Chapter 2
Temperature

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INTRODUCTION

The temperature total maximum daily load (TMDL) for the Molalla-Pudding Subbasin has been developed within hydrologic units 1709000901 (Abiqua Creek/Pudding River), 1709000902 (Butte Creek/Pudding River), 1709000903 (Rock Creek/Pudding River), 1709000904 (Senecal/Mill Creek), 1709000905 (Upper Molalla River), and 1709000906 (Lower Molalla River), which collectively comprise the entire Molalla-Pudding Subbasin. The components of a TMDL (Oregon Administrative Rule (OAR) 340-042-0040) are listed in Table 2 - 1, along with a summary of Molalla-Pudding temperature TMDL elements.

Table 2 - 1: Molalla-Pudding Subbasin Temperature TMDL Components

Name and Location **OAR 340-042-0040(4)(a)**	Perennial and intermittent streams, as identified in OAR 340-041- 0340; Figures 340A & 340B, streams in the Molalla-Pudding Subbasin, HUCs 1709000901, 1709000902, 1709000903, 1709000904, 1709000905, and 1709000906.
Pollutant Identification **OAR 340-042-0040(4)(b)**	*Pollutants*: Heat resulting from human caused temperature increases from (1) solar radiation loading and (2) warm water discharge to surface waters.
Water Quality Standards and Beneficial Uses **OAR 340-042-0040(4