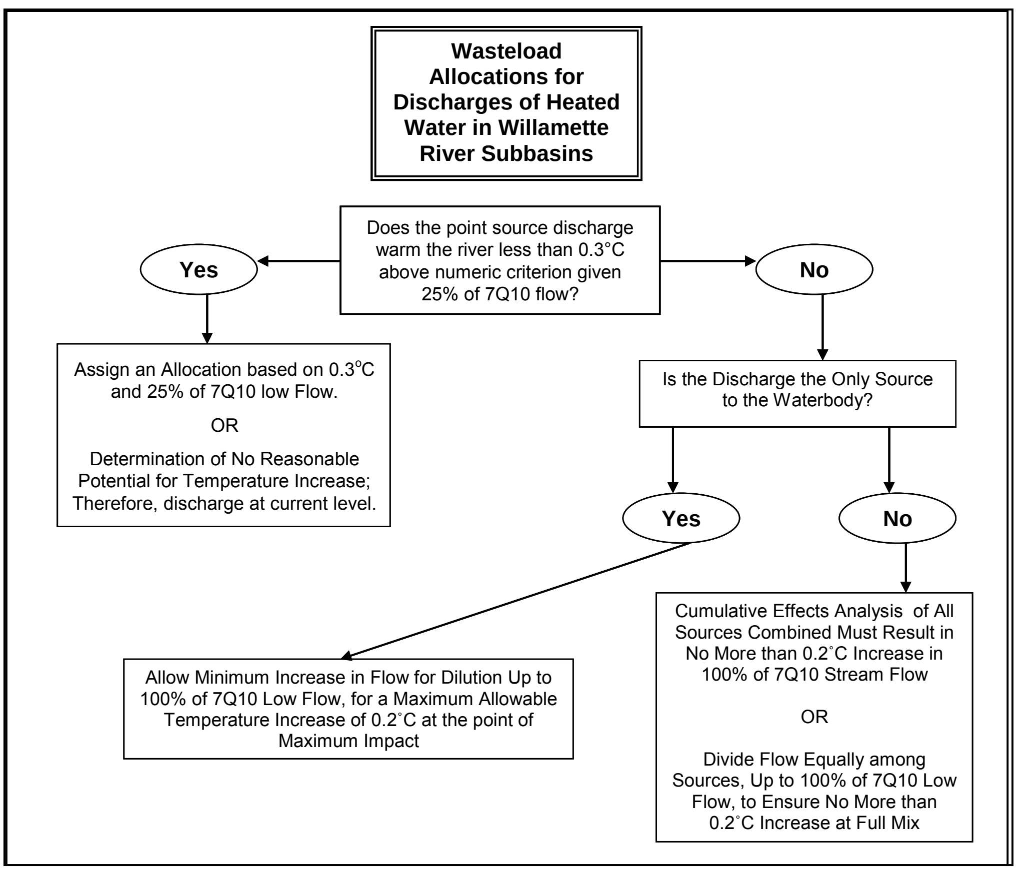
Waste Load Allocations in Small Streams

Discharges were screened to determine which would likely receive a wasteload allocation based on the type of discharge, and the volume and temperature of 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 increase in 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 Q_{ZOD} 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:

where: $$H_{PS} = (Q_{ZOD} + Q_{PS}) \frac{1 \cdot ft^3}{1 \cdot sec} \cdot \frac{1 \cdot m^3}{35.31 \cdot ft^3} \cdot \frac{1000 \cdot kg}{1 \cdot m^3} \cdot \frac{86400 \cdot sec}{1 \cdot day} \cdot \Delta T_{ZOD} \cdot c = \frac{Kcal}{day}$$

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°C allowable (°C)
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 (°C)
T_{WLA}: Maximum allowable point source effluent temperature (° C)
ΔT_{ZOD}: Change in river temperature at point of discharge - 0.3°C allowable (°C)
Q_{ZOD}: River flow volume allowed for mixing- ¼ of 7Q10 low flow statistic (cfs)
Q_{PS}: Point source effluent discharge flow volume (cfs)

No waste load allocations were developed in this TMDL as they are unnecessary to demonstrate attainment of water quality standards in impaired streams because they were found to not discharge during the critical period. The only discharges to consider for wasteload allocations are the Oregon State Penitentiary and the City of Dallas STP. The Oregon State Penitentiary discharges treated groundwater to Mill Creek at approximately 13.9˚C (57˚F). Given the usual 25% of the receiving water flow for mixing, the increase in temperature from the discharge approached but never exceeded the allowable 0.3˚C (0.54˚F) in May and October, owing to a spawning use designation for part of these months. The discharge would likely cool the receiving stream slightly during the remainder of the summer. Given there are no other sources to Mill Creek with a reasonable potential to cause temperature increases, the Oregon State Penitentiary has no reasonable potential to increase temperature in Mill Creek. No wasteload allocation was appropriate.

The City of Dallas discharges treated effluent to Rickreall Creek. The Environmental Quality Commission, based upon information provided by the Oregon Department of Fish and Wildlife, determined that Rickreall Creek was not salmon habitat and designated its use as “cool water.” However, the cool water criteria was not approved by USEPA. Although there is no numeric criterion for cool water habitat in Oregon's Administrative Rules, the criteria was written to have no increases greater than 0.3˚C (0.54˚F) above ambient temperatures. Assuming a critical condition ambient temperature of 21.1˚C (70˚F), the current discharge would not cause an increase of 0.3˚C (0.54˚F). However, anadromous salmonid fish-use upstream of this reach suggests an allocation be based on the salmonid migration corridor criterion, 20°C (68°F). This change in fish-use designation may be made in the future to the lower portion of Rickreall Creek and potentially cause the City of Dallas to have a wasteload allocation for temperature. Future allocations will be developed as described above.

Future waste load allocations will be developed for all permitted sources that discharge heated waste water to subbasin waters using Equations 1 and 2 (above). Waste load allocations for existing and future thermal point sources will ensure that the sum of waste load and load allocations result in an increase in stream temperature of no greater than 0.3°C above the applicable criteria after complete mixing and at the point of maximum impact. Pollutant trading opportunities may be available to new or existing point sources in order to offset temperature impacts.

Load Allocations

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

Load Allocations are portions of the loading capacity divided among natural, current anthropogenic, and future anthropogenic nonpoint pollutant sources. 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.

System Potential vegetation was developed to simulate a natural stream system with non-anthropogenic, natural disturbance incorporated into the riparian vegetation distribution and attributes within each geomorphic unit, see Appendix C for a detailed description. 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:

- Wind Throw
- Fire
- Insect Infestation
- Flood

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 in 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 determine the shade characteristics of the near-stream plant community.

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

It is expected that effective shade values would increase if stream channel widths decreased and riparian vegetation increased. Decreasing channel widths would increase the effectiveness of the system potential vegetation to shade the stream and in effect decrease in-stream temperatures, and also decrease the width-to-depth ratio of the stream.

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 the City of Salem indicates that there is inadequate shade throughout the Middle Willamette Subbasin. ODEQ data also suggest shade levels are less than system potential in the several Middle Willamette Subbasin creeks. Excess heat loading occurs wherever inadequate shade levels are widespread.

Surrogate Measures

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

The Middle 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 7.7, is the distance from the edge of right bank vegetation to the edge of left bank vegetation.

Figure 7.7 The Channel width and wetted 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 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 “Basis for Potential Near-Stream Land Cover for Willamette Basin TMDL Determination”, Attachment D. A shade curve has been developed for each geomorphic and upland forest unit in the Middle Willamette Subbasin, Map 7.7 to Map 7.11.

The relative areas of the geomorphic classifications of the Middle Willamette Subbasin are presented in Table 7.11. Despite the relatively fine scale of the geomorphic classifications, the differences among the various shade curves are subtle in some cases.

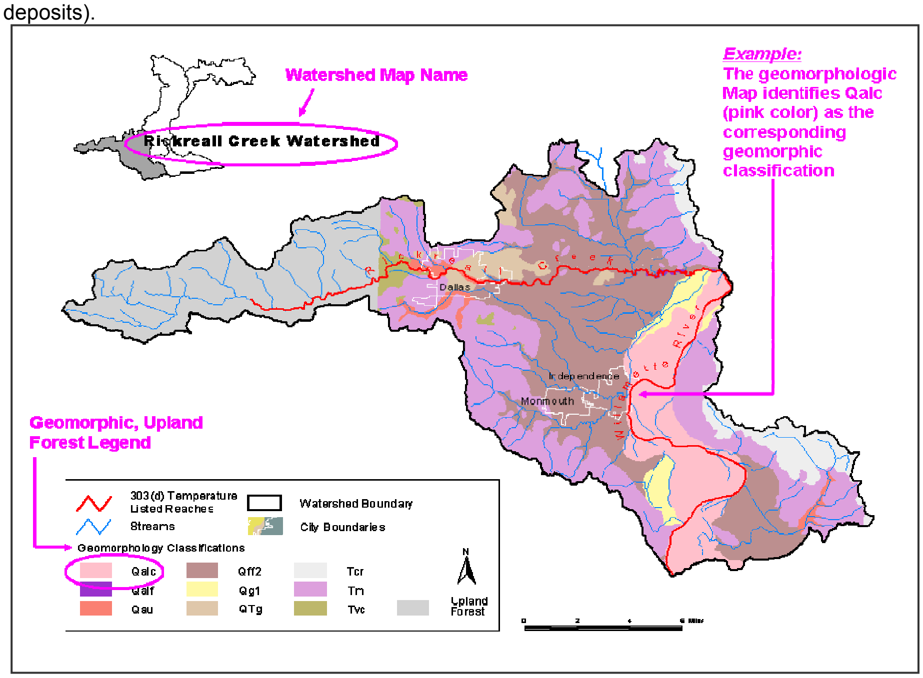
Table 7. 11 Area of Geomorphic Units in Middle Willamette Subbasin. Values are ranked in order of increasing area.

Geomorphic Unit	Acres	Square Miles	Relative Area (%)
Tertiary Volcanics Coast Range (Tvc)	1,493	2	0.3
Quaternary fine-grained flood deposits (Qff1)	3,024	5	0.7
Undifferentiated Quaternary Alluvium (Qau)	4,529	7	1
Quaternary coarse flood deposits (Qfc)	5,295	8	1
Fine-grained quaternary alluvium (Qalf)	5,873	9	1
Quaternary terrace gravels (QTg)	6,489	10	1
Quaternary Troutdale Formation (QTt)	11,134	17	2
Western Cascades tertiary volcanics (Tvw)	11,738	18	3
Quaternary Boring Lava (Qtb)	20,245	32	4
Post Flood Quaternary sand/gravel (Qg1)	24,197	38	5
Upland Forests (Uf)	29,560	46	6
Tertiary Marine sedimentary rock (Tm)	55,892	87	12
Quaternary alluvium floodplain deposits (Qalc)	59,576	93	13
Tertiary Columbia River Basalt (Tcr)	87,467	137	19
Quaternary fine-grained Flood deposits (Qff2)	133,132	208	29
Total	**459,645**	**718**	**100%**

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 Creek watershed, in the City of Independence along a tributary to 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).



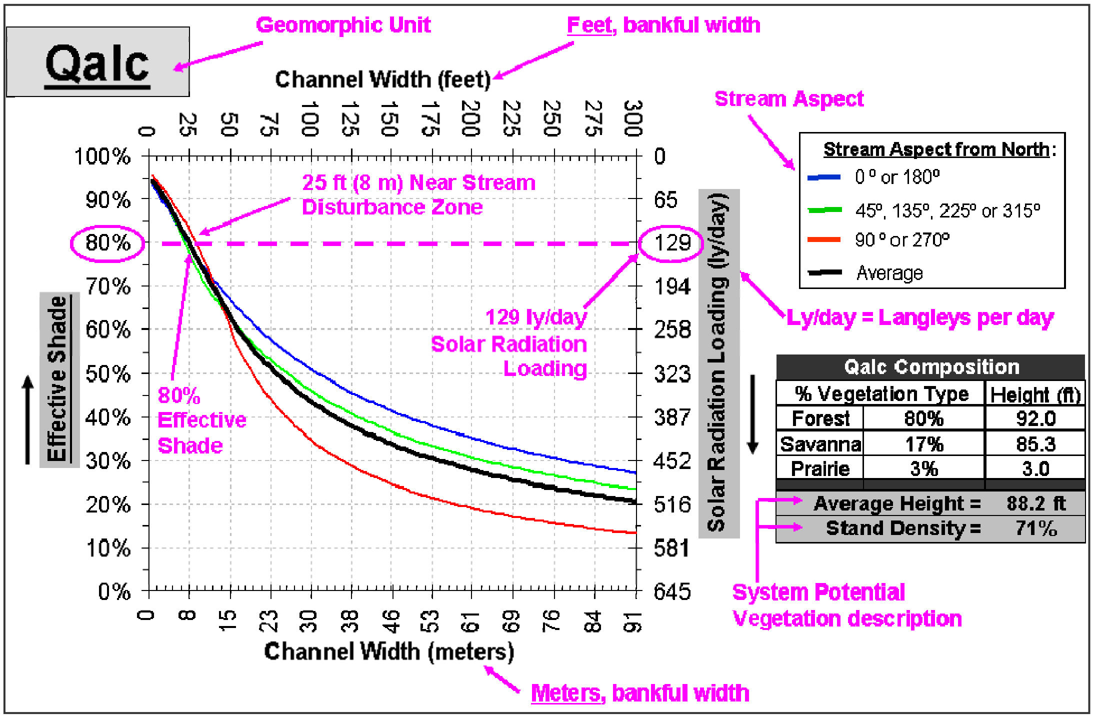
2. Determine the stream aspect from north.

Example: Based on your location on the west bank of the tributary stream 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 Willamette River width is 25 feet.

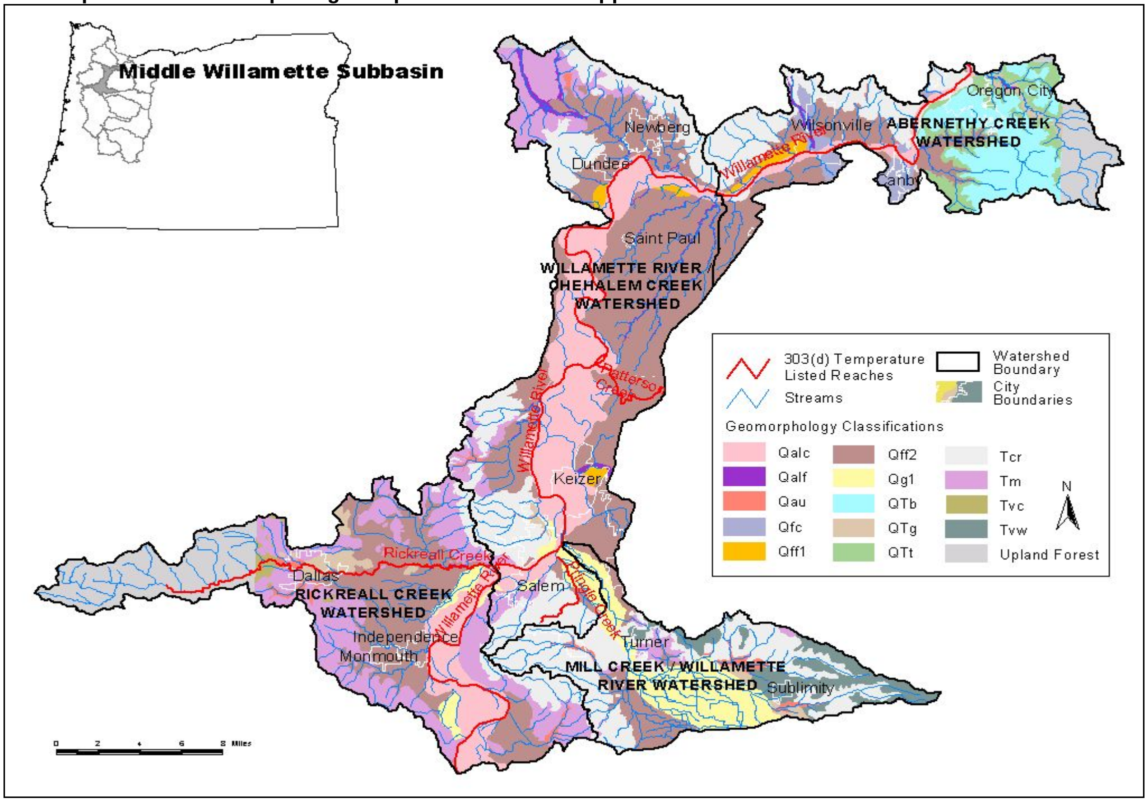
4. Using the appropriate geomorphic or upland forest Shade Curve, using the appropriate stream aspect line and channel width (x-axis), read the y-axis to determine the percent effective shade and solar radiation loading. This is the non-point source load allocation of the stream reach at system potential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



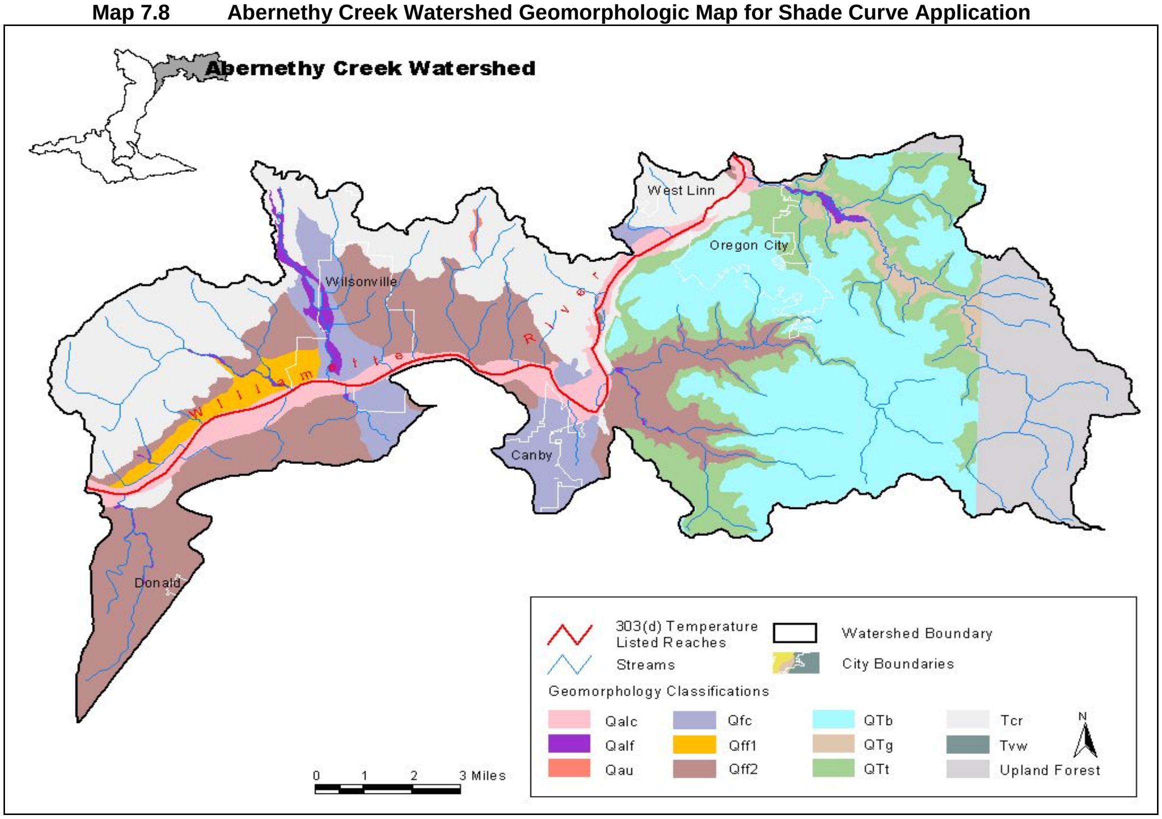
Example: A tributary to the Willamette River on the west bank near Independence with a stream aspect from north of 0º or 180º (blue line) and a channel width of 25 feet: using the blue line to determine the loading capacity from the x-axis identify the 25 feet (8 m) mark and read the y-axis, the solar 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.

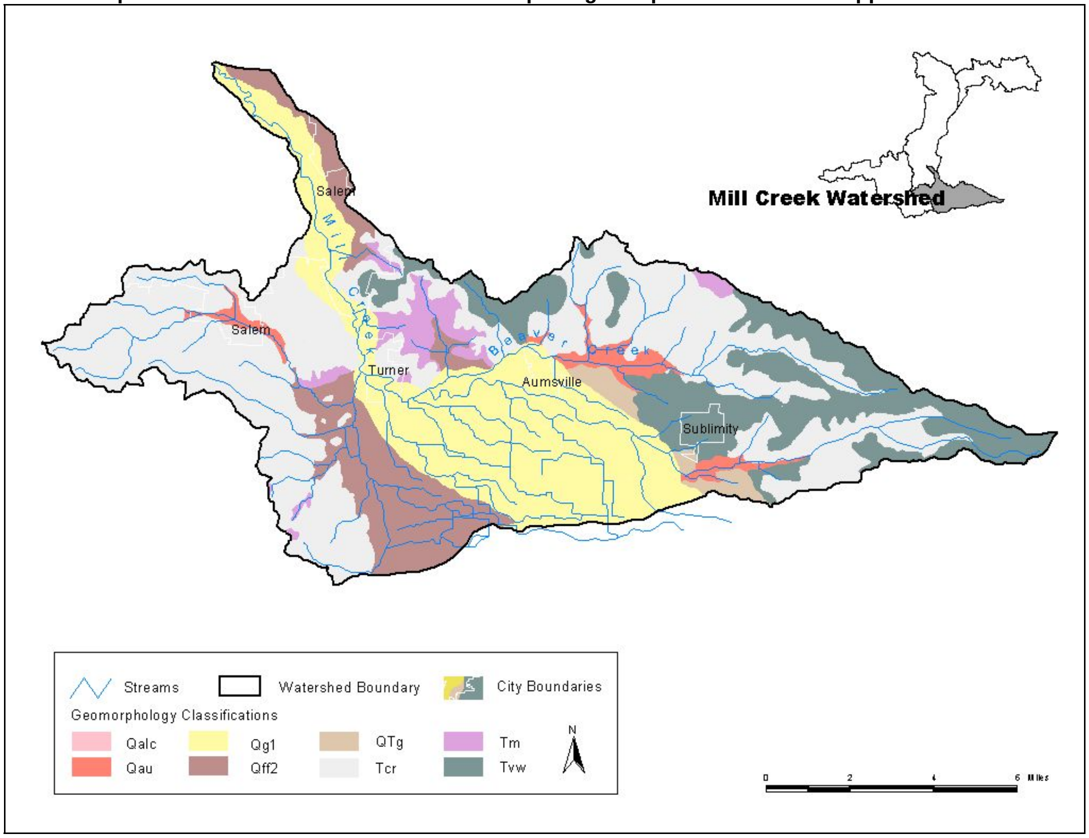
Map 7.7 Geomorphologic Map for Shade Curve Application in the Middle Willamette Subbasin.



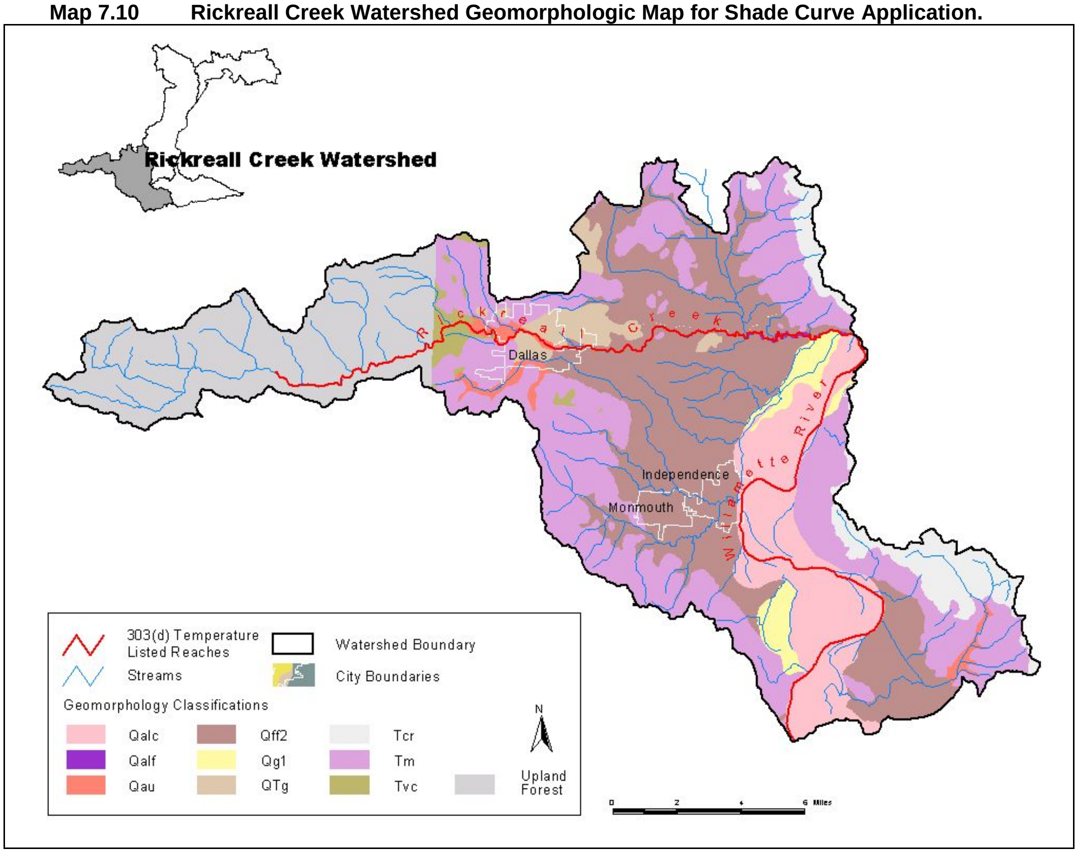
Map 7.8 Abernethy Creek Watershed Geomorphologic Map for Shade Curve Application



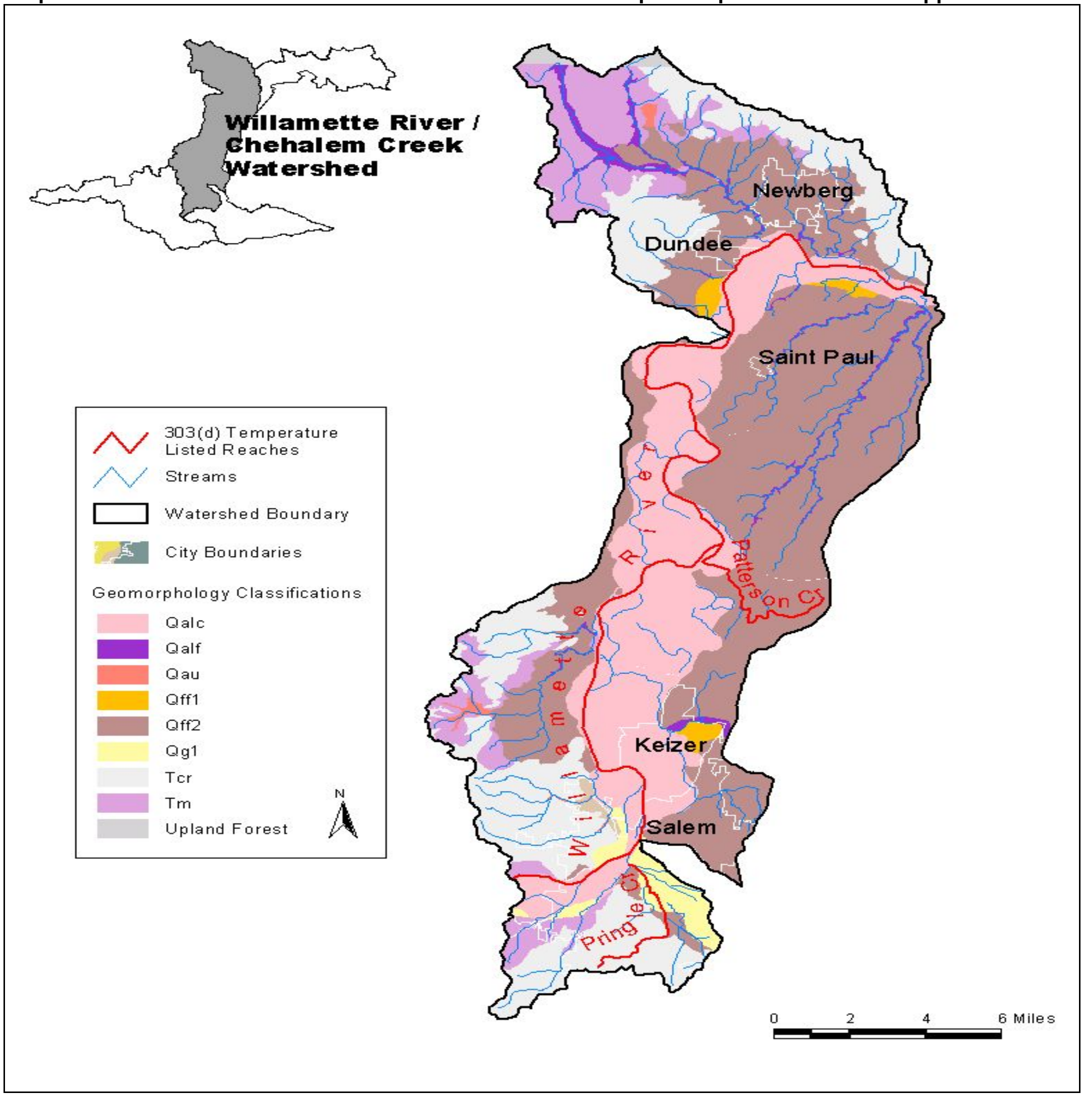
Map 7.9 Mill Creek Watershed Geomorphologic Map for Shade Curve Application.



Map 7.10 Rickreall Creek Watershed Geomorphologic Map for Shade Curve Application.

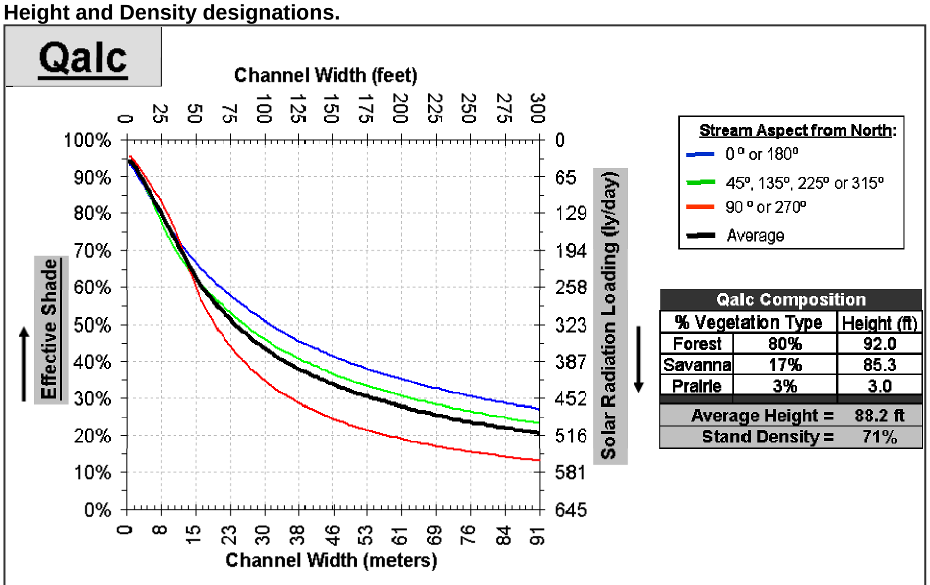


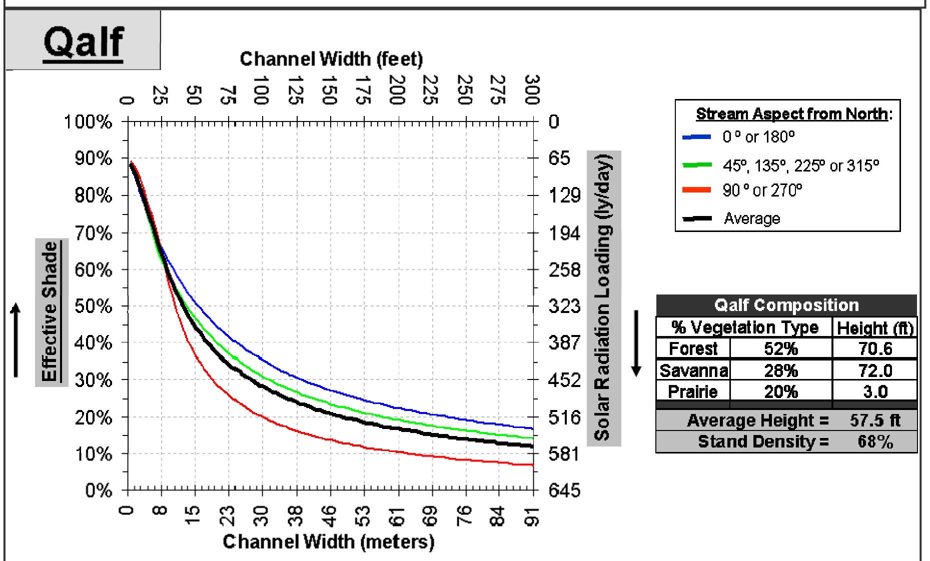
Map 7.11 Willamette / Chehalem River Watershed Geomorphic Map for Shade Curve Application.



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 7.8 apply to all water bodies in the Middle Willamette Subbasin based on the geomorphic and upland forest unit of the reach. The 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, measuring the streams channel width, and then depending on the streams aspect from north reading the appropriate shade curve in Figure 7.8 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 7.11 titled “Area of Geomorphic Units in the Middle Willamette Subbasin”, above.

Figure 7.8 Shade Curves by Geomorphic Classifications that apply to the Middle Willamette Subbasin with vegetation Height and Density designations.





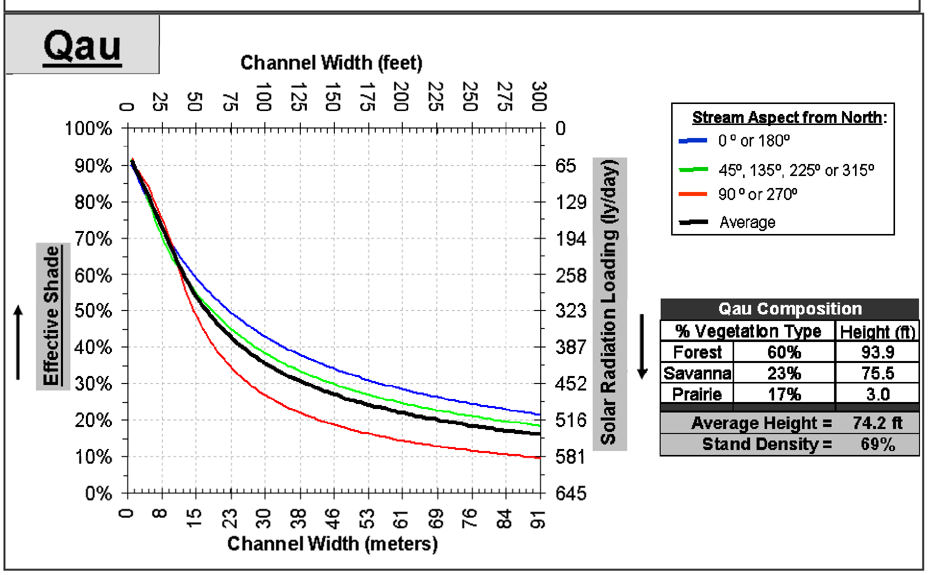
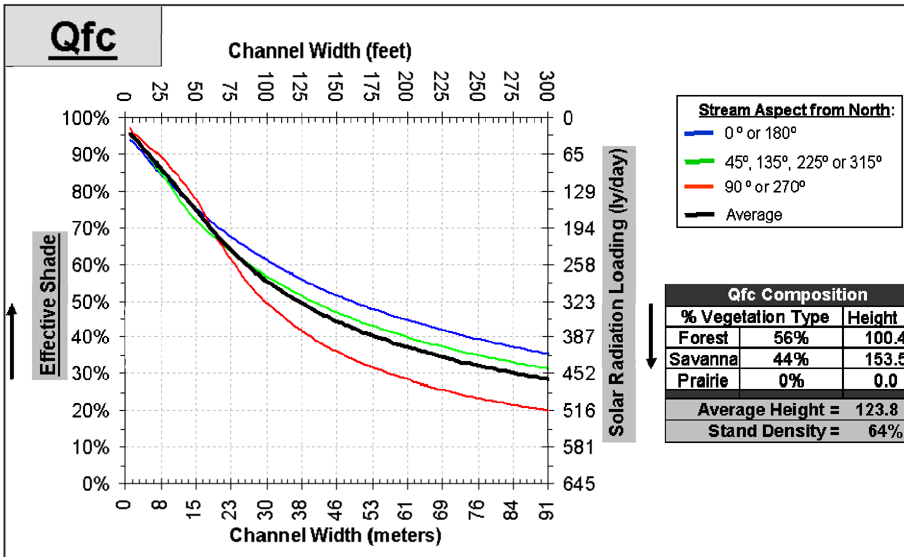
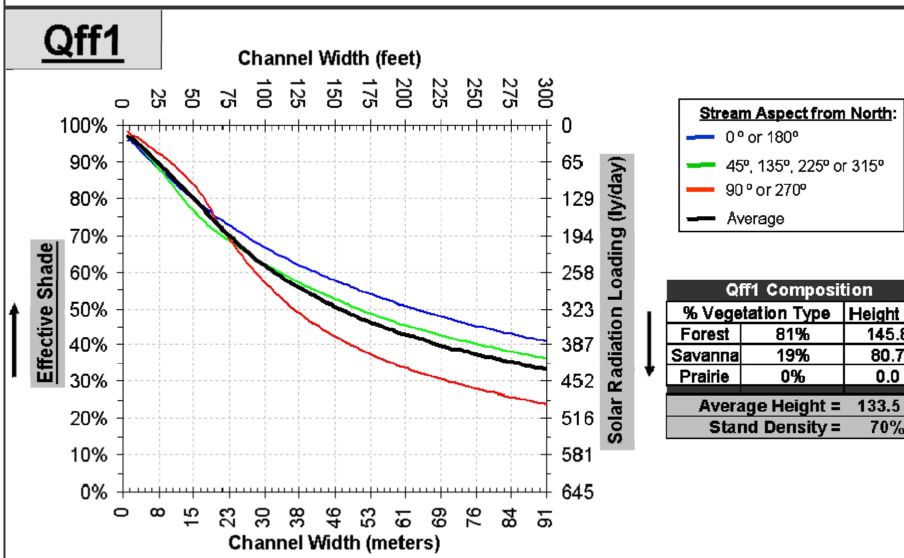


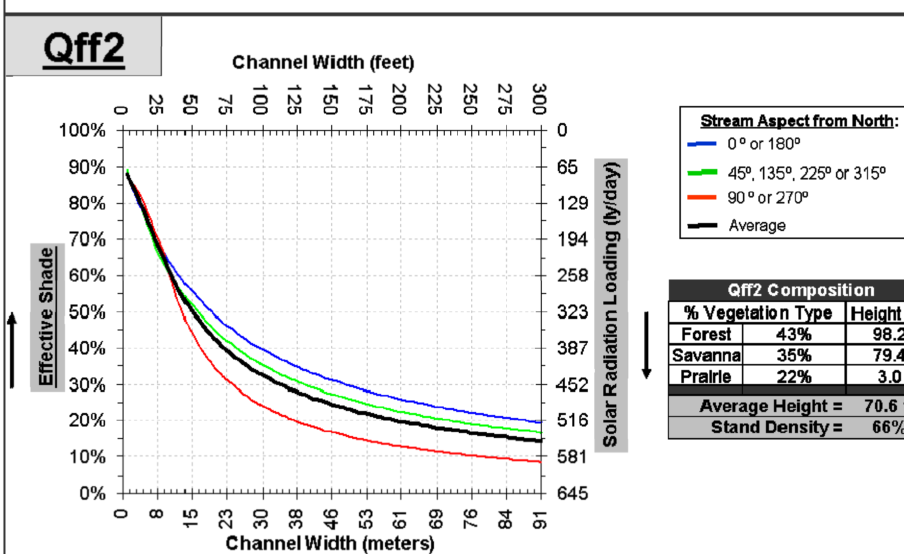
Figure 7.8. (Continued) Shade Curves by Geomorphic Classifications that apply to the Middle Willamette Subbasin with vegetation Height and Density designations.



Qfc Composition		
% Vegetation Type		Height (ft)
Forest	56%	100.4
Savanna	44%	153.5
Prairie	0%	0.0
Average Height =		123.8 ft
Stand Density =		64%

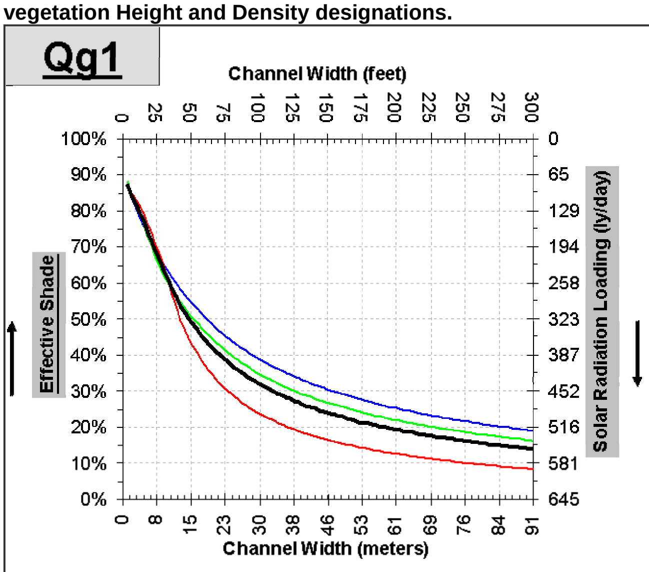


Qff1 Composition		
% Vegetation Type		Height (ft)
Forest	81%	145.8
Savanna	19%	80.7
Prairie	0%	0.0
Average Height =		133.5 ft
Stand Density =		70%

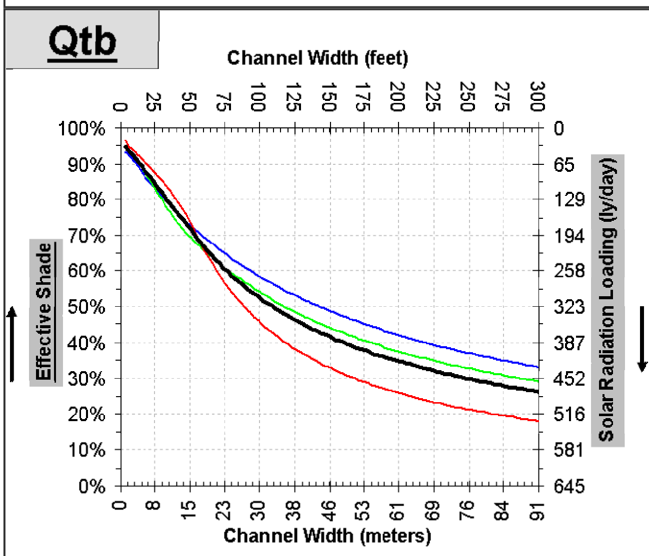


Qff2 Composition		
% Vegetation Type		Height (ft)
Forest	43%	98.2
Savanna	35%	79.4
Prairie	22%	3.0
Average Height =		70.6 ft
Stand Density =		66%

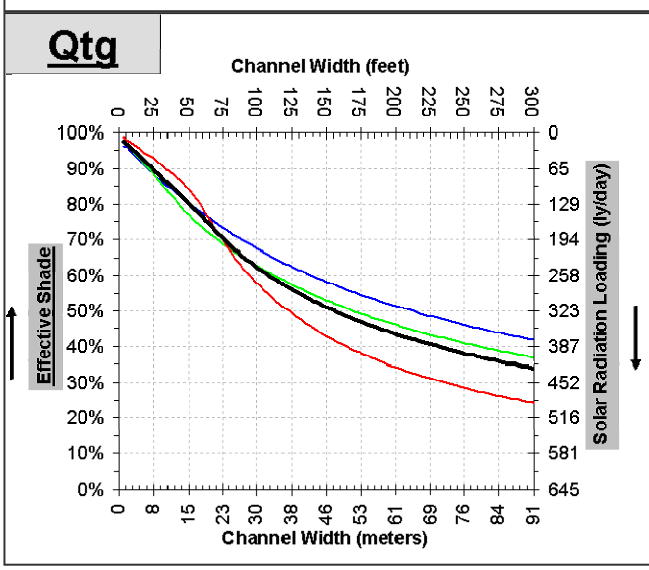
Figure 7.8. (Continued) Shade Curves by Geomorphic Classifications that apply to the Middle Willamette Subbasin with vegetation Height and Density designations.



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%

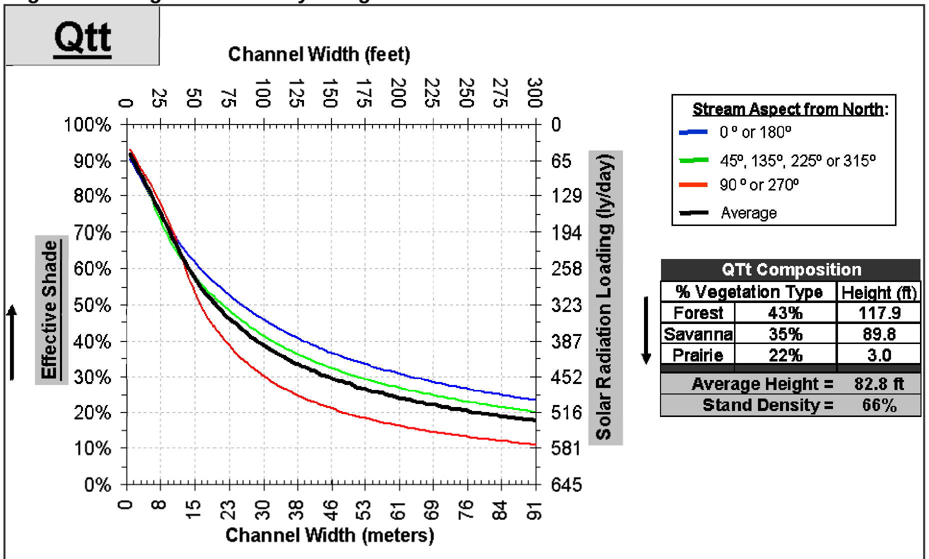


QTb Composition		
% Vegetation Type		Height (ft)
Forest	51%	132.0
Savanna	44%	109.3
Prairie	5%	3.0
Average Height =		115.6 ft
Stand Density =		64%

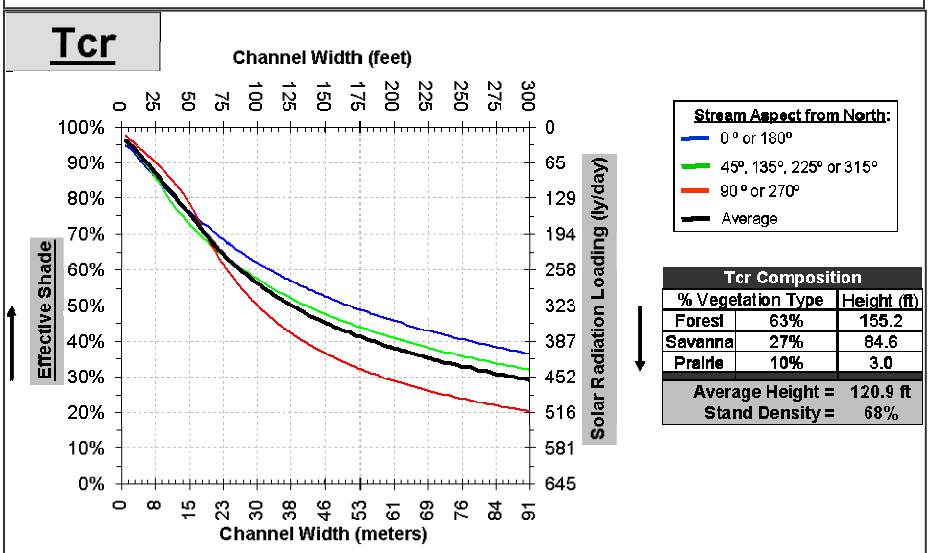


Qtg Composition		
% Vegetation Type		Height (ft)
Forest	77%	156.3
Savanna	14%	87.6
Prairie	9%	3.0
Average Height =		132.9 ft
Stand Density =		72%

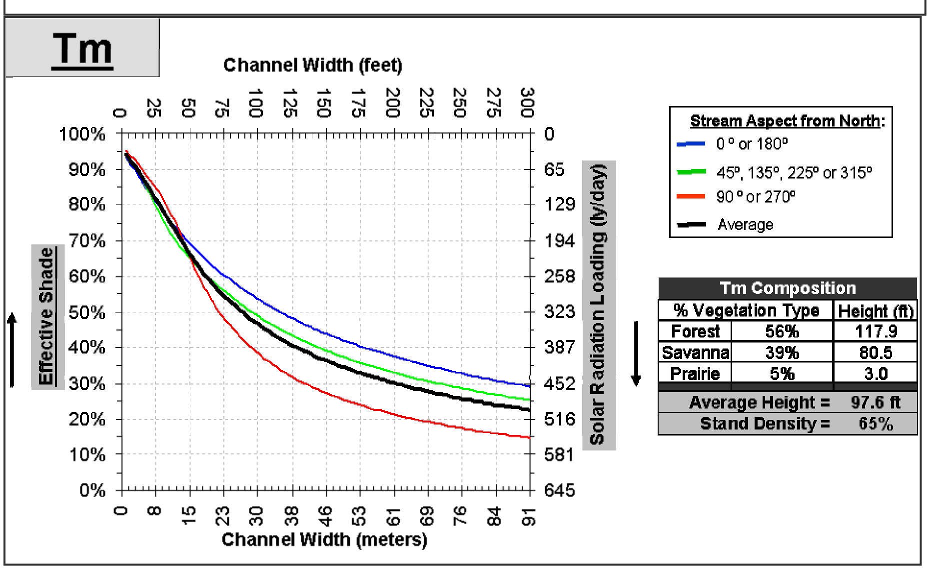
Figure 7.8. (Continued) Shade Curves by Geomorphic Classifications that apply to the Middle Willamette Subbasin with vegetation Height and Density designations.



QTt Composition		
% Vegetation Type		Height (ft)
Forest	43%	117.9
Savanna	35%	89.8
Prairie	22%	3.0
Average Height =		82.8 ft
Stand Density =		66%

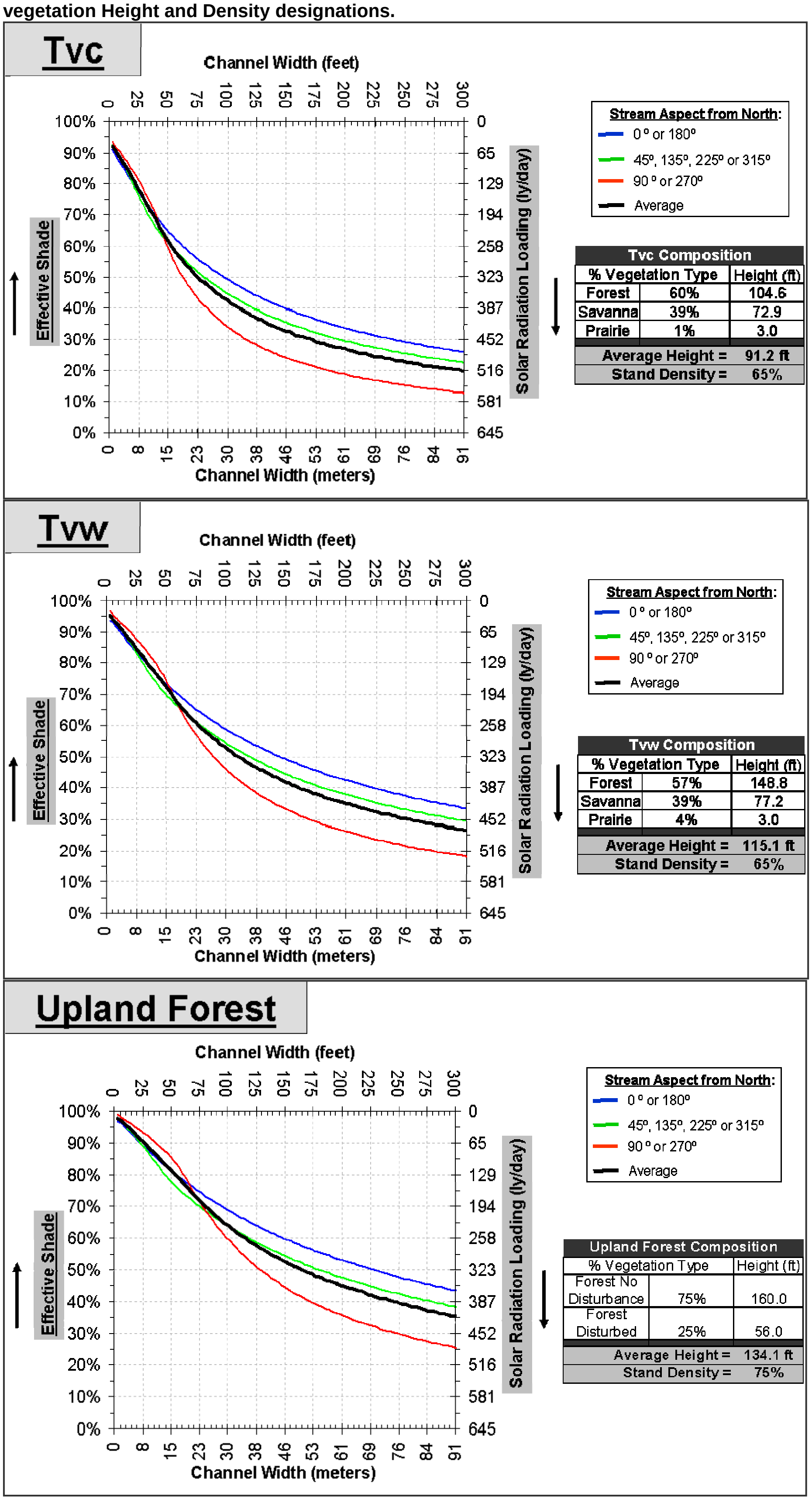


Tcr Composition		
% Vegetation Type		Height (ft)
Forest	63%	155.2
Savanna	27%	84.6
Prairie	10%	3.0
Average Height =		120.9 ft
Stand Density =		68%



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%

Figure 7.8. (Continued) Shade Curves by Geomorphic Classifications that apply to the Middle Willamette Subbasin with vegetation Height and Density designations.



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 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 7.12 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 standards 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 7. 12 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(4)(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 water body, 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. These latter 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 water body by more than 0.3°C (0.54°F) at the point of maximum impact.

In those 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.

MIDDLE WILLAMETTE BACTERIA TMDL

The bacteria TMDL for the Middle Willamette Subbasin has been developed for tributaries to the Willamette River within hydrologic unit 17090007, specifically for the Mill Creek Watershed, Pringle Creek Watershed (Pringle and Clark Creeks) and Bashaw Creek Watershed. Required TMDL components as per OAR 340-042-0040 are listed in Table 7.13.

Table 7. 13 Middle Willamette Subbasin Bacteria TMDL Components.

Name & Location of Waterbodies **OAR 340-042-0040(4)(a)**	Waterbodies within the Middle Willamette Subbasin, Hydrologic Unit Code (HUC) 170900701, 170900702, 170900703, and 170900704.
Pollutant Identification **OAR 340-042-0040(4)(b)**	*Pollutants:* Human pathogens from various sources. *E. coli* is currently used as an indicator of human pathogens to protect recreational contact. Prior to 1996, fecal coliform bacteria were used as an indicator of human pathogens.
Beneficial Uses **OAR 340-042-0040(4)(c)**	Water contact recreation is the most sensitive beneficial use to bacteria pollution in the Middle 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)***	OAR 340, Division 41 provides numeric and narrative bacteria criteria: (1) Numeric Criteria: 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)***	*Loading Capacity:* 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. Excess Load: The difference between the actual pollutant load and the loading capacity of a waterbody. *Wasteload Allocations (Point Sources)*: Wasteload allocations applicable to municipal stormwater permits are expressed as a percent reduction necessary to meet the numeric criteria. *Load Allocations (Nonpoint Sources):* 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)***	*Translates Nonpoint Source Load Allocations* 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)***	*Margins of Safety* 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)**	Future sources will be required to meet water quality criteria prior to discharge.
Water Quality Management Plan **OAR 340-042-0040(4)(l)** ***CWA §303(d)(1)***	The Water Quality Management Plan , Chapter 14,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.

Waterbodies Listed for Bacteria

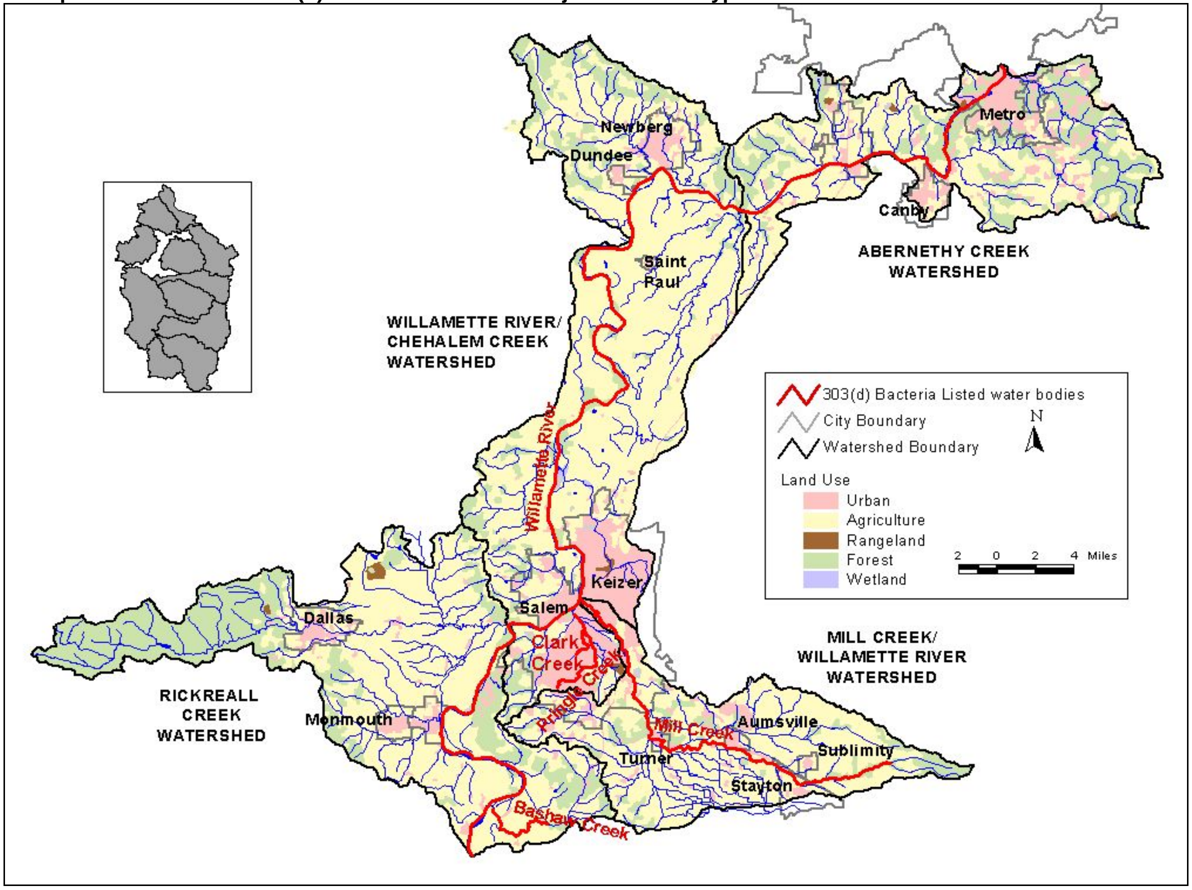
OAR 340-042-0040(4)(a)

Bashaw Creek, Clark Creek, Mill Creek, Pringle Creek, and the Willamette River (RM 26.6 to 108) are listed on Oregon's 303(d) List for exceeding water quality criteria for bacteria (Table 7.14 and Map 7.12). The land use map below identifies the major land use, rather than the secondary classification such as suburban or rural. The bacteria 303(d) listings apply year round except for the Willamette River, which is listed for the Fall-Winter-Spring period. 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 7. 14 Middle Willamette Subbasin 1998 303(d) Bacteria Listings.

Waterbody Name	Listed Reaches	Parameter	Season	Criteria
Bashaw Creek	Mouth to headwaters	Fecal Coliform	Year Round	Log mean of 200, No more than 10% > 400
Clark Creek	Mouth to headwaters	*E. coli*	Year Round	Log mean of 126 organisms per 100 ml, no single sample >406
Mill Creek	Mouth to headwaters	Fecal Coliform	Year Round	Log mean of 200, No more than 10% > 400
Pringle Creek	Mouth to headwaters	*E. coli*	Year Round	Log mean of 126 organisms per 100 ml, no single sample >406

Map 7.12 Bacteria 303(d) Listed Streams and Major Land Use Types in the Middle Willamette Subbasin.



Pollutant Identification

OAR 340-042-0040(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 Middle Willamette Subbasin.

Beneficial Use Identification

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

The most sensitive beneficial use to bacteria in the Middle 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. Therefore, 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 7.15 presents the bacteria criteria that are applicable to the Middle Willamette Subbasin.

Table 7. 15 Prior and current bacteria criteria applicable in the Middle Willamette Subbasin.

Beneficial Use	Bacteria Criteria
Water Contact Recreation	<u>Prior to July 1995:</u> • a log 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. <u>Prior to January 1996</u>: • a log 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. **<u>Effective January 1996 to present</u>: 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 Middle Willamette Subbasin. Urban areas are limited in the subbasin, with the cities of Salem, Turner, Aumsville, Stayton, and Sublimity. Rural residential areas are ubiquitous 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 Middle 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 shortened 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 are “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, with unknown failure rates.

Agricultural Runoff

The primary source of bacteria in agricultural runoff is animal waste. Livestock wastes from animals in confinement areas are 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 Middle 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 Middle 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 (Dannelle Aleshire, Marion County Sanitarian, personal communication). 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 of the four watersheds, 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 20 individual NPDES permittees in the subbasin that discharge directly to the Willamette River and are included as sources in Chapter 2 of this document. However, there are eight domestic and industrial permittees that discharge to tributaries in the Middle Willamette Subbasin (Table 7.16). Of these individual NPDES permitted facilities, only the City of Aumsville and the City of Dallas have Sewage Treatment Plants (STPs) that discharge wastewater likely to contain significant amounts of bacteria.

Table 7. 16 Individual NPDES Permits in the Middle Willamette Subbasin, that do not discharge to the Willamette River.

Facility Name	Permit Type	Permit Description	Receiving Stream	River Mile
CLACKAMAS RIVER WELL #1	NPDES-IW-O	Industrial Wastewater; NPDES non-process wastewater NEC	Abernathy Creek	1.1
Aumsville STP	NPDES-DOM-Db	Sewage - less than 1 MGD with lagoons	Beaver Creek	2.5
WALLING SAND & GRAVEL CO.	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Mill Creek	0.0
ODC - OREGON STATE PENITENTIARY	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Mill Creek	2.5
FRANZEN RESERVOIR	NPDES-IW-O	Industrial Wastewater; NPDES non-process wastewater NEC	Mill Creek	10.5
NORPAC - PLANT #1, STAYTON	NPDES-IW-O	Industrial Wastewater; NPDES non-process wastewater NEC	Mill Creek	18.5
INDUSTRIAL POPLAR TREE REUSE SYSTERM	NPDES-IW-N	Industrial Wastewater; NPDES process wastewater NEC	Rickreall Creek	10.0
Dallas STP	NPDES-DOM-C1a	Sewage Disposal; NPDES 5 MGD or more, less than 10 MGD	Rickreall Creek	10.5

There are also 228 general NPDES permits in the subbasin that discharge to tributaries. 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 46 Confined Animal Feeding Operations (CAFOs) distributed throughout the Middle Willamette Subbasin, with the majority located in the Willamette River / Chehalem Creek Watershed. CAFOs are facilities that feed animals in confinement for specified periods of time prior to selling the animals. There are 32 dairies, four feed lots, five swine lots, one horse lot, and three unidentified CAFO facilities in the subbasin.

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**.

The City of Salem, Marion County, and Polk County have Municipal Separate Storm Sewers (MS4) NPDES permits that address stormwater runoff from urban areas.

Bacteria TMDL Analytical Methods Overview

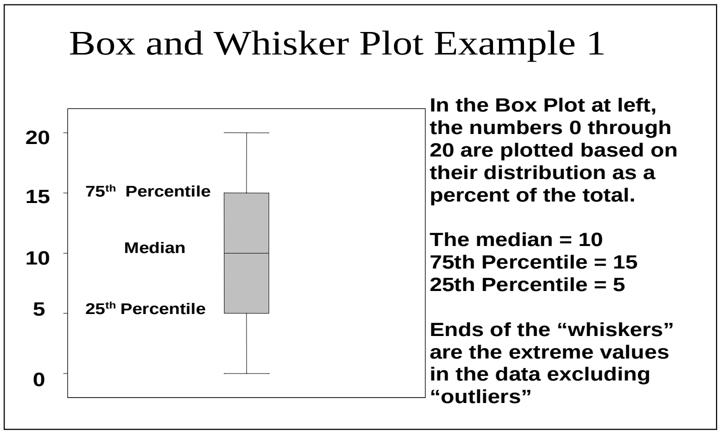
Streams in the Middle Willamette Subbasin that have been listed under section 303(d) due to bacteria contamination are primarily located near Salem. ODEQ developed the Middle Willamette Subbasin Bacteria TMDL for Mill Creek, Pringle Creek, Clark Creek, and Bashaw Creek using *E coli* data collected by the ODEQ and the City of Salem. 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). Even though the City of Salem has collected *E. coli* data on a monthly basis since the 1980's only data collected during 1996 to 2003 were analyzed for this TMDL.

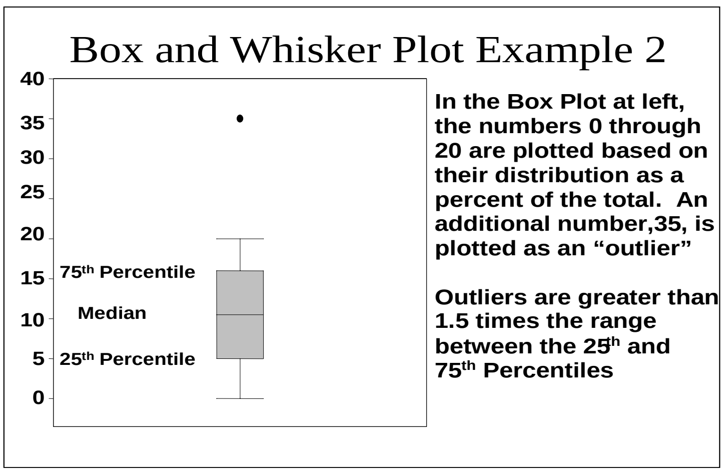
A seasonal analysis approach was applied for two reasons; because of the seasonal variability of the sources of bacteria and because of the seasonal operation of the inflow diversions from the North Santiam River to Mill Creek. The *E. coli* data were assessed:

- year-round,
- seasonally for Summer (July 1 – September 30), and
- seasonally for Fall-Winter-Spring (October 1 – June 30).

The bacteria data were then 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 7.9 shows two examples of box-and-whisker plots and how to interpret their data distribution.

Figure 7.9 **Two Box and Whisker Plot Examples.**





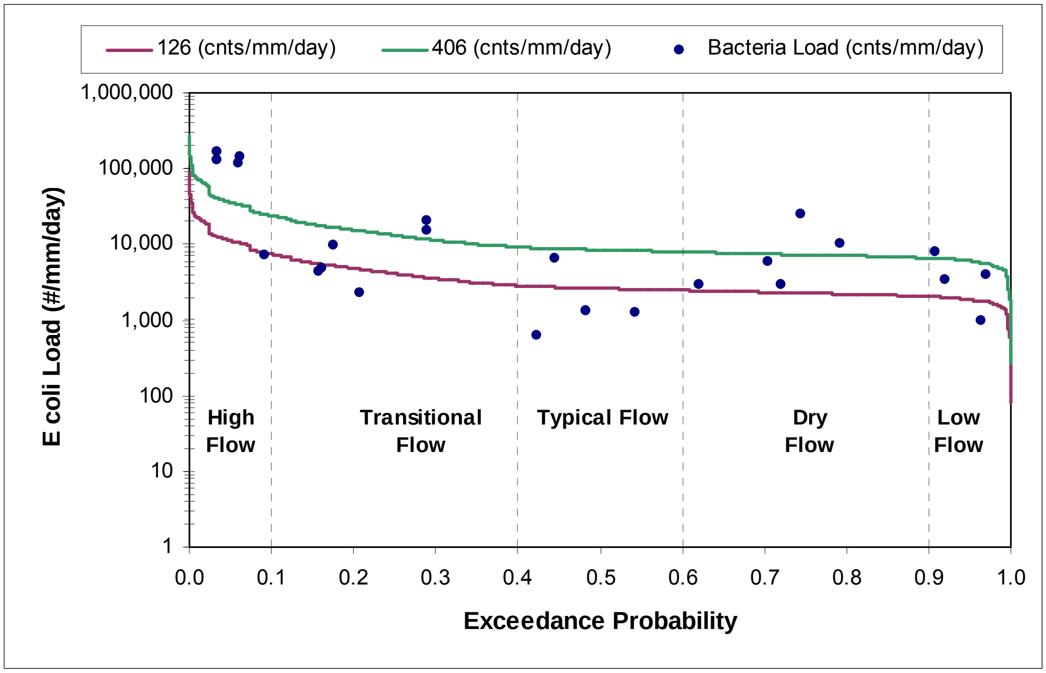
A logarithmic mean (log mean) for Mill, Pringle, Clark and Bashaw Creeks was calculated to approximate the deviation from the 30-day log mean criterion of 126 counts / 100 mL. A log mean is a measure of central tendency useful in summarizing highly skewed data. The log mean is reflected in each stream specific box-and-whisker plot by a red line with an asterisk.

Another analytical approach, a load duration curve, was developed where daily flow data were available. The load duration curve approach was chosen because it is capable of illustrating relative impacts under various flow conditions and can be used in targeting appropriate water quality restoration efforts (Cleland, 2002). Load duration curves are a method of determining a flow based loading capacity, assessing current conditions, and calculating the necessary reductions to comply with water quality criteria.

Bacterial loads are plotted in relation to the likelihood that a given flow rate will occur (exceedance probability) based on historical flow data. Low flows are frequent and occur at a high exceedance probability, while high flows occur less frequently and have a low exceedance probability. Load duration curves are capable of illustrating relative impacts under various flow conditions and can be used in targeting appropriate water quality restoration efforts (Cleland 2002). An example is provided in Figure 7.10.

This procedure requires a continuous flow record and associated bacterial concentration data. There were only two sites in the subbasin with sufficient data for this analysis, Mill Creek at Salem, WRD real-time flow gage #14192000 (RM 1.1), and one historic flow gage at Penitentiary Annex near Salem, USGS gage #14191500 (Mill Creek RM 7). The flow record from the latter of these stations was incomplete, and was estimated by comparison to the real-time and continuous data set at the Mill Creek at Salem gage. These load duration curves are for informational purposes, and were not used for the development of bacteria load capacity and allocation. They 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 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. The example below indicates exceedances of the single sample 406 numeric criteria occurred in the high, transitional, dry and low flow scenarios.

Figure 7.10 Example Load Duration Curve showing the loading capacity and calculated event loads



Finally, land-use specific percent reductions were calculated for each 303(d) listed stream and applied to each watershed based on land use. The land use for each watershed was determined from the USGS *Land Use Land Cover* spatial coverage developed in 1980. Results were generalized by major land use for application to other parts 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. Seasonal patterns in *E. coli* concentrations have been assessed for longitudinal variability throughout the year, the summer low flow period from July 1 to September 30, and for the fall-winter-spring period of high flow from October 1 to June 30 in each of the watersheds of the Middle Willamette Subbasin. Analysis is based on instream bacteria data collected by ODEQ and the City of Salem from January 1996 to March 2003. ODEQ intensive surveys collected bacterial concentration data in summer 2002 and winter 2003, intensive log-mean concentrations were calculated for some of the sampling sites and reflect summer low flow or winter high flow conditions. Allocations address seasonal fluctuations in bacteria concentrations evident in the data. In addition to normal seasonal variations in rainfall, flow and waste accumulation, Mill and Pringle Creek are also subject to seasonal operation of the in-flow diversions from the North Santiam River. Units of the number of bacteria used in all tables and graphs are counts of *E. coli* per 100 mL.

Mill Creek Watershed

Mill Creek was listed as water quality limited on the 1998 303(d) list due to excess loading of bacteria year round. The creek is listed from its mouth in Salem upstream to its headwaters in the Cascade foothills. Mill Creek was initially listed based on the elevated fecal coliform counts reported by the City of Salem. The City collected 781 samples of which 32% (249 of 781) exceeded the 90th percentile criterion (400 MPN/100ml).

Mill Creek downstream of RM 11.5 is considered urban for purposes of this TMDL. Violations of the bacterial criteria occur year round, but show slightly different distributions in the Mill Creek Watershed in summer than fall-winter-spring periods.

There are four NPDES individual permits in the Mill Creek Watershed. These include three year-round industrial wastewater discharges and one seasonal domestic sewage treatment plant for the City of Aumsville. The Aumsville STP discharges to Beaver Creek from November to April. There are 21 stormwater and 3 non-stormwater general permits in the subbasin. Sources and sites sampled by ODEQ and the City of Salem for bacterial concentrations are presented in Map 7.13.

There are 10 CAFOs in the Mill Creek Watershed including eight dairies, one feed lot, and one swine lot. Five of the dairies and one feed lot are located on the McKinney Creek system. There are also dairies at the mouth of Perrin Lateral Canal and Beaver Creek as it flows into Mill Creek upstream of Turner.

Seasonal and Spatial Patterns

Seasonal patterns were different between the Mill Creek and Battle Creek stations. Battle Creek is a tributary to McKinney Creek which has several CAFO operations within its drainage boundary. Mill Creek stations are primarily in urban land use, while Battle Creek is entirely agricultural or rural (Tables 7.17 and 7.18). Mean concentrations of *E. coli* in Mill Creek were roughly similar comparing the same stations in summer and winter, but 90th percentile values were usually higher in winter than in summer suggesting that extreme values are more common during winter runoff events. Regardless of runoff conditions, winter concentrations were generally higher than summer concentrations. In Battle Creek, summer concentrations tended to be much higher than winter concentrations. This suggests dry-weather sources, such as failing septic systems or direct deposition from animals to be more significant in Battle Creek.

Map 7.13 Mill Creek Watershed Spatial Distribution of Bacteria 303(d) Listed Streams, Land Use, Sampling Sites, & Point Sources

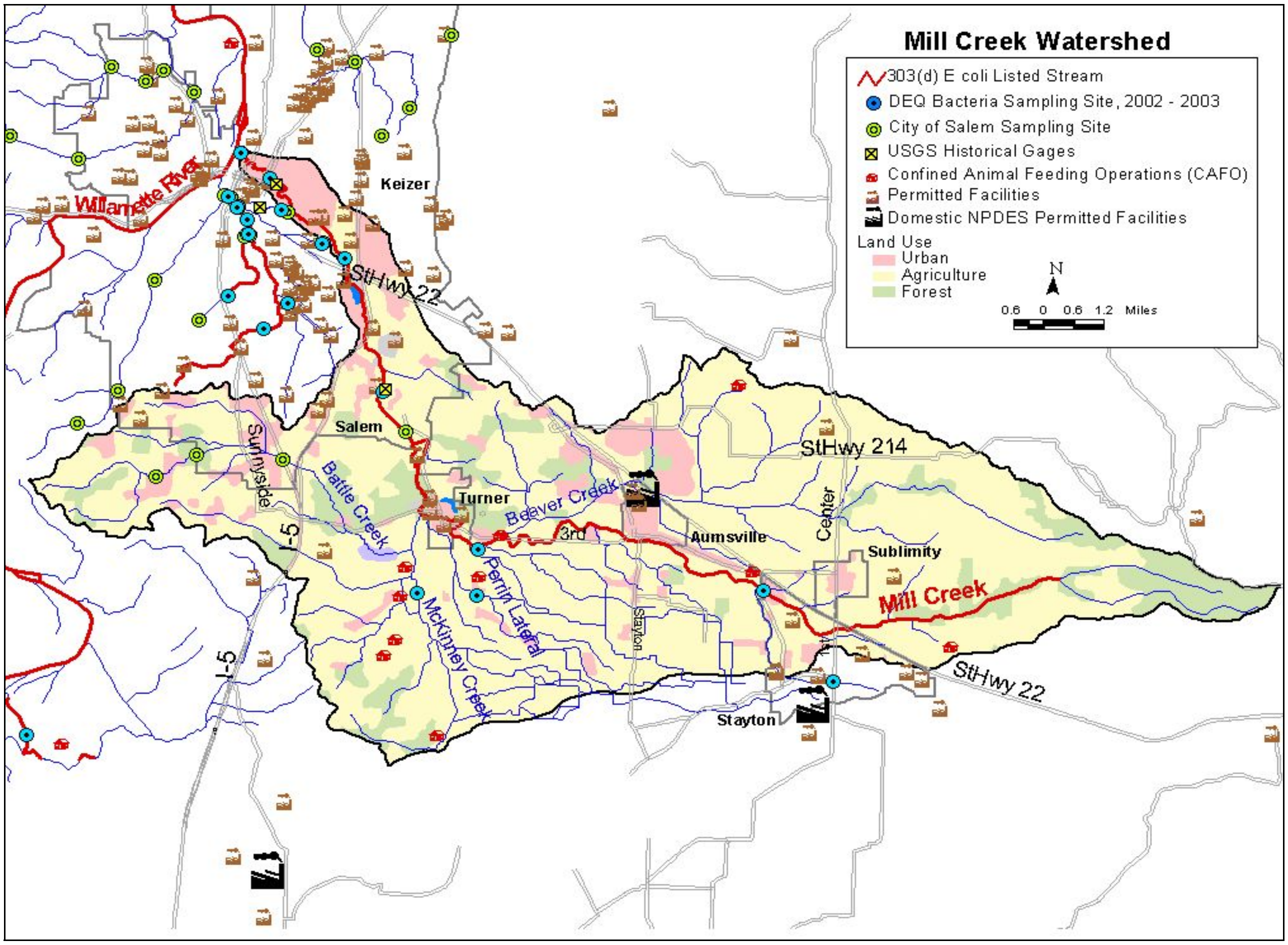


Table 7. 17 Summer Mill Creek Watershed E. coli Survey Results, ODEQ and City of Salem Data.

Summer Statistics

Rm	Site	ODEQ Intensive Survey Log Mean (7/15 - 7/18/2002)	N	Log Mean	Mean	90th Percentile	% > 406	max	Land Use
Mill Creek Watershed									
Mill Creek									
1.0	Mill Creek at Capitol St / Front Street Bridge	572 *	11	657	829	1,414	73%	2,416	Urban
2.3	**Out Flow** Mill Race at Mill Race Park (RM 1.2)		7	389	501	914	29%	1,553	Urban
3.5	**Out Flow** Shelton Ditch u/s Airport Road (RM 1.9)	151	12	202	277	269	8%	1,414	Urban
3.8	Mill Creek at Hawthorne Street	162	5	162	180	288	0%	341	Urban
8.2	Mill Creek @ Walling Sand & Gravel		6	358	377	534	33%	579	Urban
Battle Creek <tributary to McKinney Creek @ RM 0.8>									
3.6	Battle Creek at Commercial St SE		7	1,637	1,903	2,419	86%	2,419	Agriculture
5.5	Battle Creek Creekside Golf Course		7	601	1,034	2,007	57%	2,419	Agriculture
6.5	Battle Creek Bates Road S		7	508	953	2,419	43%	2,419	Agriculture

* 30-day Log Mean standard applies to 5 or more samples taken w/in 30 days: Standard does not apply to Mill Creek at Capital St / Front Street Bridge because less than 5 samples were taken within a 30 day period during the ODEQ intensive survey in 2002.

(shaded): exceeding criteria

Table 7. 18 Fall-Winter-Spring Mill Creek Watershed E. coli Survey Results, ODEQ and City of Salem Data

Fall-Winter-Spring Statistics

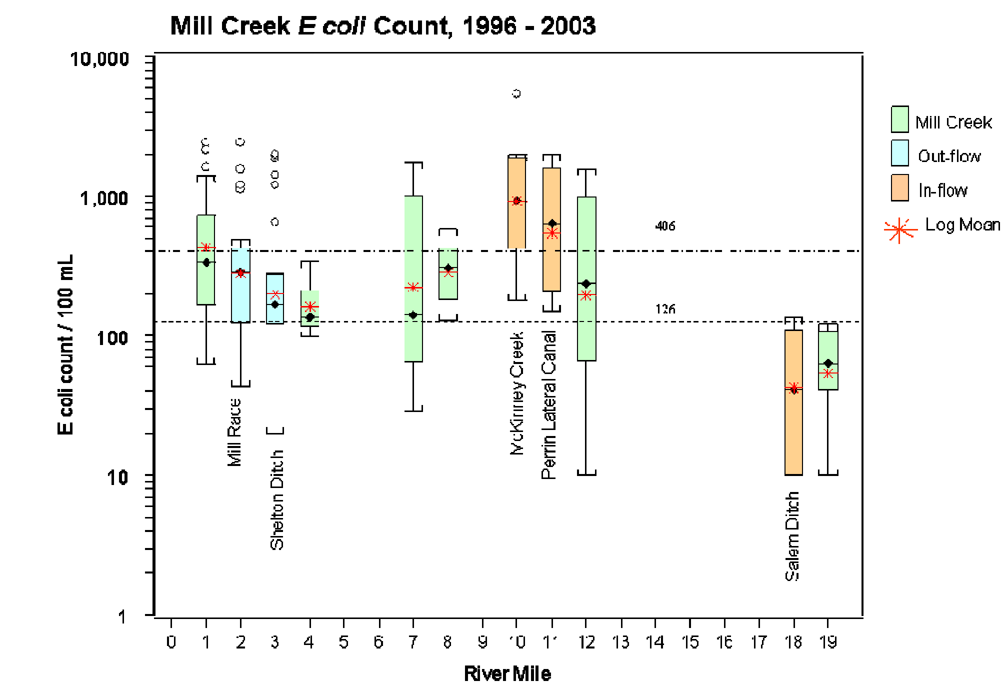
Rm	Site	ODEQ Intensive Survey Log Mean (2/19, 3/3, 3/5 - 3/7/2003)	N	Log Mean	Mean	90th Percentile	% > 406	max	Land Use
Mill Creek Watershed									
Mill Creek									
1.1	Mill Creek at Capitol St / Front Street Bridge	306	22	262	451	974	27%	2,143	Urban
2.3	**Out Flow** Mill Race at Mill Race Park (RM 1.2)		13	235	491	1,186	23%	2,419	Urban
3.5	**Out Flow** Shelton Ditch u/s Airport Road (RM 1.9)	207	22	196	496	1,806	27%	1,986	Urban
7.0	Mill Creek at Turner Road / Walling Sand & Gravel	318	22	213	477	1,414	32%	1,733	Urban
10.0	**In Flow** McKinney Creek at Hennes Road (RM 1.8)	920	8	920	1,503	3,004	75%	5,371	Agriculture
10.2	**In Flow** Perrin Lateral Ditch at Marion Road (RM 2.1)	539	8	539	872	1,974	50%	1,989	Agriculture
11.9	Mill Creek at Marion Road	195	8	195	521	1,529	38%	1,562	Agriculture
18.7	**In Flow** Salem Ditch at 2nd St, Stayton (RM 3.1)	42	7	42	63	119	0%	135	Forest
19.0	Mill Creek at Golf Club Road	54	7	54	67	113	0%	121	Forest
Battle Creek <tributary to McKinney Creek @ RM 0.8>									
3.6	Battle Creek at Commercial St SE *		14	172	371	876	21%	1,733	Agriculture
5.5	Battle Creek Creekside Golf Course		14	66	90	201	0%	219	Agriculture
6.5	Battle Creek Bates Road S		14	40	102	218	7%	488	Agriculture

: exceeding criteria

Tables 7.17 and 7.18 show statistical summaries of observed data. Sites identified as In Flow and Out Flow are sites on tributaries or diversions. River miles shown for such sites are river miles where tributary or diversions enter or exit the stream.

E. coli concentrations generally increased with distance downstream from headwaters. Concentrations were below water quality criteria in the upper Mill Creek watershed, but were generally above the criteria in the mid and lower watershed where agriculture, rural residential and urban development becomes the dominant land use. The two sites farthest upstream, Mill Creek at Golf Course Road (RM 19.0) and Salem Ditch, did not exceed the bacteria criteria. Data collectively illustrate annual violations of bacteria water quality criteria occurring in Mill Creek at Marion Road, RM 11.9, and downstream (Figure 7.11**)**. Median concentrations in this reach were well above the log mean criterion and there were common violations of the single sample criterion. These stations included both in-flow and out-flow diversions from Mill Creek. Salem Ditch diverts water from the North Santiam River into Mill Creek just downstream of Golf Course Road. In-flows from Perrin Lateral Canal and McKinney Creek, as well as the outflows at Shelton Ditch and Mill Race also demonstrate high counts of *E. coli* instream exceeding both the log mean criterion and the single sample criterion.

Figure 7.11 **Mill Creek Year-Round Longitudinal Profile of E. coli Counts, including Tributary In-Flows and Out-Flows**



Source: ODEQ, City of Salem

Concentrations of *E. coli* exceeded the bacteria criteria from Mill Creek at Marion Road, RM 11.9, downstream to the mouth in all seasons (Figure 7.11 and Figure 7.12). Fall-winter-spring *E. coli* concentrations in the headwater site on Mill Creek, Golf Course Road (RM 19.0) and the diversion at Salem Ditch are in compliance with both the log mean and the single sample criteria. Both sites represent a forest land use. Agricultural land use is represented by sites on Mill Creek at Marion Road (RM 11.9), McKinney Creek, and Perrin Lateral Canal. Concentrations at agricultural sites exceeded both criteria throughout the fall-winter-spring period, with highest observed concentrations in McKinney Creek. Maximum *E. coli* concentrations are observed at the mouth of Mill Creek year round, during the summer in Mill Creek at Front Street Bridge (RM 0.1) and in the fall-winter-spring in Mill Creek at Capital Street (RM 1.1). Both Mill Creek at Front Street and at Capital Street are downstream of Shelton Ditch and Mill Race, two diversions to Pringle Creek.

Figure 7.12 Mill Creek Summer Longitudinal Profile of E. coli Counts

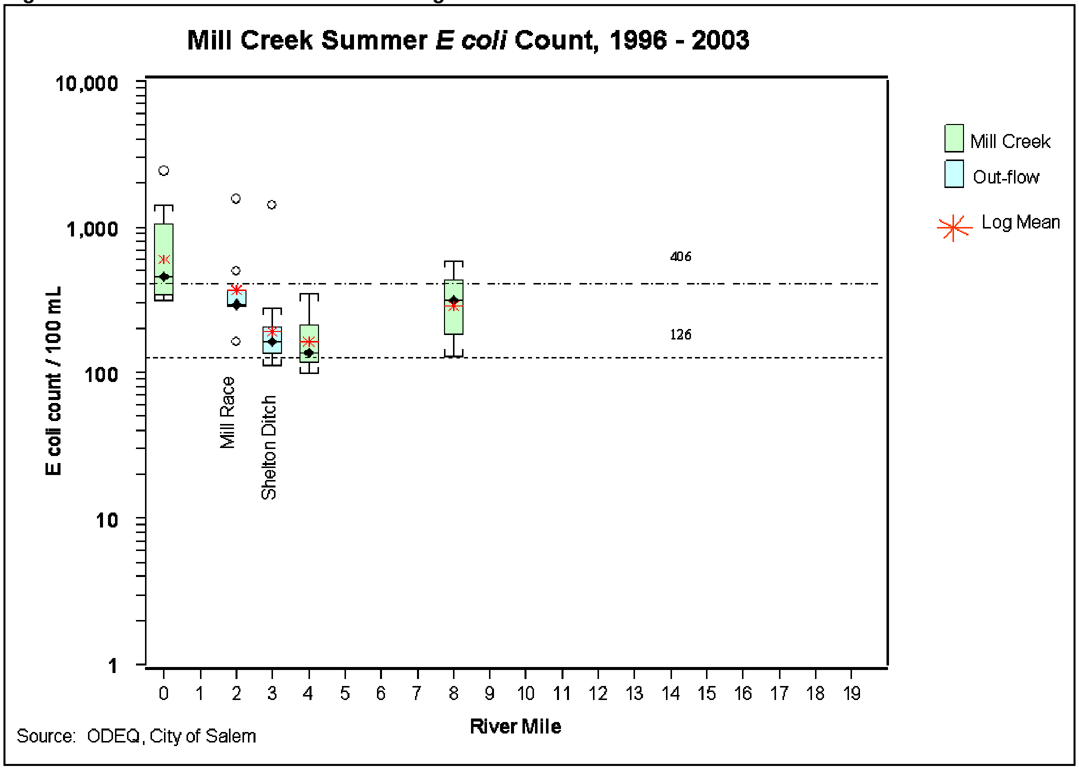
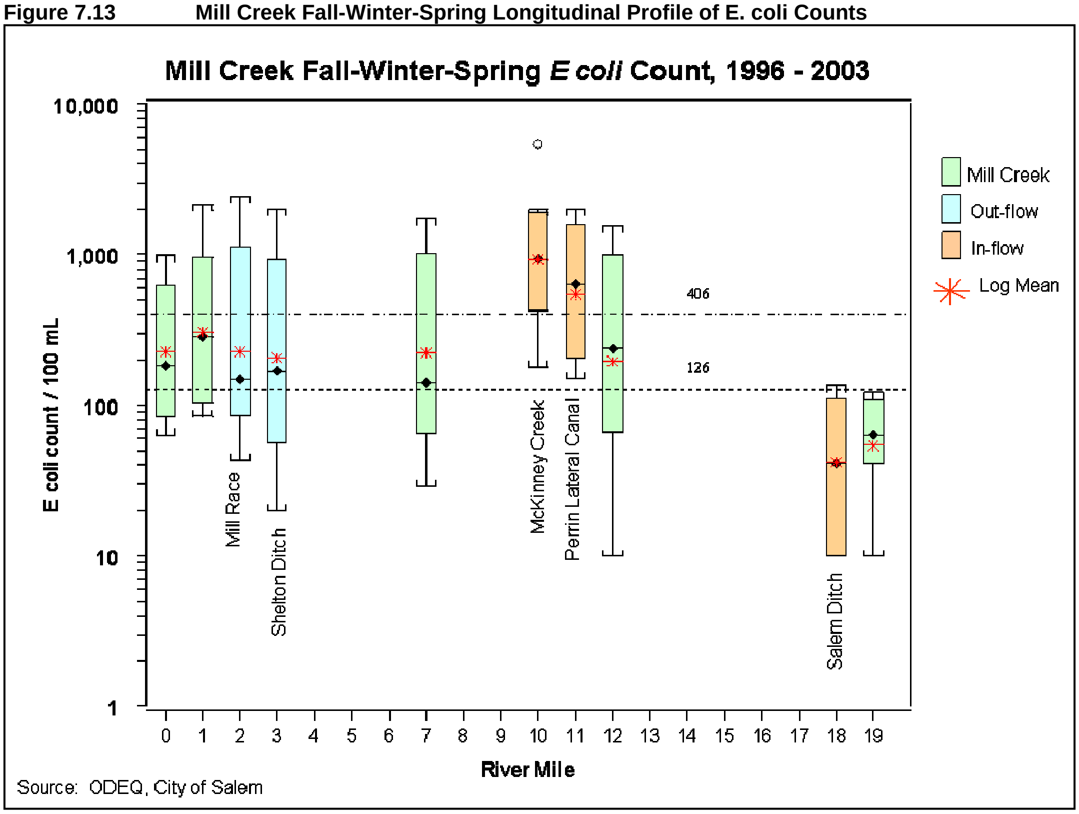


Figure 7.13 Mill Creek Fall-Winter-Spring Longitudinal Profile of E. coli Counts



Battle Creek

Battle Creek flows to McKinney Creek downstream of ODEQ's sampling point on McKinney Creek. Land use in this subwatershed is primarily agricultural and rural residential. The City of Salem began collecting *E. coli* data from Battle Creek in 2001. Concentrations of *E. coli* were greatest at the mouth at river mile 3. with both the log-mean and single sample criteria exceeded (Figure 7.14). Summer concentrations are generally higher than in the fall-winter-spring at all stations on Battle Creek (Figure 7.15), and violate both the log mean and single sample criteria. No violations of the *E. coli* criteria occurred during the fall-winter-spring.

Figure 7.14 Battle Creek Year-Round Longitudinal Profile of E. coli Counts, Tributary to McKinney Creek

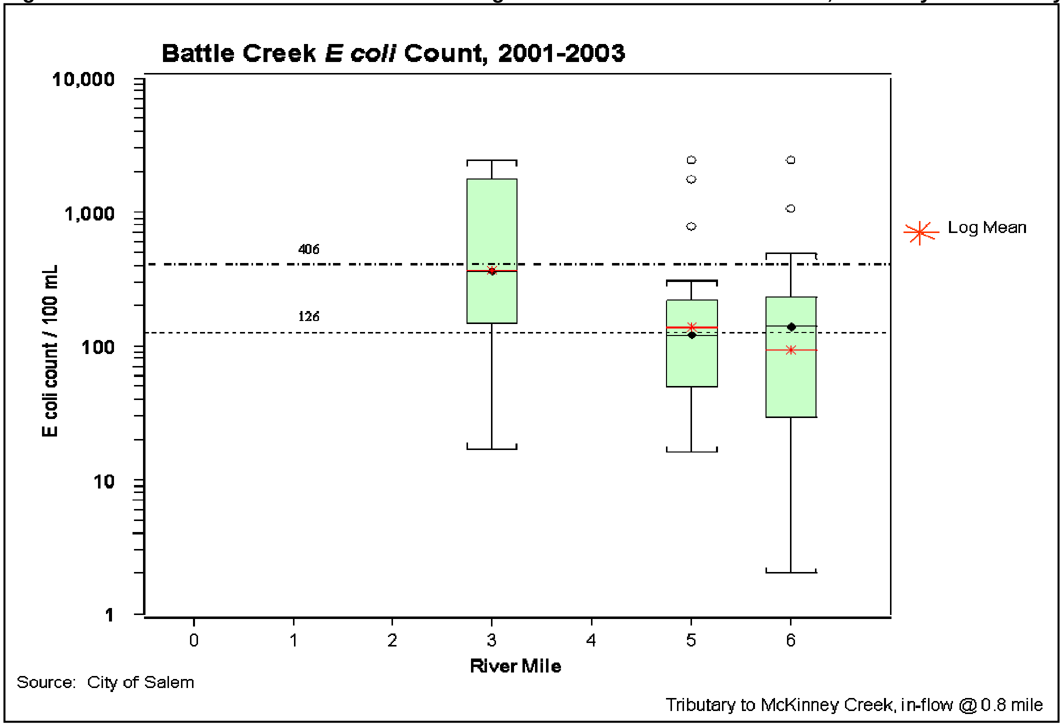
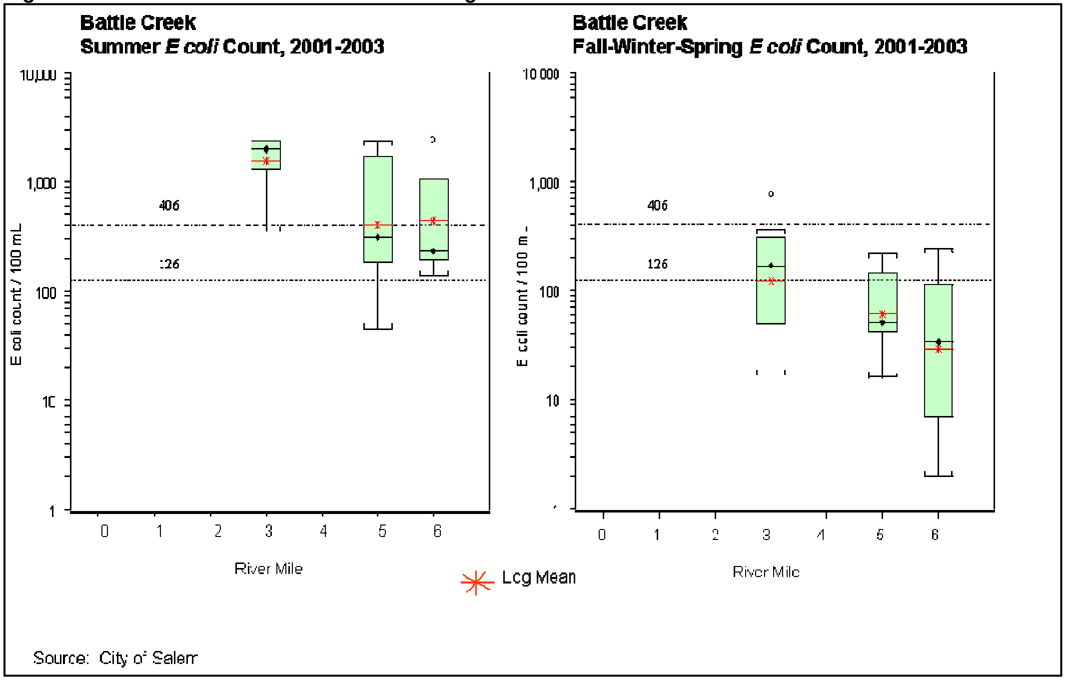


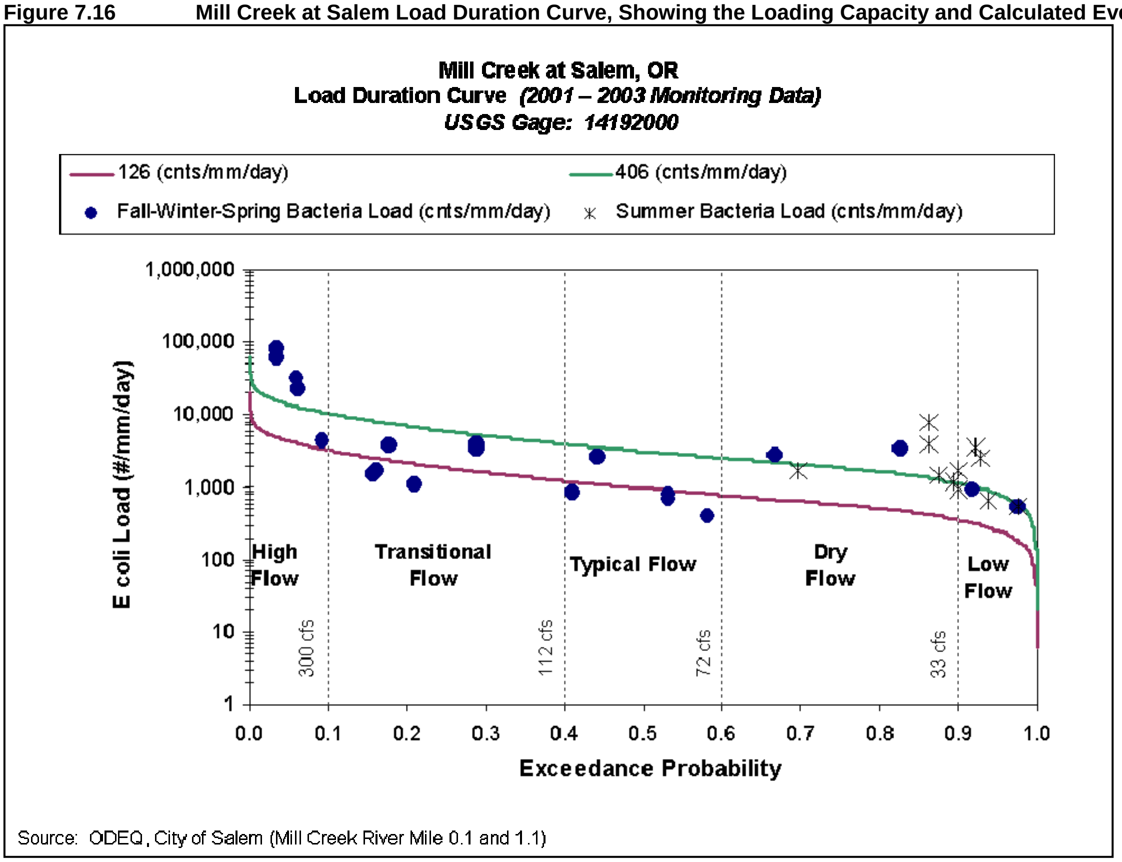
Figure 7.15 Battle Creek Seasonal Longitudinal Profile of E. coli Concentrations.



Load Duration Curves

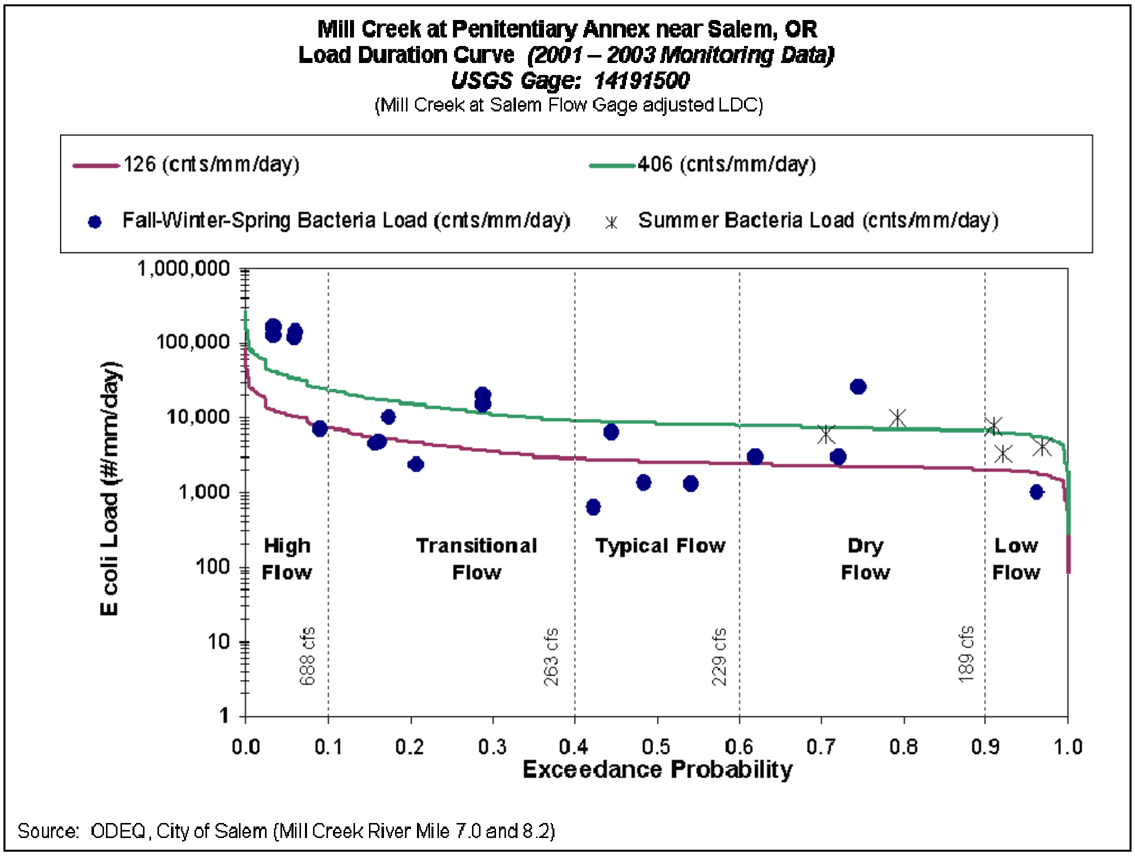
A load duration curve was developed for the flow gage operated by the USGS on Mill Creek at Salem, RM 1.1 (Figure 7.16**)**. This curve represents conditions at the mouth of Mill Creek and includes data from stations at Front Street Bridge (RM 0.1) and Capitol Street (RM 1.1). Bacterial loads were calculated for samples collected at nearby sites by multiplying the concentration of the sample by the flow volume and standardizing to a 24-hour day. The hydrograph was normalized by the drainage area represented by the flow gage in millimeters (mm). The two curves indicate the loads associated with both the log mean and single sample 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. This curve indicates violations of the single sample criterion occur year round, and during low (below 33 cfs), dry (between 33 cfs and 72 cfs), and high flow (greater than 300 cfs) conditions. Violations at lower flow rates may indicate ongoing discharges from failing septic systems, cross connections between storm and sanitary sewers, pet / wildlife / waterfowl direct deposition of waste, and improper manure management from upstream reaches.

Figure 7.16 Mill Creek at Salem Load Duration Curve, Showing the Loading Capacity and Calculated Event Loads



USGS operated a flow gage on Mill Creek near Penitentiary Annex (RM 7.0) that recorded daily flow data from 1940 to 1956. The Mill Creek at Salem gage was also recording data during this time, and has a continuous record to the present time. The relationship between flow at Salem and at Penitentiary Annex from 1940-1956 was used to simulate flow at Penitentiary Annex for the same period of record as Mill Creek at Salem. The simulated flow data for Penitentiary Annex was adjusted based on a factor generated by comparing the hydrological response to volume and timing of the current condition hydrograph to account for changes in development of the upper watershed during the intervening years. The hydrograph was also normalized by the drainage area represented by the flow gage in millimeters (mm). Bacteria loads for the historic flow gage near Penitentiary Annex hydrograph were calculated with *E. coli* data from Mill Creek at Turner Road (RM 7.0) and at Walling Sand and Gravel (RM 8.2) (Figure 7.17). Violations of the single-sample criterion occurred year-round, and during low (below 189 cfs), dry (between 189 cfs to 229 cfs), transitional (between 263 cfs to 688 cfs), and high (greater than 688 cfs) flows. This is consistent with analysis of the concentration data among stations presented in earlier tables and figures.

Figure 7.17 Mill Creek at Penitentiary Annex Load Duration Curve, Showing the Loading Capacity and Calculated Event Loads

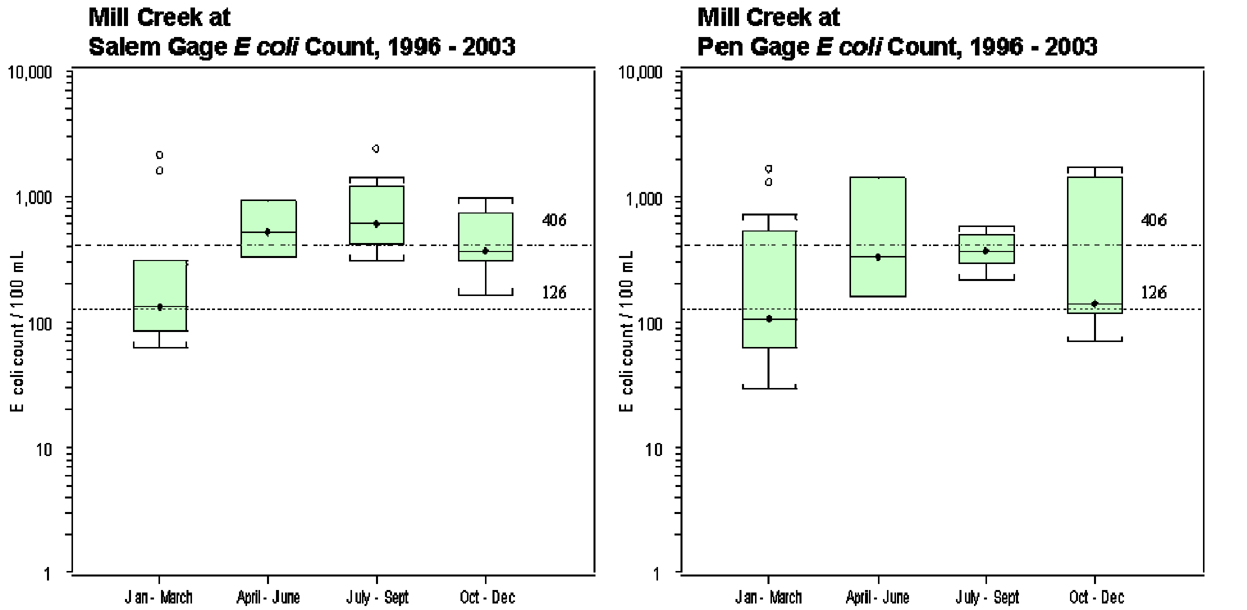


The load duration curves developed for Mill Creek at Salem and at Penitentiary Annex near Salem show that exceedances of the single sample criterion occur under all flow regimes, and identify a year-round bacteria problem in the lower watershed. When event loads exceed the loading capacity during high or transitional flows it is likely that the loading is due to runoff related sources such as urban stormwater or overland runoff sources such as pet waste.

Bacteria loading usually decreases during low, dry and typical flow periods, however, the loading capacity of the river has also decreased during low flows. Violations of the water quality criteria at low flows are not likely runoff related. Warm-blooded animals in streams, failing septic systems, waste water treatment plants and improper discharge of sewage are possible non-runoff related sources.

An analysis of the *E. coli* concentration data used in the Load Duration Curve plots shows that both data sets, Mill Creek at Salem and Mill Creek at Penitentiary Annex, exceed *E. coli* single sample criteria in all seasons (Figure 7.18**)**. Generally, concentrations were lower from January through March than in April through December. Mill Creek at Salem median *E. coli* concentrations exceeded the log mean criterion in all seasons, while the Mill Creek at Penitentiary median concentrations exceeded the log mean criterion from April through December.

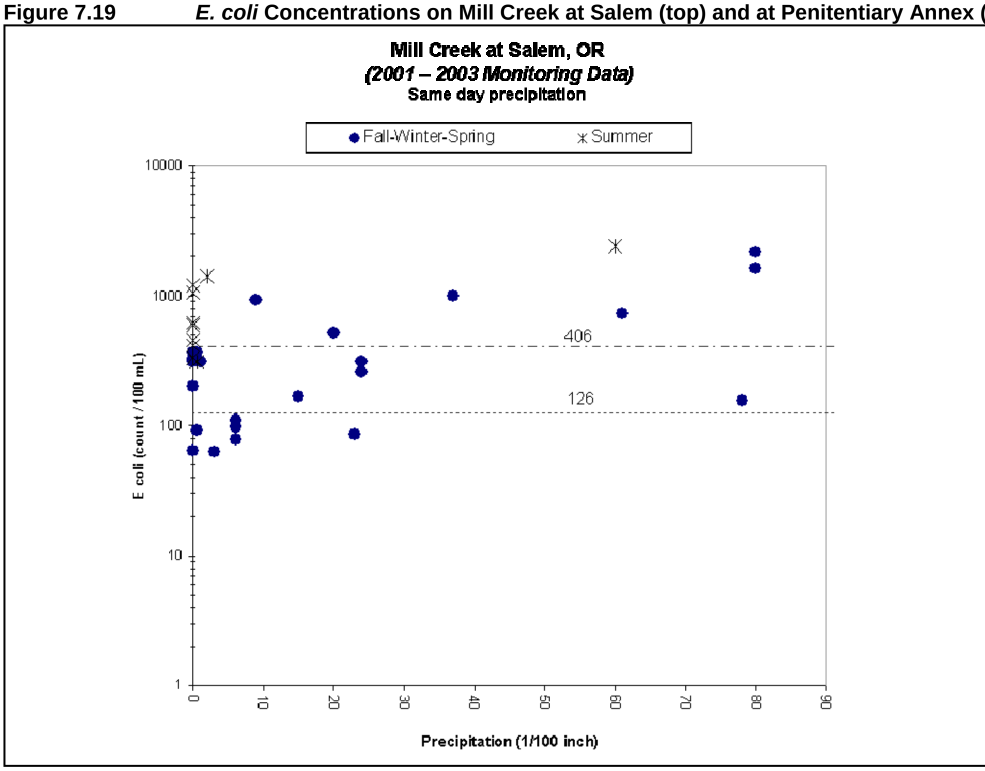
Figure 7.18 Seasonal Comparison of E. coli Counts at Mill Creek at Salem Flow Gage (left), Penitentiary Annex Flow Gage (right)

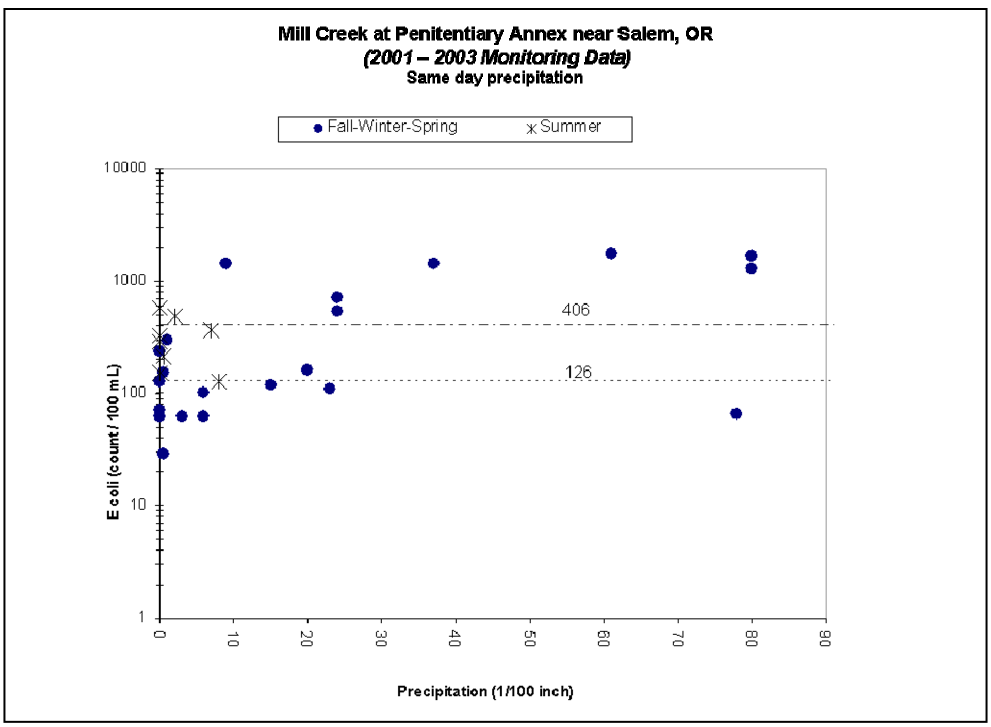


Source: ODEQ, City of Salem (Mill Creek River Mile 0.1 and 1.1)

E. coli concentrations were also plotted against the same-day precipitation to determine if violations of the criteria were occurring during precipitation events or dry weather, (Figure 7.19). *E. coli* counts plotted in red represent data collected during a same day precipitation event. Both data sets show that *E. coli* criteria violations occur year-round and during both dry and wet weather events, although concentrations appear to be higher during precipitation events.

Figure 7.19 ***E. coli*** **Concentrations on Mill Creek at Salem (top) and at Penitentiary Annex (bottom).**





Point Source Discharges

The Mill Creek Watershed has one permitted sewage treatment plant (STP). Although there are other discharges to the watershed, they are generally unlikely to contain significant concentrations of bacteria. The Aumsville STP discharges to Beaver Creek, which is a tributary to Mill Creek at RM 12.6. Aumsville STP does not discharge to Beaver Creek from May to October, and discharge limits must be met at the point of discharge to the creek. Discharge limits are the criteria for the protection of recreational contact. The STP exceeded both the log mean and single sample criteria in December of 2001 (Table 7.19). There have been no other violations during the period from January 2001 to February 2003. Municipal stormwater discharges are also regulated through the NPDES permit program, and are the only significant point source in the Mill Creek Watershed. There are no data available for these sources.

Table 7. 19 Aumsville STP Discharge Record, January 2001 – February 2003

Date	Average Effluent Flow (MGD)	Maximum Effluent Flow (MGD)	Average E. coli Concentration (#/100 ml)	Maximum E. coli Concentration (#/100 ml)
			Permit Limit 126/100ml	Permit Limit 406/100ml
Jan-01	0.53	0.68	89	309
Feb-01	0.48	0.37	16	20
Mar-01	0.54	0.74	93	51
Apr-01	0.51	0.70	37	340
No Discharge from May to October				
Nov-01	0.40	0.59	79	99
Dec-01	0.89	1.60	**255**	**1203**
Jan-02	0.60	0.70	43	32
Feb-02	1.13	0.90	18	39
Mar-02	NA	NA	NA	NA
Apr-02	0.58	0.59	NA	NA
No Discharge from May to October				
Nov-02	0.65	0.81	80	80
Dec-02	0.77	0.62	6	8
Jan-03	1.15	0.75	6	7
Feb-03	1.02	0.87	4	4

Pringle Creek Watershed

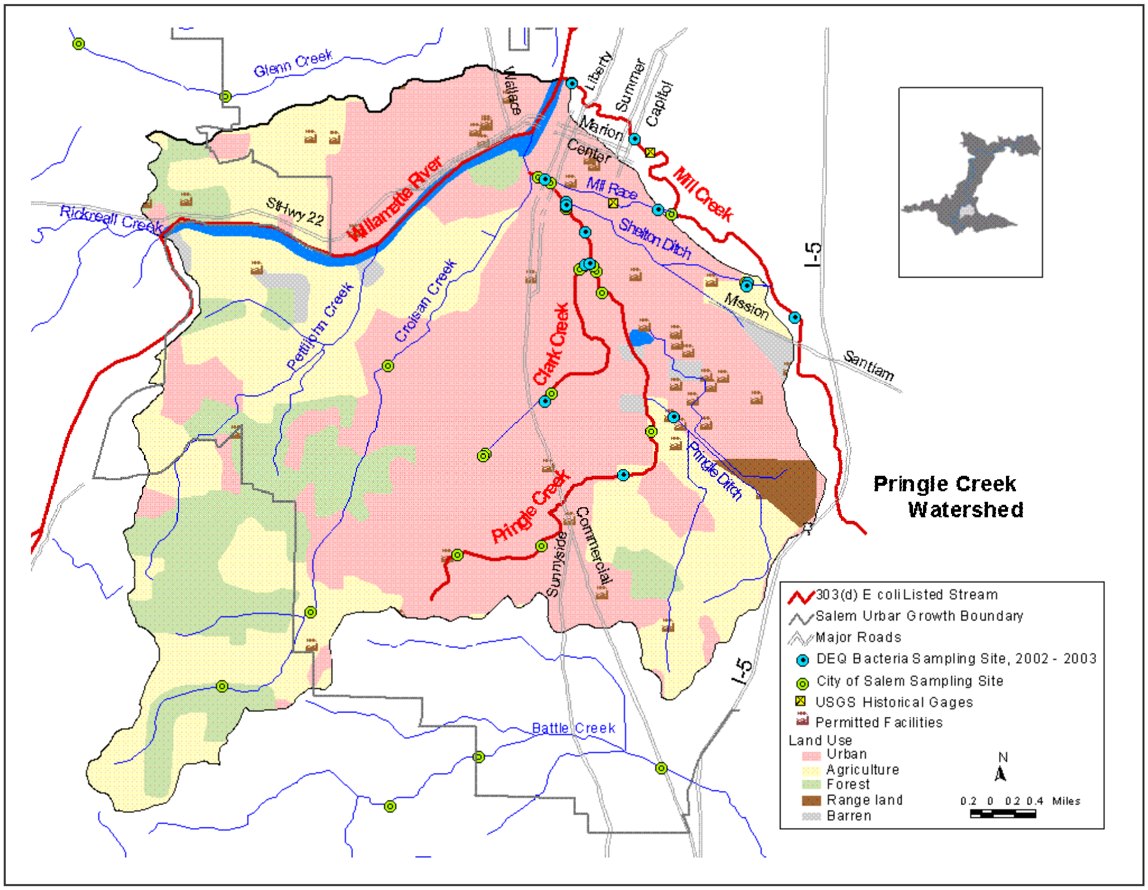
Pringle and Clark Creeks are listed on the 1998 303(d) list for violating the bacteria criterion year-round. Clark Creek is a tributary to Pringle Creek, flowing into Pringle Creek at RM 1.0. Both creeks are listed from mouth to headwaters, and flow within the City of Salem's urban growth boundary. Concentrations in half of the samples collected (23 of 46) by the City of Salem at two sites on Pringle Creek exceeded the single sample criterion of 406 counts / 100 mL, with a high value of 1330 *E. coli* counts/100 mL. Forty-four percent of the samples collected by the City of Salem in Clark Creek exceeded the single sample criteria, with a maximum value reported of 11,700 *E. coli* counts/100 mL.

The watershed is predominantly in urban land use, and there are no CAFOs reported by the Department of Agriculture as of March 2003. However smaller unregulated livestock operations (hobby farms) may exist in the watershed.

Pringle Creek has three man-made diversions from Mill Creek that discharge water to Pringle Creek through Pringle Ditch (Pringle Creek RM 2.6), Shelton Ditch (Pringle Creek RM 0.4) and Mill Race (RM 0.2). Pringle Ditch is considered part of the Pringle Creek system which consists of West, Middle and East Pringle creeks. These year-round in-flows have been engineered to mitigate flooding in downtown Salem and to maintain a minimum stream flow in Pringle Creek.

ODEQ and the City of Salem have collected water samples for E. coli monitoring at 20 sampling sites in this watershed (Map 7.14).

Map 7.14 Pringle Creek Watershed Spatial Distribution of Bacteria 303(d) Listed Streams, Land Use, Sampling Sites, and Point Sources.



Seasonal and Spatial Patterns

Overall, bacterial concentrations generally exceeded the bacteria criteria at nearly all stations and throughout the year. The exceptions were stations on Croisan Creek, some of which still violated criteria in summer. The Pringle Creek Watershed is almost entirely urbanized. Log mean concentrations are likely to be higher in summer, and more likely to exceed the single sample criterion than in fall-winter-spring (Tables 7.20 and 7.21). In addition to ongoing monitoring, ODEQ conducted intensive surveys at sampling sites during 2002 summer low flow conditions and during 2003 winter storm (high flow) conditions, the intensive log-mean concentrations generally exceeded criteria at most stations during both of these surveys.

Due to the limited number of *E. coli* samples collected from 1996 to 2003 in Clark Creek at Ratcliff Drive, RM 1.9, fecal coliform data collected by the City of Salem from 1990 to 1995 was 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.

Table 7. 20 Summer Pringle Creek Watershed *E. coli* Survey Results, ODEQ and City of Salem Data

Summer Statistics

Rm	Site	ODEQ Intensive Survey Log Mean (7/15 - 7/18/2002)	N	Log Mean	Mean	90th Percentile	% > 406	max	Land Use
Pringle Creek Watershed									
Pringle Creek									
0.1	Pringle Creek at Commercial St		7	362	596	1,335	29%	2,419	Urban
0.2	**In Flow** Mill Race at Fire Station 1 (RM 0.01)		7	384	440	736	43%	921	Urban
0.4	**In Flow** Shelton Ditch at Church St (RM 0.02)		7	250	364	841	29%	1,046	Urban
0.5	Pringle Creek at Pringle Park / Church Street	177	17	491	721	1,555	65%	2,940	Urban
1.0	**In Flow** Clark Creek at mouth in Bush Park (RM 0.1)	435	19	1,150	1,548	2,479	79%	4,920	Urban
1.1	Pringle Crk at Bush Park / 12th / Cross St	207	24	485	637	1,150	58%	1,986	Urban
2.6	**In Flow** Middle Pringle Creek at Madrona Ave (RM 0.3)	3,096	5	3,096	3,334	4,671	100%	4,884	Urban
3.0	West Pringle at Madrona Rd / Pringle Rd	839	17	669	1,026	2,159	53%	3,654	Urban
4.7	West Fork Pringle Creek at Woodmansee Park		12	454	764	1,773	58%	2,940	Urban
5.6	West Fork Pringle Creek at Cannery Park		12	180	543	1,687	42%	2,080	Urban
Clark Creek <tributary to Pringle Creek @ RM 1.0>									
0.1	Clark Creek at mouth in Bush Park	435	19	1,150	1,548	2,479	79%	4,920	Urban
1.9	Clark Creek at Radcliffe Drive *	985	14	498	680	1,505	50%	1,782	Urban
2.7	Clark Creek at Ewald St		19	382	898	2,571	53%	3,680	Urban
Mill Race <tributary to Pringle Creek @ RM 0.2>									
0.01	Mill Race at Fire Station 1		7	384	440	736	43%	921	Urban
1.2	Mill Race at Mill Race Park		7	389	501	914	29%	1,553	Urban
Shelton Ditch <tributary to Pringle Creek @ RM 0.4>									
0.02	Shelton Ditch at Church St		6	276	402	876	33%	1,046	Urban
1.9	Shelton Ditch u/s Airport Road	151	12	202	277	269	8%	1,414	Urban
Croisan Creek									
1.3	Croisan Creek Courthouse Athletic Club		7	552	841	1,816	43%	2,419	Urban
3.9	Croisan Creek Ballyntyne Rd S		7	117	800	2,419	43%	2,419	Agriculture
5.2	Croisan Creek Inwood Ln S		4	17	34	56	0%	60	Forest

* Clark at Radcliff, RM 1.9, Used 1990 – 2003 E coli and Fecal transformed data using Cude equation

(shaded): exceeding criteria

Table 7. 21 Fall-Winter-Spring Pringle Creek Watershed *E. coli* Survey Results, ODEQ and City of Salem Data

Fall-Winter-Spring Statistics

Rm	Site	ODEQ Intensive Survey Log Mean (2/19, 3/3, 3/5 - 3/7/2003)	N	Log Mean	Mean	90th Percentile	% > 406	max	Land Use
Pringle Creek Watershed									
Pringle Creek									
0.1	Pringle Creek at Commercial St *	154	16	158	347	1,013	19%	1,986	Urban
0.2	**In Flow** Mill Race at Fire Station 1 (RM 0.01)		12	238	508	1,181	25%	2,419	Urban
0.4	**In Flow** Shelton Ditch at Church St (RM 0.02)		13	160	344	1,060	23%	1,733	Urban
0.5	Pringle Creek at Pringle Park / Church Street	209	38	278	441	1,048	32%	2,419	Urban
1.0	**In Flow** Clark Creek at mouth in Bush Park (RM 0.1)	612	39	676	1,067	1,547	72%	11,700	Urban
1.1	Pringle Crk at Bush Park / 12th / Cross St	138	46	184	336	863	30%	1,414	Urban
2.6	**In Flow** Middle Pringle Creek at Madrona Ave (RM 0.3)	30	8	30	57	158	0%	187	Urban
3.0	West Pringle at Madrona Rd / Pringle Rd	393	39	214	547	1,738	33%	4,110	Urban
4.7	West Fork Pringle Creek at Woodmansee Park		31	104	270	600	19%	1,300	Urban
5.6	West Fork Pringle Creek at Cannery Park		29	91	366	890	21%	3,888	Urban
Clark Creek <tributary to Pringle Creek @ RM 1.0>									
0.1	Clark Creek at mouth in Bush Park	612	39	676	1,067	1,547	72%	11,700	Urban
1.9	Clark Creek at Radcliffe Drive **		15	137	232	517	13%	694	Urban
2.7	Clark Creek at Ewald St		43	111	291	671	16%	2,419	Urban
Mill Race <tributary to Pringle Creek @ RM 0.2>									
0.01	Mill Race at Fire Station 1		12	238	508	1,181	25%	2,419	Urban
1.2	Mill Race at Mill Race Park		13	235	491	1,186	23%	2,419	Urban
Shelton Ditch <tributary to Pringle Creek @ RM 0.4>									
0.02	Shelton Ditch at Church St		13	160	344	1,060	23%	1,733	Urban
1.9	Shelton Ditch u/s Airport Road	207	22	196	496	1,806	27%	1,986	Urban
Croisan Creek									
1.3	Croisan Creek Courthouse Athletic Club		14	75	125	317	0%	387	Urban
3.9	Croisan Creek Ballyntyne Rd S		14	37	103	268	0%	387	Agriculture
5.2	Croisan Creek Inwood Ln S		12	28	68	169	0%	219	Forest

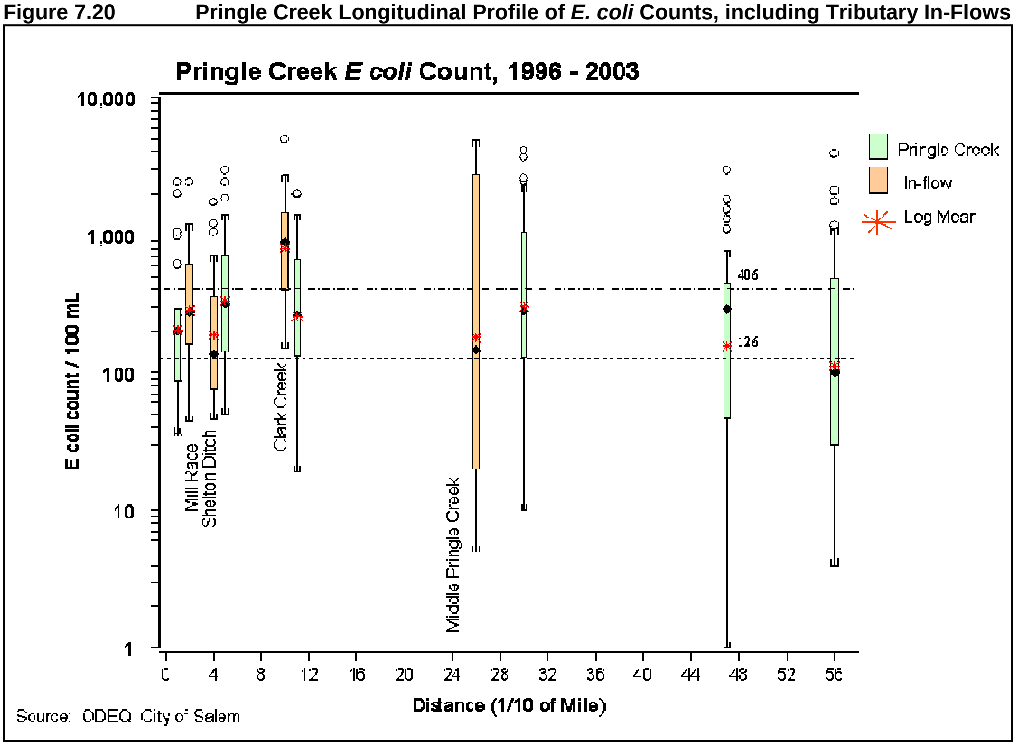
* Pringle Creek at Commercial St, RM 0.1, 30-day Log Mean standard applies to 5 or more samples taken w/in 30 days: Standard does not apply

** Clark at Radcliff, RM 1.9, Used 1990 – 2003 E coli and Fecal transformed data using Cude equation

(shaded): exceeding criteria

The year round distribution of *E. coli* data collected on Pringle Creek by the City of Salem and ODEQ indicate violations of criteria (Figure 7.20). Bacteria concentrations in tributaries to Pringle Creek, including the diversions from Mill Creek, were elevated, and concentrations in Pringle Creek upstream of these inflows were also elevated, with the maximum values observed in Clark Creek at the mouth. The site farthest upstream on Pringle Creek, West Fork Pringle Creek at Kroger Park, had the lowest log mean of the data set, 111 *E. coli* counts / 100 mL.

Figure 7.20 Pringle Creek Longitudinal Profile of *E. coli* Counts, including Tributary In-Flows



Concentrations of *E. coli* tended to be higher in summer than in fall-winter-spring (Figures 7.21 and 7.22). The most remarkable difference was in the Pringle Ditch (Middle Pringle Creek) inflow to Pringle Creek, where the summer log mean concentration was over 3,096 counts / 100 ml while the fall-winter-spring concentration was only 30 counts / 100 ml. All samples for the summer assessment of this site were collected during the 3-day intensive survey completed in July 2002, while samples for the fall-winter-spring period were collected over a longer period.

Figure 7.21 Pringle Creek Summer Longitudinal Profile of *E. coli* Counts

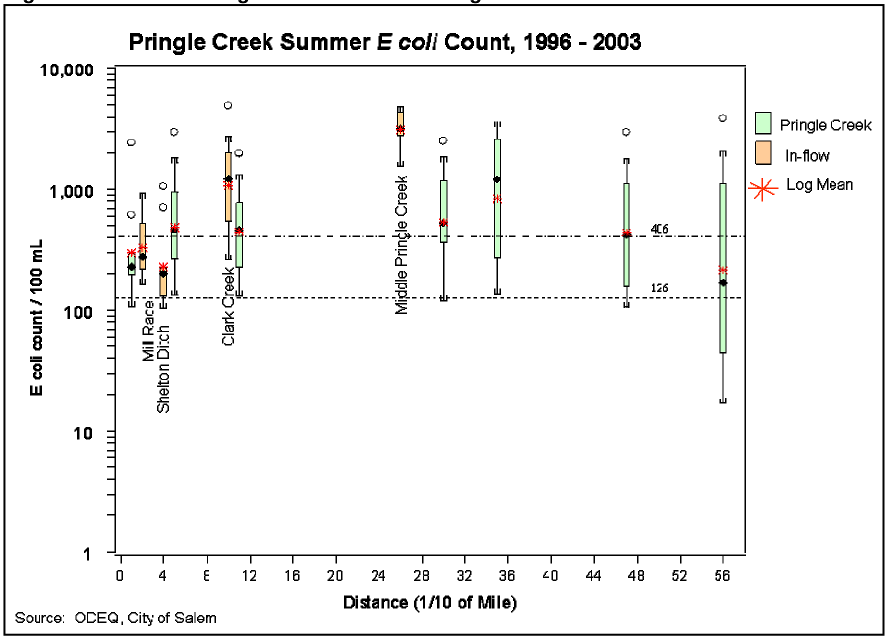
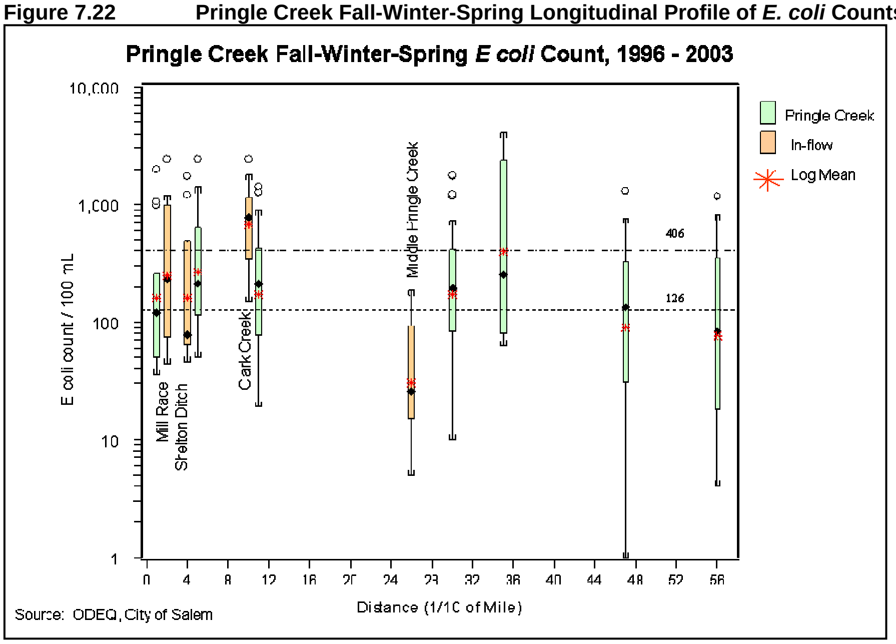


Figure 7.22 Pringle Creek Fall-Winter-Spring Longitudinal Profile of *E. coli* Counts



Concentrations at sites in the upper watershed tended to be below criteria in fall-winter-spring though not during summer. Concentrations of bacteria were higher at the mouths than upstream sampling sites in Clark Creek and Croisan Creek (Figures 7.23 through 7.26).

Figure 7.23 **Clark Creek Longitudinal Profile of *E. coli* Counts**

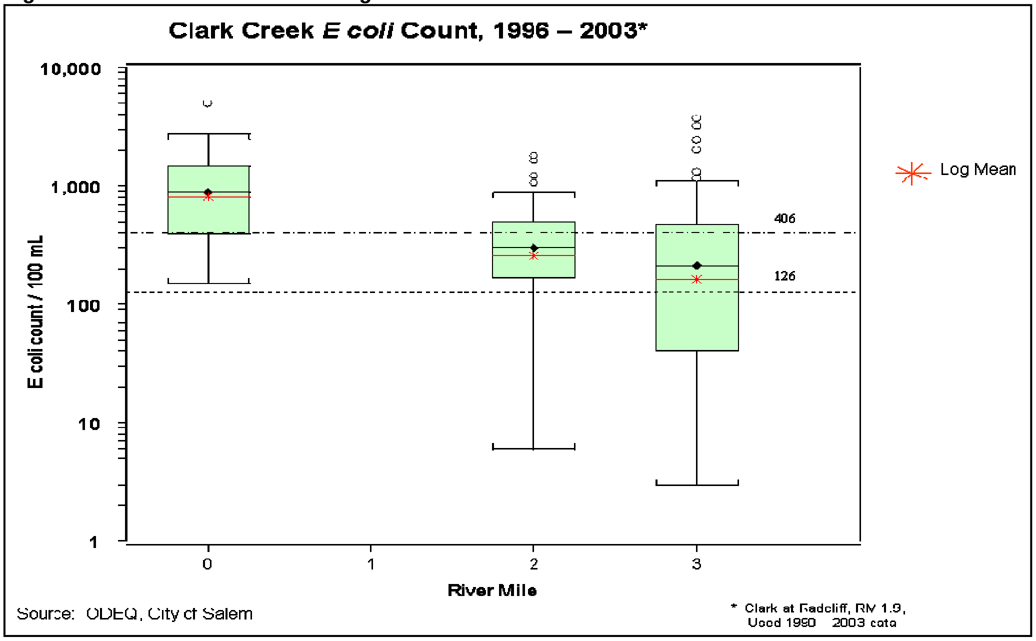


Figure 7.24 **Clark Creek Seasonal Longitudinal Profile of *E. coli* Counts**

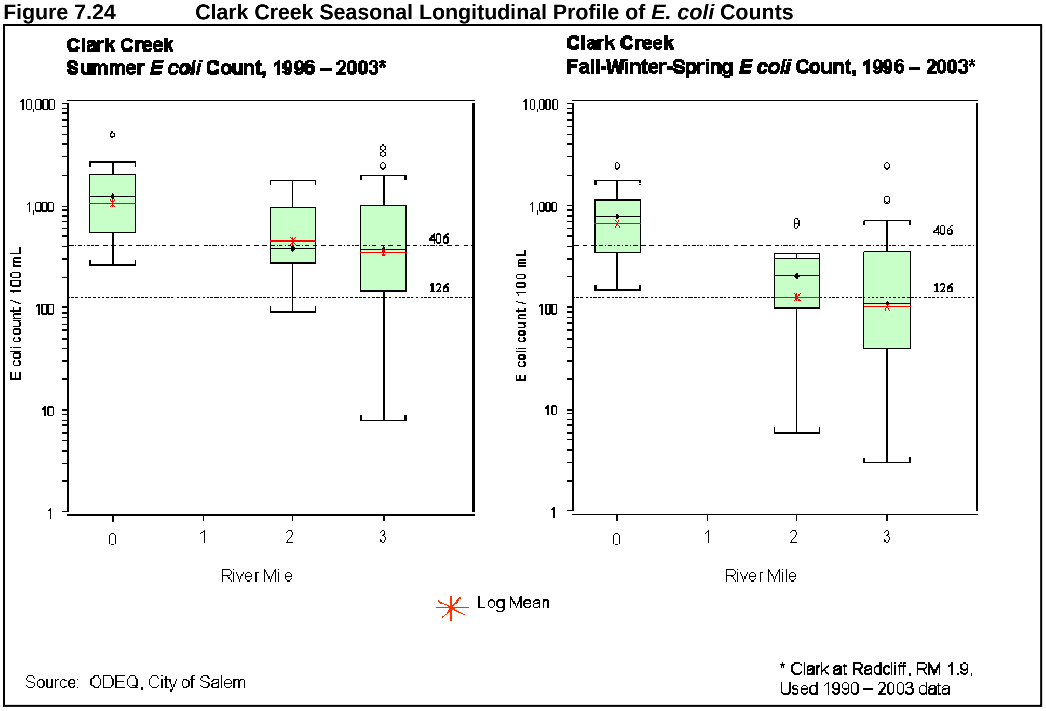


Figure 7.25 Croisan Creek Longitudinal Profile of *E. coli* Counts

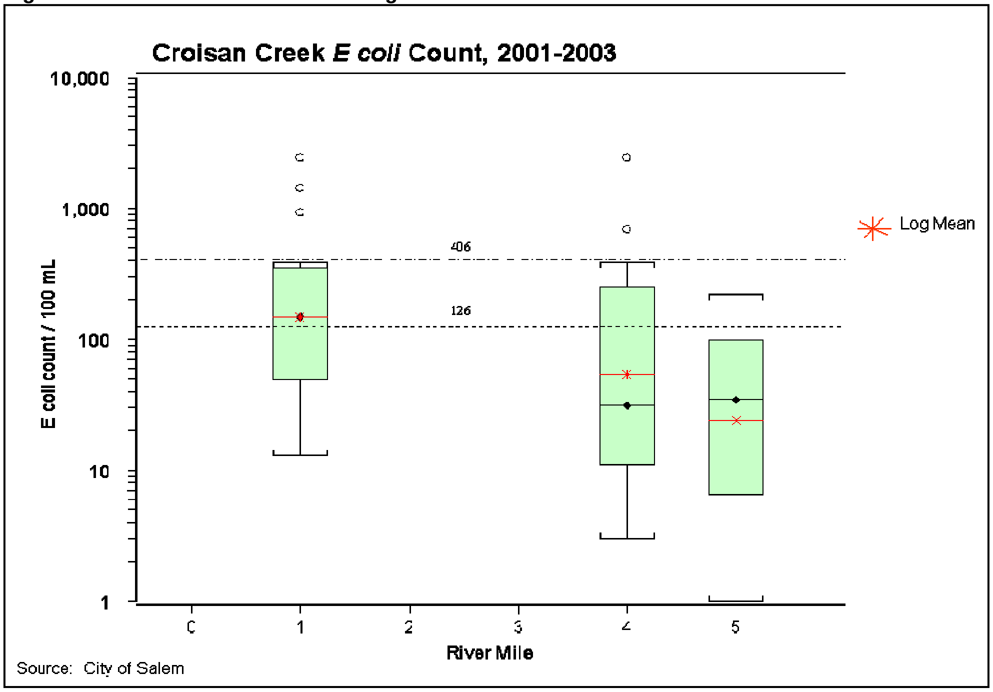
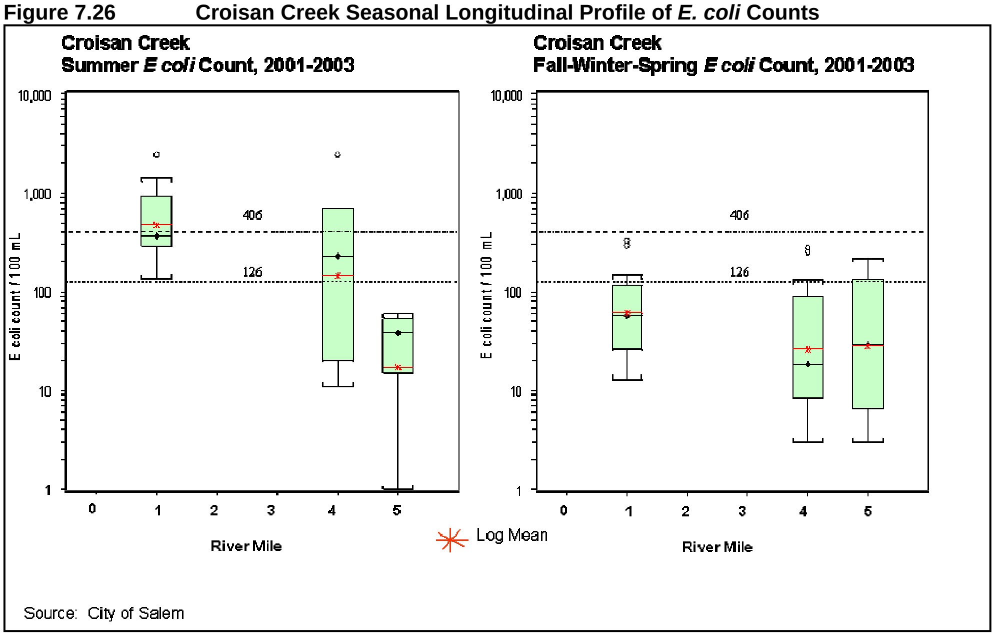


Figure 7.26 Croisan Creek Seasonal Longitudinal Profile of *E. coli* Counts



The three man-made diversions from Mill Creek: Mill Race, Shelton Ditch and Pringle Ditch; contributed *E. coli* concentrations above the criteria during both the summer and fall-winter-spring seasons, except for Pringle Ditch concentrations which were below both criteria in the fall-winter-spring. Year-round log means and single sample concentrations were greater than the criteria at both the Mill Race and Shelton Ditch sites (Figures 7.27 through 7.29). Mill Race and Shelton Ditch divert water from Mill Creek to Pringle Creek. Mill Race is located closer to the mouth of Pringle Creek, diverting water from Mill Creek at RM 2.3 and discharging into Pringle Creek at RM 0.2. Shelton Ditch is located upstream of Mill Race and diverts water from Mill Creek at RM 3.5 that flows into Pringle Creek at RM 0.4.

Figure 7.27 Mill Race and Shelton Ditch Longitudinal Profile of *E. coli* Counts

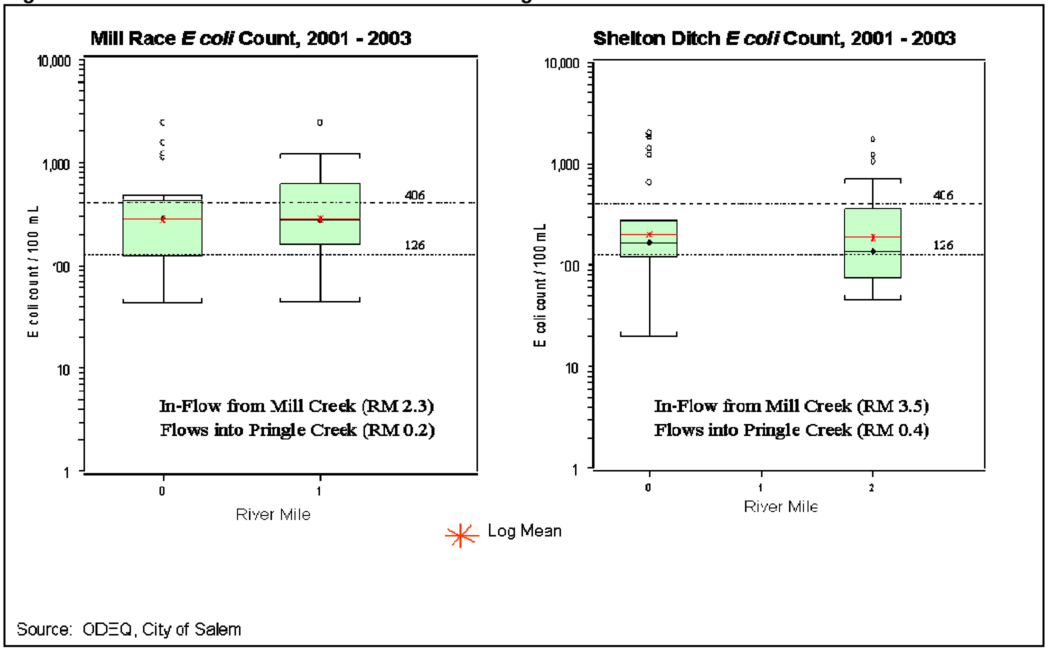


Figure 7.28 Mill Race Seasonal Longitudinal Profile of *E. coli* Counts

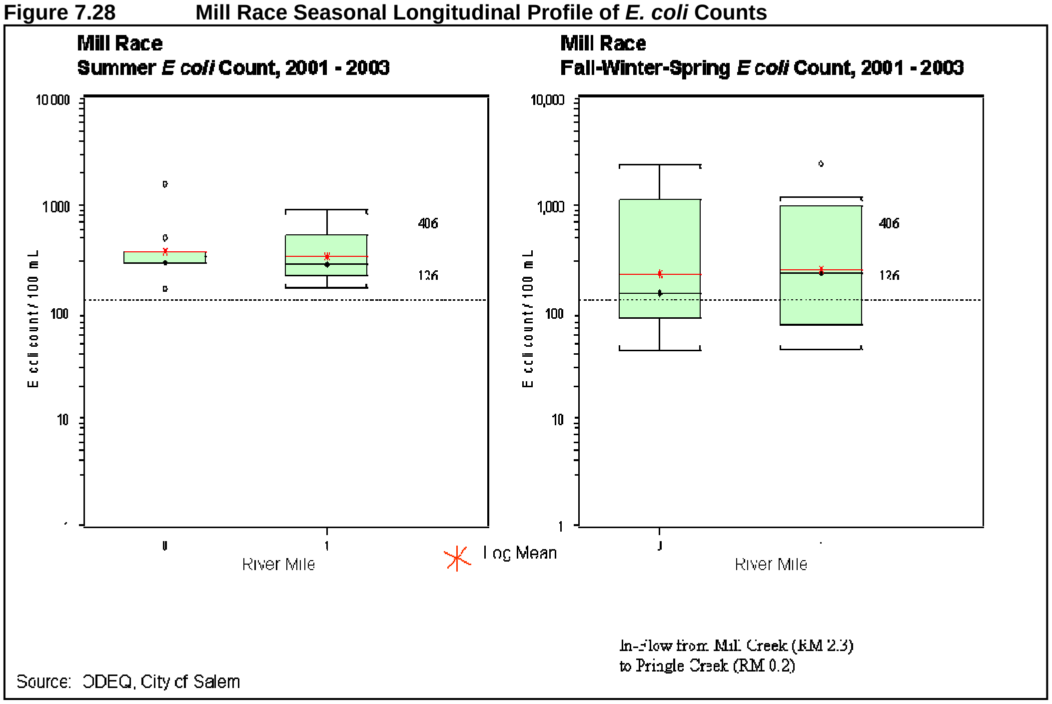
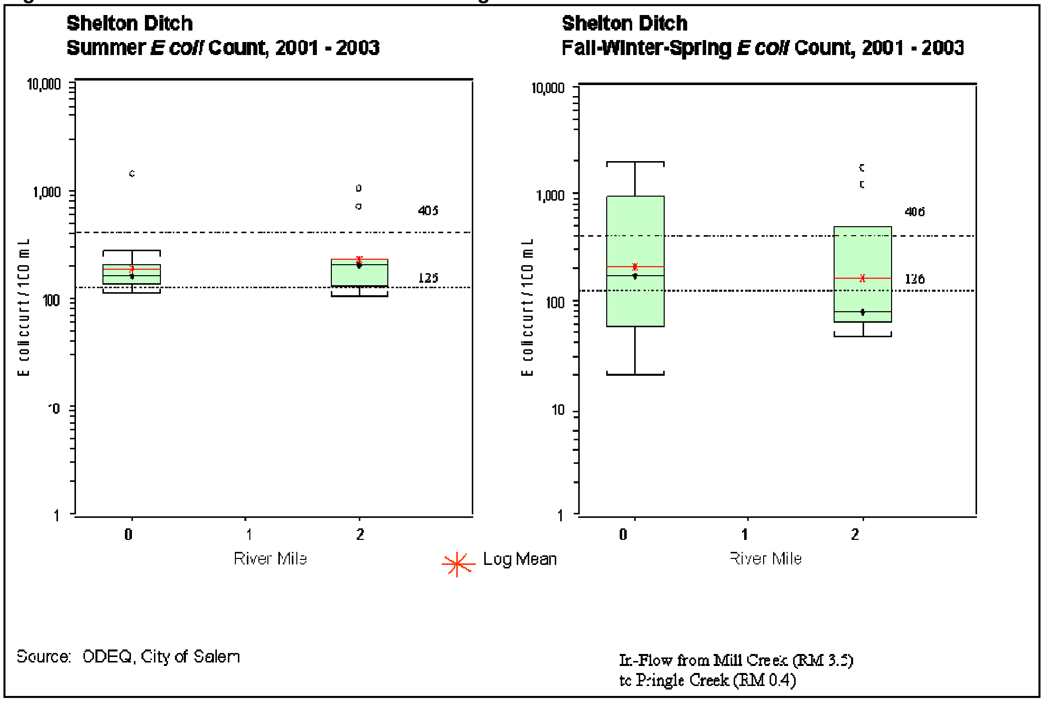


Figure 7.29 Shelton Ditch Seasonal Longitudinal Profile of *E. coli* Counts



Rickreall Creek Watershed-Bashaw Creek

The only listed waterbody in the Rickreall Creek Watershed is Bashaw Creek, which is listed as water quality limited year round for exceeding the bacteria criteria (Map 7.15). Note that while Bashaw Creek is classified as part of the Rickreall Creek Watershed, it is located on the opposite side of the Willamette River from Rickreall Creek and is not a tributary to Rickreall. The Bashaw Creek listing is based on fecal coliform data collected by ODEQ from 1983 to 1985. Half (4 of 8) of the samples collected exceeded the fecal coliform 90^{th} percentile criterion of 400 colonies per 100 mL, with a maximum value of 4600 fecal coliform colonies per 100 mL reported. ODEQ's bacteria criteria changed from fecal coliform to *E. coli* in 1996.

Miller Creek splits to form Bashaw Creek and Sydney Power Ditch. Approximately 2 miles of Bashaw Creek's headwaters flow through Ankeny National Wildlife Refuge, where it flows through several marshes and duck ponds.

There are no individual NPDES permits issued in the Bashaw Creek Watershed. There are two general permits in the Watershed, one for a winery that is not permitted to discharge to surface waters, and a storm water permit for a painting facility near Creswell Canyon Creek. Neither of these facilities is a likely source of bacteria. The only CAFO in the Watershed is an 800 animal dairy adjacent to Bashaw Creek.

Bashaw Creek and Rickreall Creek were both sampled by ODEQ during February and March 2003 during the ODEQ intensive survey, providing the only *E. coli* data available for analysis, (Table 7.22 and Figure 7.30). Concentrations in Bashaw Creek during the winter survey exceeded the log mean criterion slightly (132 counts/100 ml) and 25% (2) of the samples exceeded the single sample criterion (406 counts/100 ml). *E. coli* concentrations in Rickreall Creek did not exceed the log mean criterion, and had one modest violation (426 counts / 100 ml) of the single sample criterion. Both Bashaw and Rickreall Creek represent agricultural land use, although Bashaw Creek also flows through Ankeny National Wildlife Refuge.

Map 7.15 Bashaw Creek Watershed Spatial Distribution of Bacteria 303(d) Listed Streams, Land Use, Sampling Sites, Point Sources, and Wildlife Refuge Boundary.

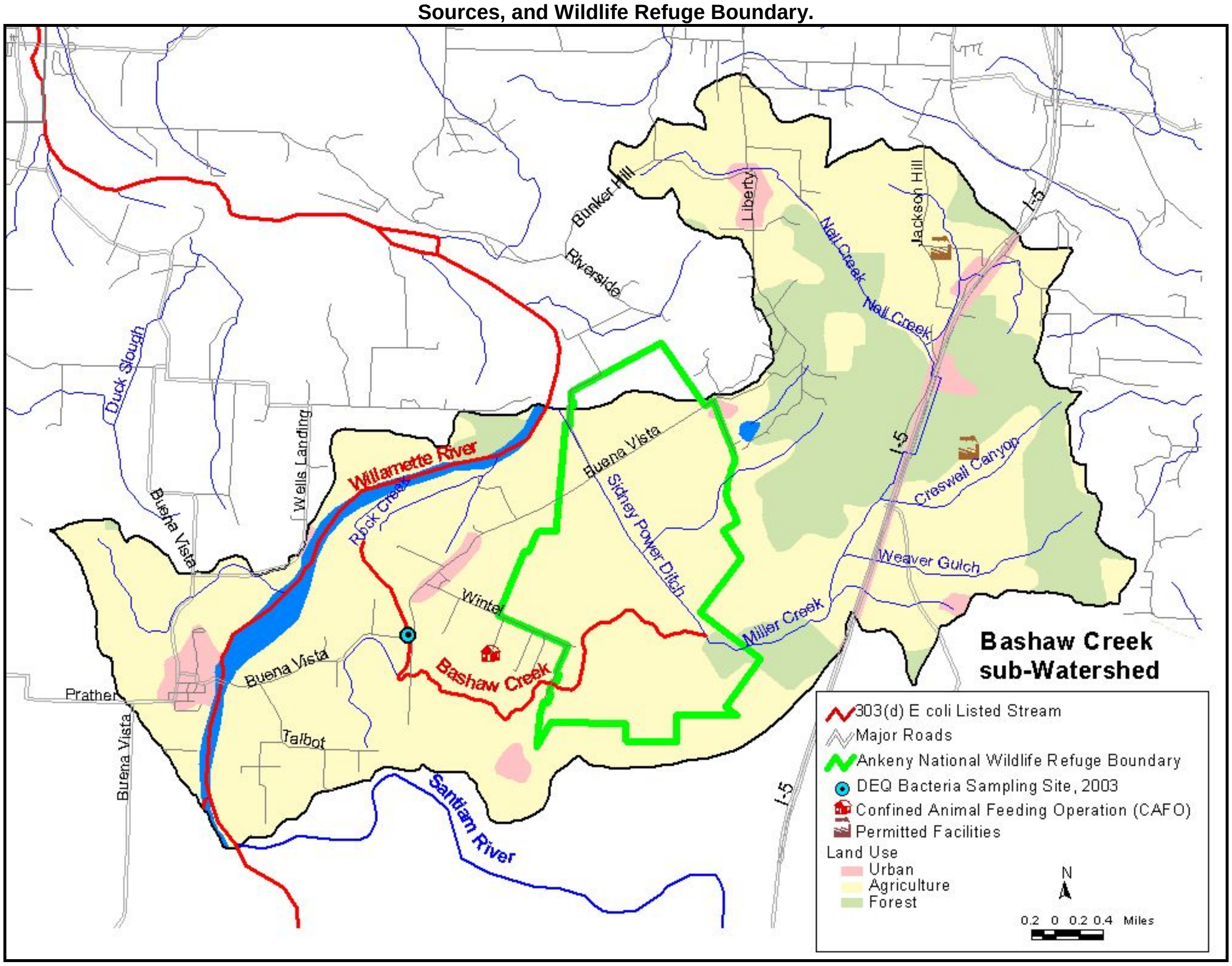
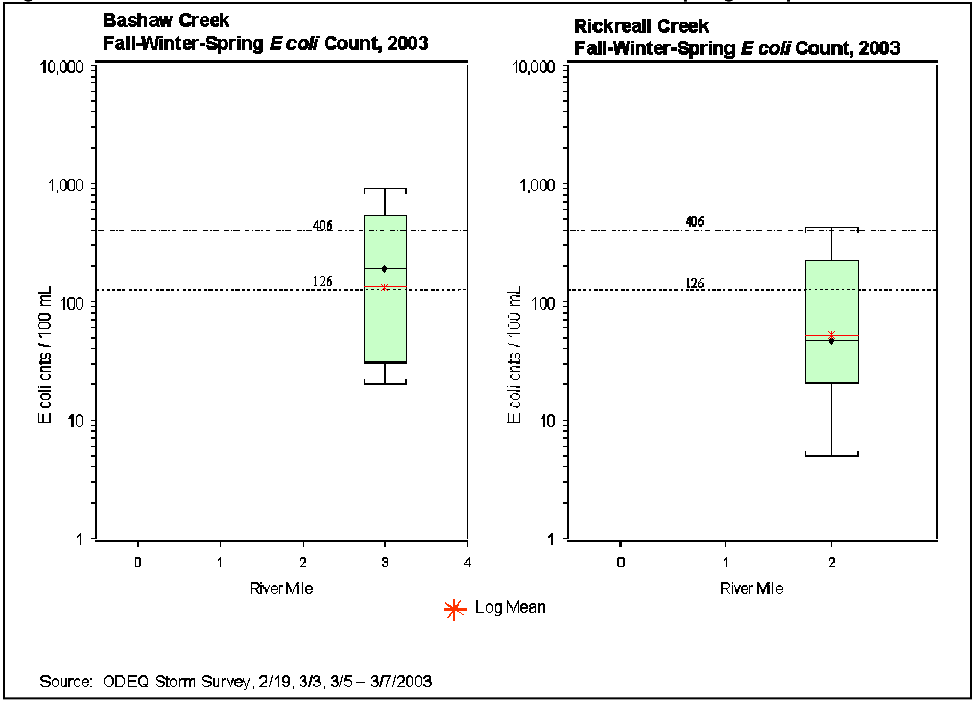


Table 7. 22 Fall-Winter-Spring Bashaw Creek and Rickreall Creek *E. coli* Survey Results, ODEQ Data

Fall-Winter-Spring Statistics									
Rm	Site	ODEQ Intensive Survey Log Mean (2/19, 3/3, 3/5 - 3/7/2003)	N	Log Mean	Mean	90th Percentile	% > 406	max	Land Use
Bashaw Sub-Watershed									
Bashaw Creek									
3.8	Bashaw Creek at Buena Vista Road	132	8	132	301	812	25%	907	Agriculture
Rickreall Creek Watershed									
Rickreall Creek									
2.2	Rickreall Creek at Hwy. 51	52	8	52	127	357	13%	426	Agriculture
							[shaded]	: exceeding criteria	

Figure 7.30 Bashaw Creek and Rickreall Creek Fall-Winter-Spring box plot of E. coli Counts



Loading Capacity

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

The loading capacity is applied to all the water bodies in the Middle 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 Middle Willamette Subbasin.

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 concentrations 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.

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[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.

USEPA 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

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

Wasteload Allocations

OAR 340-042-0040(4)(e), 40 CFR 130.2(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 7.23). 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.

Wasteload allocations for treatment plants are variable depending on effluent and river flow. Regardless of the actual load discharged by treatment plants, they are required to meet water quality standards at the end of the pipe (prior to discharge). ODEQ has included an estimate of the potential loading based on a measure of flow from the treatment plants. This is only an estimate and not a regulatory limit. However, the estimate serves to demonstrate that loads from WWTPs are relatively small and if controlled at the end of the pipe will not contribute to violations of water quality standards.

Table 7. 23 Wasteload Allocations for Wastewater Treatment Plants (WWTP) and Confined Animal Feeding Operations (CAFO). CAFO loads are limited by permit requirements.

Facility	Receiving Water	River Mile	Geometric Mean Limit (MPN/100 ml *E. coli*)	Instantaneous Limit (MPN/100 ml *E. coli*)	Estimate of Wet Weather Load (Organisms / day)
City of Aumsville (no discharge June 1-Oct. 31)	Beaver Cr.	2.5	126	406	5.49×10^9
City of Dallas	Rickreall Cr.	10.5	126	406	8.37×10^9
Confined Animal Feeding Operations (CAFO)[a]	Various	NA	0	0	0

a= CAFOs are allowed zero discharge from confinement, storage, or concentration areas under terms or NPDES permit.
NA = Not Applicable

The total estimate of loading assumes all of the point sources discharge at the criterion for protection of human health. Each of these point sources and any future facilities have a flow based allocation that allows discharge of bacteria at this concentration or lower. This method of allocation ensures water quality standards are met by definition and a more explicit WLA is unnecessary.

Load Allocations

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

Load allocations have been developed for both the summer low flow period from July 1 to September 30, and for high flow fall-winter-spring period, October 1 to June 30. The allocations are calculated to protect the sensitive beneficial use, water contact recreation.

Load allocations are expressed in terms of the percent reduction of in-stream bacteria concentrations necessary to achieve the numeric criteria. The percent reduction calculated for each watershed is based on the maximum percent reduction needed to meet the numeric criteria for each land use. The sampling site within each watershed with the maximum percent reduction needed is defined as the compliance point. Allocations are determined separately for each 303(d) listed stream watershed; Mill Creek Watershed, Pringle Creek Watershed (which includes Clark Creek) and Bashaw Creek Watershed. The percent reductions are determined separately for summer and for fall-winter-spring periods according to land use type.

An allocation has also been developed for the remainder of the Middle Willamette Subbasin outside of the Mill Creek, Pringle Creek and Bashaw Creek Watersheds. These overall allocations are land-use specific and are based on the averaging of percent reductions calculated for each land use in the 303(d) listed stream watersheds.

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 both MS4 and nonpoint source (load) allocations. The percent reduction was calculated by using the 75th percentile of the measured samples, rather than the calculated log mean of the data set to meet the log mean criteria. This approach was used in other Willamette subbasin bacteria TMDLs. 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 94% 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 at the 75th percentile.

Mill Creek Watershed

The percent reduction in in-stream bacteria concentrations necessary to meet the log-mean criterion for the summer period in Mill Creek is presented in Table 7.24. The table indicates the calculated percent reduction necessary at each sampling site along the stream reach to achieve compliance with the bacteria criteria.

Mill Creek is allocated an 89% reduction of *E. coli* counts in the summer at the compliance point located at the mouth near the Capitol Street / Front Street Bridge. Water quality samples were only collected in the urban portion of Mill Creek during the summer period, however application of the 89% reduction to the Mill Creek Watershed as a whole during the summer season will attain water quality standards at the mouth of Mill Creek.

The percent reductions necessary to meet the log mean criterion for the fall-winter-spring period in Mill Creek watershed are presented in Table 7.25. The fall-winter-spring sampling in Mill Creek includes three land use types; urban, agricultural and forest lands. Mill Creek's urban point of compliance is at Turner Road and is allocated an 81% reduction. The agricultural point of compliance for Mill Creek is at Marion Road, which is allocated an 83% reduction. There were no violations of the bacteria criteria in forested sites in Mill Creek, thus a 0% reduction is allocated. The 81% urban, 83% agricultural, and 0% forested land use percent reductions apply to all streams in the Mill Creek Watershed as per their designated land use classification.

Pringle Creek Watershed

The percent reductions necessary to meet the log mean criterion for the summer period in the Pringle Creek watershed are presented in Table 7.24. Pringle Creek is allocated a 90% reduction in the summer at West Pringle Creek at Madrona Road / Pringle Road compliance point. Clark Creek was allocated a 94% reduction in the summer, with a compliance point on Clark Creek at Bush Park. Both compliance points represent an urban land use and are stream specific. An average of the percent reductions calculated for Pringle Creek and Clark Creek is applied to all other streams in the Pringle Creek watershed, allocating a 92% reduction for the summer period.

The percent reductions necessary to meet the log mean criterion for the fall-winter-spring period are presented in Table 7.25, and are stream specific. Pringle Creek is allocated a 79% reduction of *E. coli* counts in the summer at the compliance point of West Pringle Creek at Pringle Park / Church Street. Clark Creek was allocated an 89% reduction of *E. coli* counts in the summer, with a compliance point of Clark Creek at Bush Park. Both compliance points represent an urban land use. The average of the percent reductions calculated for Pringle Creek and Clark Creek is applied to the non 303(d) bacteria listed streams in the Pringle Creek Watershed for fall-winter-spring, allocating a reduction of 84%.

Bashaw Creek Watershed and Rickreall Creek

Bashaw Creek is allocated a 68% reduction of *E. coli* counts year round, Table 7.25. The compliance point on Bashaw Creek at Buena Vista Road represents an agricultural land use. Water quality sampling of *E. coli* occurred during the fall-winter-spring, with no samples collected during the summer period. However, the 68% reduction of *E. coli* applies year round and should result in compliance with both bacteria criteria. The 68% reduction applies to all streams in the Bashaw Creek sub-watershed.

Table 7. 24 Summer Percent Reductions. Note: Bashaw Creek sub-watershed is not shown in this table but is allocated a 68% reduction during the summer period.

Summer
Compliance Points:

Rm	Site	N	% Reduction: based on 75th Percentile (126)	Land Use
Mill Creek Watershed				
Mill Creek 89% reduction				
1.0	Mill Creek at Capitol St / Front Street Bridge	11	89%	Urban
Pringle Creek Watershed				
Pringle Creek 90% reduction				
3.0	West Pringle at Madrona Rd / Pringle Rd	17	90%	Urban
Clark Creek 94% reduction				
0.1	Clark Creek at mouth in Bush Park	19	94%	Urban

Table 7. 25 Fall-Winter-Spring Percent Reductions.

Fall-Winter-Spring
Compliance Points:

Rm	Site	N	% Reduction: based on 75th Percentile (126)	Land Use
Mill Creek Watershed				
Mill Creek 81% reduction Urban / 83% reduction Agriculture / 0% reduction Forestry				
7.0	Mill Creek at Turner Road	22	81%	Urban
11.9	Mill Creek at Marion Road	8	83%	Agriculture
19.0	Mill Creek at Golf Club Road	7	0%	Forestry
Pringle Creek Watershed				
Pringle Creek 79% reduction				
0.5	Pringle Creek at Pringle Park / Church Street	38	79%	Urban
Clark Creek 89% reduction				
0.1	Clark Creek at mouth in Bush Park	35	89%	Urban
Bashaw Creek sub-Watershed				
Bashaw Creek 68% reduction in Agriculture				
1.0	Bashaw Creek at Buena Vista Road	8	68%	Agriculture

Middle Willamette Subbasin Percent Reductions

The Middle Willamette Subbasin percent reductions apply to streams in watersheds not otherwise allocated in previous sections. The percent reductions for each land use in the subbasin were calculated based on statistical analysis of all the data presented in this TMDL. The percent reduction calculated for each land use within the subbasin was calculated as the percent reduction needed to meet the log mean criteria for the 75th percentile of the data set.

A summer percent reduction for the Middle Willamette Subbasin is presented in Table 7.26. The Middle Willamette Subbasin is allocated an agriculture percent reduction of 95%, forested land use is allocated a 0% reduction, and urban land use is allocated an 88% reduction in *E. coli* bacteria counts during the summer period.

Table 7. 26 Middle Willamette Subbasin Summer Percent Reductions per Land Use

Summer Statistics				
Land Use	**N**	**Log Mean**	**75th percentile**	**% Reduction: based on 75th Percentile (126)**
Agriculture	21	486	2,419	**95%**
Forest	4	17	50	**0%**
Urban	199	471	1,090	**88%**

A fall-winter-spring Middle Willamette Subbasin land use based percent reduction is presented in Table 7.27. The Middle Willamette Subbasin is allocated a 61% reduction in agriculture land uses, a 0% reduction in forest land uses, and a 75% reduction in urban land uses during the fall-winter-spring period.

Table 7. 27 Middle Willamette Subbasin Fall-Winter-Spring Percent Reductions per Land Use

Fall-Winter-Spring Statistics				
Land Use	**N**	**Log Mean**	**75th percentile**	**% Reduction: based on 75th Percentile (126)**
Agriculture	93	108	327	**61%**
Forest	26	37	109	**0%**
Urban	408	183	511	**75%**

Excess Load

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

Since neither load allocations for nonpoint sources nor wasteload allocations for point sources were directly calculated, 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 Middle 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 compliance 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 Middle 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 75th percentile to compare to the 126 *E. coli* counts / 100 mL log mean criteria. The 75th 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 Middle 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.

Reserve Capacity for the Middle Willamette Subbasin was set at 1/10th of the Loading Capacity. This allows for future growth and expansion overall, though it is not provided to increase loading for point source discharges. Point source discharges are currently limited to meeting bacterial water quality criteria prior to discharge. In this way, point sources do not decrease loading capacity of the stream. Increased and existing point source discharges will also be required to meet these criteria prior to discharge to the Middle Willamette Subbasin streams.

DIELDRIN DISCUSSION PAPER: MIDDLE WILLAMETTE SUBBASIN

The Middle Willamette Subbasin dieldrin discussion paper provides a data summary of dieldrin in Pringle and Champoeg Creeks, and a plan of action proposed by ODEQ to identify and control dieldrin loading in the Pringle Creek and Champoeg Creek Watersheds. This document will also discuss the fate and transport of dieldrin, the sensitive beneficial use impairment, water quality standards for dieldrin, a discussion of past and current dieldrin studies, and a synthesis of the dieldrin data available.

Pringle and Champoeg Creeks are listed on Oregon's 303(d) list for exceeding the dieldrin criteria for protection of aquatic life year round. Total Maximum Daily Loads (TMDLs) are developed for streams listed on the 303(d) List as water quality limited; however, a toxics TMDL was not developed for the Middle Willamette Subbasin that would address the dieldrin listing in Pringle and Champoeg Creeks. The decision to not complete a toxics TMDL was due to the lack of dieldrin data available to develop an accurate source assessment and load allocation in time for the Willamette Basin TMDL public draft. ODEQ did collect water column data during the summer of 2002, and in the winter of 2003, in the Pringle Creek Watershed for the purposes of developing this TMDL. However, the data set was limited in scope and did not clearly identify a source. The goal of a Middle Willamette Subbasin Toxics TMDL is to reduce the concentration of dieldren in the water column, which will reduce the threat to human health due to fish and water consumption and minimize the negative impacts on aquatic life. A toxics TMDL must demonstrate that water quality standards will be met and beneficial uses protected year-round. Due to the lack of dieldrin data, ODEQ recommends further monitoring of dieldrin to develop a better understanding of the magnitude of the distribution of dieldrin in the Pringle Creek Watershed, especially near Bush Park, and in the Champoeg Watershed. At a minimum, dieldrin sample collection should occur during precipitation and non-precipitation events to develop a better understanding of the temporal and spatial distribution of dieldrin in-stream and to determine if dieldrin loading increases during runoff events. Data collection should also include stream flow, temperature, total suspended solids, and pH collection at the time of dieldrin sample collection. This additional data collection effort will provide for the development of an accurate source assessment, and other necessary components of a TMDL. ODEQ recommends the stabilization and erosion control of upland sediment to control erosion and overland flow of soils which may be contaminated with dieldrin because dieldrin does bind tightly to soil (Anderson, et.al, 1997).

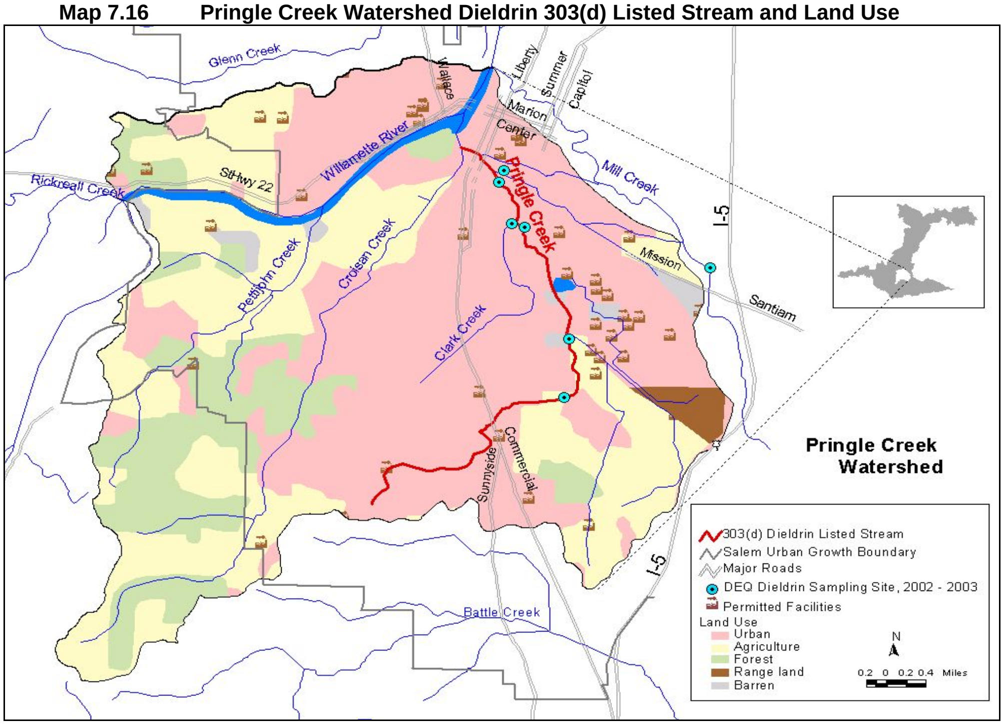
303(d) Listing

Pringle and Champoeg Creeks are listed on the 303(d) List for exceeding the fresh water chronic criteria for dieldrin, a toxic organochlorine pesticide. Dieldrin was identified in the water column of Pringle Creek by the United States Geological Survey (USGS) as part of their National Water Quality Assessment (NAWQA) Program, 1991 - 1995. The listing is based on the identification of two out of three samples collected in Pringle Creek at Bush Park exceeding the fresh water chronic, and the water and fish ingestion criteria. The three samples averaged 0.0025 μg /L. Dieldrin was again detected in the water column of Pringle Creek by the USGS in six of six samples in 1996, with an average concentration of 0.1 ug/L. Champoeg Creek is also listed on the 303(d) list for exceeding the fresh water chronic criteria with dieldrin data collected by the USGS. Two out of two samples collected by the USGS exceeded the fresh water chronic criteria. Both Pringle Creek and Champoeg Creek are listed year round.

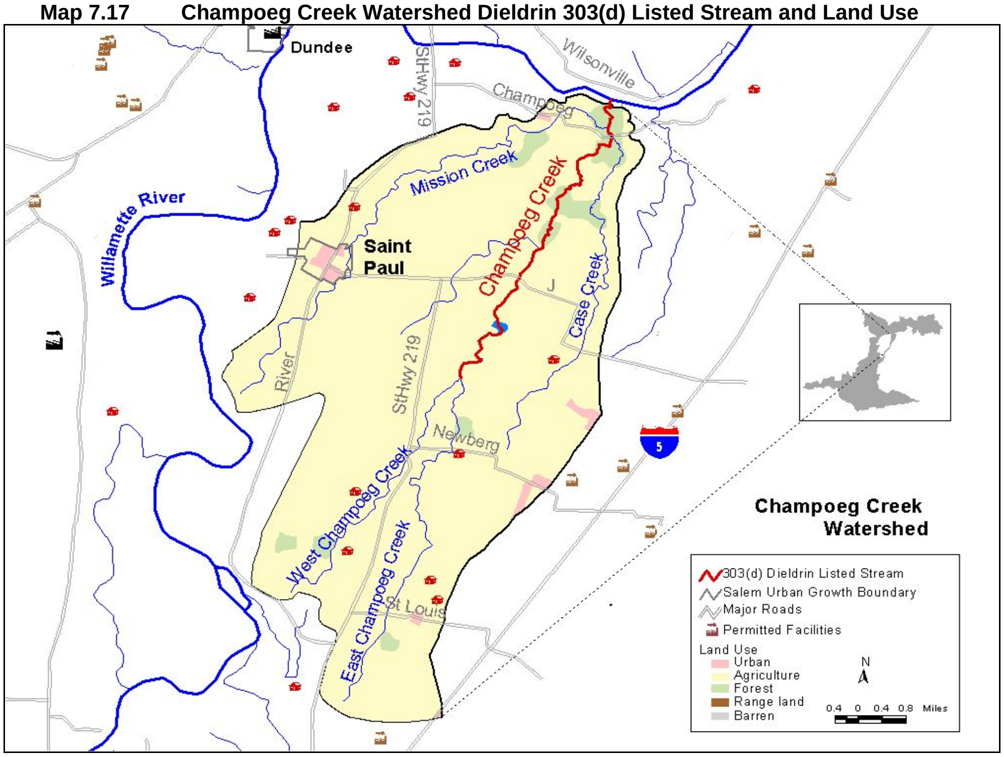
Watershed Background

Pringle Creek is located in the Pringle Creek Watershed (USGS Hydrologic Unit Code 170900070302) and is 28 square miles (17,920 acres), Map 7.16. Champoeg Creek is located in the Champoeg Creek Watershed (Hydrologic Unit Code 170900070305) and is 44 square miles (28,342 acres), Map 7.17. Both watersheds flow through the eastern valley bottom to the Willamette River, are primarily flat low lying streams consisting of rolling hills of moderate slope. Pringle Creek Watershed is completely within the Salem city limits and Champoeg Creek Watershed overlaps the city of Saint Paul.

Map 7.16 Pringle Creek Watershed Dieldrin 303(d) Listed Stream and Land Use



Map 7.17 Champoeg Creek Watershed Dieldrin 303(d) Listed Stream and Land Use



Pringle Creek Watershed is highly developed with 44% of the area classified as urban. Agricultural land use represents 38% of the watershed, predominantly in the headwaters of Pettijohn and Croisan Creek. Pringle Creek drains an urban land use. Champoeg Creek watershed is primarily an agricultural land use watershed. Historically, the agricultural plots in the City of Salem were plotted above a drain tile system. As land use changed from agriculture to rural to urban in the watershed it has caused tiles to be destroyed and neglected affecting the drainage and soil stability (Laenen, 1983).

Pringle Creek Watershed contains two large tracts of public land: the Salem Airport and the Fairview Training Center site. However, the majority of the watershed is privately owned. Champoeg Creek watershed is entirely privately owned.

Due to the dominant urban land use within the Pringle Creek Watershed there are no CAFOs reported by the Department of Agriculture as of March 2003, however hobby farms may exist. Due to the dominant agricultural use in Champoeg Creek Watershed there are seven CAFOs reported within its boundaries.

There are 45 general permits in the watershed, 32 of which are storm water permits. There are no point sources within the Champoeg Creek watershed.

Pringle Creek has three man made in-flows from Mill Creek, Pringle Ditch (Pringle Creek RM 2.6), Shelton Ditch (Pringle Creek RM 0.4) and Mill Race (RM 0.2). The in-flows have been engineered to mitigate flooding in downtown Salem and to maintain a minimum stream flow in Pringle Creek. The in-flows are operational year-round.

There are no real-time or historic flow gages in the Pringle Creek and Champoeg Creek watersheds.

Properties of Dieldrin and Historical Use

Dieldrin is a chlorinated pesticide that is a persistent, bioaccumulative, and toxic pollutant (PBT). Dieldrin is extremely persistent in the environment, and by means of bioaccumulation it is concentrated many times as it moves up the food chain. Its persistence is due to its extremely low volatility and low solubility in water resulting in a high affinity for fat. Dieldrin has a low Koc value, which does not allow dieldrin to be correlated with suspended solids. The Koc value is the soil organic carbon-water partitioning coefficient. It is the ratio of the mass of a chemical that is adsorbed in the soil per unit mass of organic carbon in the soil per the equilibrium chemical concentration in solution. It is the "distribution coefficient" (Kd) normalized to total organic carbon content. Koc values are useful in predicting the mobility of organic soil contaminants; higher Koc values correlate to less mobile organic chemicals, while lower Koc values correlate to more mobile organic chemicals. Pesticides with high Koc values are typically not very water soluble and will preferentially adhere to soils rather than be dissolved in water. This means that pesticides in this class are unlikely to be carried off-site in runoff as dissolved substances; instead, they are transported on sediment particles.

Dieldrin released to soil will persist for long periods (> 7 yr), will reach the air either through slow evaporation or adsorbtion on dust particles, will not leach, and will reach surface water by overland flow. Once dieldrin reaches surface waters it will adsorb strongly to sediments, bioconcentrate in fish and slowly photodegrade. Biodegradation and hydrolysis are not important fate processes. Dieldrin in soil and water breaks down very slowly. It photorearranges to photodieldrin with a water half-life of 4 months. Due to the extensive past use and the persistence of dieldrin, it is virtually ubiquitous in the environment and has been detected in virtually all media (water, soil, tissue, etc.). Dieldrin is a carcinogen and a suspected endocrine disrupter that may affect reproduction or development of aquatic organisms or wildlife by interfering with natural hormones.

Dieldrin is a long-lived oxidation breakdown product of the organochlorine pesticide aldrin. Aldrin quickly breaks down into dieldrin in the body or in the environment, typically within a matter of days. Thus, the environmental concentrations of dieldrin are a cumulative result of the historic use of both aldrin and dieldrin. Sunlight and bacteria change aldrin to dieldrin so that dieldrin is mostly found in the environment.

In the United States, the use of dieldrin was banned in 1987 by the United States Environmental Protection Agency (USEPA). Prior to 1987 dieldrin was primarily used for control of corn pests by application to the soil. Other uses included general crop protection from insects, timber and lumber preservation, and termite-proofing of plastic and rubber coverings of electrical and telecommunication cables.

The USEPA ban in 1987 canceled the production and distribution of dieldrin. However, USEPA did allow use of existing stocks under certain conditions, specifically the use of dieldrin as an active ingredient in other pesticides. In August 23, 2000 the Oregon Department of Agriculture (ODA) adopted an emergency rule that prohibited any use of pesticide products containing ten specific active ingredients identified as PBTs, to include dieldrin and aldrin. The rule prohibiting the use of these PBTs went into effect immediately. As a result, ODA became the first state agency to take action on Governor Kitzhaber's executive order to eliminate releases of PBTs into the environment. ODA's new rule now prohibits any and all use in Oregon. (http://oda.state.or.us/pesticide/pubform/newsletters/fall00.pdf)

The quantity and geographic distribution of historical organochlorine pesticide use in the Pringle Creek and Champoeg Creek Watersheds has not been well documented. However, it is clear that historical use of dieldrin and aldrin in the watersheds continues to cause violations of water quality criteria. The organochlorine pesticide, dieldrin, is considered a legacy pollutant since it is highly unlikely that significant amounts of the chemical have been applied in the watershed since the ban in 1987.

Beneficial Use Identification

The most sensitive beneficial use related to dieldrin in Pringle and Champoeg Creeks is fishing. Oregon Administrative Rules OAR 340-041-0340 Table 340A lists all the beneficial uses occurring within the Willamette River Basin tributaries. Numeric and narrative water quality standards are designed to protect the most sensitive beneficial uses.

Water Quality Criteria

Acceptable concentrations of toxic compounds are listed in OAR 340-41, Table 20 and 33A. Applicable criteria values for regulatory purposes depend on the most sensitive beneficial use to be protected and what level of protection is necessary for aquatic life and human health.

The concentration for each compound listed in these tables is a criterion not to be exceeded in waters of the state in order to protect aquatic life and human health. All values are expressed as micrograms per liter (µg/L) except where noted. The acute criteria refer to the average concentration for one (1) hour and the chronic criteria refer to the average concentration for 96 hours (4 days), and that these criteria should not be exceeded more than once every three (3) years.

The criteria in the Table 7.28 reflect a mixture of those criteria shown in Tables 20 and 33A from the Oregon Administrative Rules (340-41) which can be found at http://www.deq.state.or.us/wq/wqrules/wqrules.htm . EPA has yet (as of March 2005) to approve the new criteria adopted by the EQC in May 2004; therefore, OAR 340-041-0033 stipulates that for those criteria more stringent than the criteria in effect before rule adoption, the Table 33A criteria are effective and for the remaining criteria, Table 20 criteria are effective. However, for Clean Water Act purposes, only more stringent State criteria can be used. Therefore, "Table 20" indicates that the most stringent criterion is from Table 20; "Table 33A" indicates that the most stringent criterion is from Table 33A. EPA has indicated that they hope to have a decision on ODEQs water quality toxics criteria revisions by May 2006.

The fresh water numeric criteria for dieldrin is 0.0019 µg /L for a chronic exposure and 0.24 µg /L for an acute exposure, Table 7.28. Marine environments have their own chronic and acute criteria. The human health criteria for water and fish ingestion is 0.000052 µg /L and 0.000054 µg /L for fish consumption.

Table 7. 28 Dieldrin Water Quality Criteria

Freshwater (µg/L)				Saltwater (µg/L)				Human Health (µg/L)			
Acute (CMC)		Chronic (CCC)		Acute (CMC)		Chronic (CCC)		Water + Organism[B]		Organism only[B]	
0.24	Table 33A	0.0019	Table 20	0.71 O	Table 33A	0.0019 O	Table 33A	0.000052	Table 33A	0.000054	Table 33A

B	Human Health criteria values were calculated using a fish consumption rate of 17.5 grams per day (0.6 ounces/day) unless otherwise noted.
O	This criterion is based on EPA recommendations issued in 1980 that were derived using guidelines that differed from EPA's 1985 Guidelines for minimum data requirements and derivation procedures. For example, a "CMC" derived using the 1980 Guidelines was derived to be used as an instantaneous maximum. If assessment is to be done using an averaging period, the values given should be divided by 2 to obtain a value that is more comparable to a CMC derived using the 1985 Guidelines.

USGS Studies

The presence of the organochlorine pesticide, dieldrin, was detected by the USGS in both surface water and streambed sediment in the Pringle Creek Watershed. In the 1990's, the USGS conducted four studies examining the distribution of organochlorine pesticides in the Willamette Basin, a summary of each follows:

- **NAWQA's Water Quality in the Willamette Basin**, 1991-1995 (Wentz, et al, 1998):

The USGS NAWQA report, 1991 – 1995, identified two out of three samples collected in Pringle Creek at Bush Park exceeding the fresh water chronic criteria, and water and fish ingestion criteria, with an average of 0.0025 µg /L (USGS Circular 1161). This data was used as the means for the Pringle Creek year-round dieldrin 303(d) listing. The study also identified the likely association of dieldrin with aquatic biota, incorporated into tissue, or bed sediment rather than the water column (Wentz, et al, 1998).

- **Occurrence of Selected Trace Elements and Organic Compounds and their Relation to Land Use in the Willamette River Basin**, 1992-1994 (Anderson, et.al; 1996):

This study identified that water quality samples collected at Pringle Creek at Bush Park exceeded the freshwater aquatic life criteria for chronic toxicity, and the criteria for protection of human health for water and fish ingestion (carcinogenic risk level of 1 in 1 million). Champoeg Creek below Mission Creek near Butte Ville was also sampled and exceeded the dieldrin fresh water chronic criteria.

- **Distribution of Dissolved Pesticides and Other Water Quality Constituents in Small Streams, and their Relation to Land Use, in the Willamette River Basin**, 1996 (Anderson, et.al; 1997):

This study supported the conclusions generated from previous USGS studies that organochlorine pesticides are a localized concern confined to specific streams in subbasins where they historically were used, for example, the historical use of dieldrin in the Pringle Creek and Champoeg Creek Watersheds.

- **Selected Elements and Organic Chemicals in Streambed Sediment in the Salem Area,** 1999 (Tanner, 2002):

Dieldrin was detected in four Salem area streambed sediment samples, including Pringle Creek. Aldrin was detected in stream bed sediment in East Fork Pringle Creek. The largest concentration of dieldrin of the 14 sites in the streambed sediment study was found in Clark Creek. The study questioned the possibility of a common source for aldrin, and ultimately dieldrin, in the East Fork Pringle Creek drainage area. Aldrin degrades naturally into dieldrin which can then become stored in lipid tissue. In the study, dieldrin was positively correlated with urban land use. The concentrations at all 14 sites were in the range previously found throughout the Willamette Basin. The study recommended testing of invertebrate and fish tissues for dieldrin to help assess potential hazards to humans. This study also recommends further monitoring of the water column in the Salem area.

- **NAWQA's Water Quality in the Willamette Basin**, 2003 (phone conversation with Mike Sarantou, USGS, 2003)

The USGS sampled streams in the Salem area several times in 2003, as part of the Willamette NAWQA Urban Land-Use Gradient Study (ULUG). One of the analytes will be dieldrin, but only on filtered water samples. Results were currently unavailable.

ODEQ Study

As part of the Middle Willamette Subbasin TMDL, a work plan was developed in 2001 to address the 303(d) listing of Pringle Creek for exceeding the dieldrin criteria. Champoeg Creek was 303(d) listed in 2002, so the ODEQ study focused on the Pringle Creek listing which occurred in 1998. The basis of the Pringle Creek dieldrin work plan was to review existing data and to develop a sampling plan that would answer the following two questions regarding the dieldrin 303(d) listing in Pringle Creek:

1) Does existing data verify that dieldrin is still a water quality concern?

2) What are the source(s) of the toxic loading into the stream?

In the summer of 2002 (July 16 – 18) and in the winter of 2003 (March 5 -7) ODEQ completed intensive surveys of Pringle Creek and its tributaries, see Table 7.29 for a complete list of sites sampled.

Table 7. 29 ODEQ Dieldrin Sampling Sites

LASAR #	Site Name
28964	Clark Creek at Mouth
28962	Mill Creek at Hawthorne St
10655	Pringle Creek At Church Street
28736	Pringle Creek at Pringle Road
28966	Pringle Creek u/s Clark Creek
28967	Pringle Ditch at Madrona Ave
28737	Shelton Ditch at Church St

Each water column sample was analyzed at ODEQ's laboratory for the presence of chlorinated pesticides, including dieldrin. Each water sample was extracted within seven days of collection by Solvent Extraction GC / ECD method, with a method reporting limit of 0.001 ug/L, (Table 7.30) However, the water quality samples collected during the ODEQ summer sampling period were not analyzed immediately for chlorinated pesticides but rather only PCB's. Once the error was discovered the samples were analyzed for chlorinated pesticides as a means of only detecting their presence in the water column sample rather than reporting a quantified chlorinated pesticide concentration. The summer dieldrin samples were found to be in-conclusive. The winter water column samples were analyzed for chlorinated pesticides within the specified holding time limit, and provide a quantified concentration of dieldrin in each water column sample.

Table 7. 30 Water Chemistry Summary

Sampling Description	Analytes	Preservation	Holding Time	Analytical Method	Analytical Method Refer.	MRL
Laboratory Analysis	Chlorinated Pesticide/ PCB	Refrigerate @ 4°C	7 Days to extract	Solvent Extraction, GC/ECD	R2/608	0.001 ug/L

Method References: R2 = Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, Revised 3/83.

The winter ODEQ water column samples identified elevated dieldrin concentrations in Clark Creek at the mouth (Bush Park), Table 7.31. Two of the three samples collected at the mouth exceeded the fresh water numeric criteria for dieldrin of 0.0019 µg /L for a chronic exposure. The average of the two samples collected in Clark Creek at the mouth is 0.0020 µg /L. Sampling sites in Pringle Creek and Pringle Ditch did not exceed the chronic criteria. The winter ODEQ samples were taken during a precipitation event. No relationship was established between water column dieldrin concentrations and TOC, or dieldrin concentrations and precipitation.

Table 7. 31 Water Chemistry Results for ODEQ's Winter Sampling

LASAR #	Site Name	Date	Time	Dieldrin µg/L	TOC
10655	Pringle Creek at Church Street	3/5/03	13:20	0.001	1
10655	Pringle Creek at Church Street	3/6/03	15:20	0.001	1
10655	Pringle Creek at Church Street	3/7/03	11:55	<0.001 Est	3
28736	Pringle Creek at Pringle Road	3/5/03	10:10	0.001	1
28736	Pringle Creek at Pringle Road	3/6/03	13:45	0.001	1
28736	Pringle Creek at Pringle Road	3/7/03	9:55	<0.001 Est	2
28736	Pringle Creek at Pringle Road	3/7/03	9:56	<0.001 Est	2
28964	**Clark Creek at Mouth**	**3/5/03**	**11:50**	**0.002**	**1**
28964	**Clark Creek at Mouth**	**3/6/03**	**14:35**	**0.002**	**2**
28964	Clark Creek at Mouth	3/7/03	11:29	<0.001 Est	3
28967	Pringle Ditch at Madrona Ave	3/5/03	10:45	0.001	1
28967	Pringle Ditch at Madrona Ave	3/6/03	14:15	0.001	2
28967	Pringle Ditch at Madrona Ave	3/7/03	10:35	<0.001 Est	3

ODEQ was able to determine from this data collection effort that dieldrin is still a water quality concern within the Pringle Creek Watershed, specifically targeting Bush Park as a potential source (confluence of Clark Creek and Pringle Creek). However, the existing data set was not able to identify source(s) of the toxic loading into the stream or its correlation with runoff (precipitation) events.

Synthesis

In the early 1990's the USGS identified Pringle Creek at Bush Park and Champoeg Creek below Mission Creek near Butte Ville as having elevated concentration of dieldrin in the water column. This data was used to list Pringle Creek and Champoeg Creek on the 303(d) List. In 1999 the USGS and in 2003 the ODEQ identified elevated dieldrin concentrations in Clark Creek at the mouth. The USGS identified the largest concentration of dieldrin in streambed sediments in Clark Creek at the mouth of 14 sites sampled in Pringle Creek Watershed; and ODEQ identified water column dieldrin concentrations exceeding the chronic criteria in Clark Creek at the mouth. It is possible that upstream loading of dieldrin may be occurring in Clark Creek or soil runoff carrying particles associated with dieldrin may be flowing into both Clark Creek and Pringle Creek from Bush Park. Both the Pringle Creek site noted as having excess dieldrin concentrations by the USGS and the mouth of Clark Creek are located in Bush Park. It is possible that overland flow from Bush Park may be causing dieldrin loading to the streams. The ODEQ and USGS have not sampled the water column or stream sediment upstream of the mouth of Clark Creek. Champoeg Creek has not been sampled by the ODEQ.

The current data available does not show a definitive source of dieldrin loading to either Clark Creek, Pringle Creek or Champoeg Creek. However, a possible geographic source has been identified for the Pringle Creek listing, Bush Park, at the confluence of Clark Creek and Pringle Creek.

ODEQ recommends further monitoring of dieldrin in the water column and stream sediment in the Pringle Creek Watershed, especially in the headwaters of Clark and Pringle Creek, and at Bush Park, as well as Champoeg Creek. It is important to sample longitudinally along a stream over a one year period to capture the variability of dieldrin both temporally, spatially and seasonally, in relation to flow and precipitation. This data will provide further information on the magnitude and possible sources of dieldrin in the Pringle Creek Watershed. This data will also provide information regarding the correlation between overland flow of upland soils contaminated with dieldrin and in-stream deildrin concentrations. It is also recommended and important to record the stream flow and the in-stream total organic carbon (TOC) content at each dieldrin sampling site. A detailed source assessment identifying the historic application and storage locations of dieldrin in the subbasin will also provide information regarding potential geographic sources of dieldrin and will aid in the development of establishing monitoring stations. This source assessment could be conducted by interviewing residents and designated management agency officials, such as agricultural representatives, to determine where dieldrin was applied historically.

To date there has been no fish tissue sampling for organochlorine pesticides within the Pringle Creek and Champoeg Creek Watersheds. Conducting a fish study will provide valuable information to the actual bioaccumulation of dieldrin in fish species in the watershed, and will provide a baseline investigation into the current in-stream concentration of dieldrin in relation to the dieldrin concentration in fish species. In absence of fish tissue data collection, a lipid bag may be used to collect dieldrin data to simulate concentrations in fish tissue.

Dieldrin does have a strong adsorption to soil and may be released to the aquatic environment during runoff events. ODEQ recommends the implementation of erosion control practices within the Pringle Creek and Champoeg Creek Watersheds to avoid the erosion and runoff of soil contaminated with dieldrin into streams. The implementation of riparian vegetation along stream corridors may help to reduce the soil runoff.

REFERENCES

Anderson, C.W., Rinella, F.A., and Rounds, S.A. 1996 Occurrence of selected trace elements and organic compounds and their relation to land use in the Willamette River Basin, Oregon, 1992–94: U.S. Geological Survey Water-Resources Investigations Report 96–4234.

Anderson, C.W., Wood, T.M., and Morace, J.L. 1997. Distribution of dissolved pesticides and other water-quality constituents in small streams, and their relation to land use, in the Willamette River Basin, 1996: U.S. Geological Survey Water-Resources Investigations Report 97–4268.

Bell, M.C. 1986. Fisheries handbook of engineering requirements and biological criteria. Fish Passage Development and Evaluation Program, U. S. Army Corps of Engineers, North Pacific Division. Portland, Oregon.

Brett, J.R. 1952. Temperature Tolerance in Young Pacific Salmon, Genus Oncorhynchus. J. Fish. Res. Bd. Can., 9(6):265-323.

Cleland, B. 2002. TMDL Development from the “Bottom Up” – Part II: Duration Curves and Wet-Weather Assessments. Unpublished Manuscript.

Cleland, B. 2002. TMDL Development from the “Bottom Up” – Part III: Using Duration Curves to Connect the Pieces. Unpublished Manuscript.

Cude, C. G., 2001. Draft Prediction of Fecal Coliform from Escherichia Coli for the Oregon Water Quality Index (OWQI).

Dufour, A.P. 1984. Health Effects Criteria for Fresh Recreational Waters. Cincinnati, Ohio. USEPA. EPA-600/1-84-004.

Heath A. G. and G. M. Hughes. 1973. Cardiovascular and respiratory changes during heat stress in rainbow trout (Salmo gairneri). J. Exp. Biol., 59:323-338.

Hemesath, L., Nunez, T. 2002. Pringle, Glenn-gibson, Claggett and Mill Creeks Watershed Assessment. Greater Salem-Keizer Area Watershed Councils.

Hogan, J.W. 1970. Water temperature as a source of variation in specific activity of brain acetylcholinesterase of bluegills: Bulletin of Environ. Contamination and Toxicology 5(4):347-353.

Hokanson, K., C.F. Kleiner and T.W. Thorslund. 1977. Effects of Constant Temperatures and Diel Temperature Fluctuations on Specific Growth and Mortality Rates and Yield of Juvenile Rainbow Trout, Salmo gairdneri. J. Fish. Res. Bd. Can., 34:639-648.

Laenen, Antonius. 1983. Storm Runoff as Related to Urbanization Based on Data Collected in Salem and Portland, and Generalized for the Willamette Valley, Oregon. Water Resources Investigations Report 83-4143.

Mattson, K., Gallagher, A. 2001. Rickreall Watershed Assessment. Rickreall Watershed Council.

O’Connor, Jim E., Sarna-Wojcicki, Andre, Wozniak, Karl C., Polette, Danial J. Fleck, Robert J. 2001. Origin, Extent, and Thickness of Quaternary Geologic Units in the Willamette Valley, Oregon. U.S. Geological Survey Professional Paper 1620. Denver, Co.

ODA. 2003. ODA cancels use of ten pesticide ingredients known as "PBT"s http://www.oda.state.or.us/information/news/PBT.html October 30, 2003.

ODEQ. 1993. Rickreall Creek Water Quality Report. Portland, OR.

ODEQ. 1995. 1992-1994 Water Quality Criteria Review. Portland, OR.

Pipes, W.O. 1982. Bacterial indicators of pollution. CRC Press, Boca Raton, Florida, USA.

Tanner, D.Q. 2002. Selected Elements and Organic Chemicals in Streambed Sediment in the Salem Area, Oregon, 1999: U.S. Geological Survey Water-Resources Investigations Report 02-4194.

USEPA. 2002. Implementation Guidance for Ambient Water Quality Critria for Bacteria. Draft. Office of Water. EPA 841-R-00-002.

USEPA. 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Criteria EPA 823-B-02-003, Region 10 Office of Water, Seattle, WA.

USEPA. 2003. http://www.epa.gov/opptintr/pbt/aldrin.htm

Wentz, D.A., Bonn, B.A., Carpenter, K.D., Hinkle, S.R., Janet, M.L., Rinella, F.A., Uhrich, M.A., Waite, I.R., Laenen, A., and Bencala, K.E. 1998. Water quality in the Willamette Basin, Oregon, 1991–95: U.S. Geological Survey Circular 1161.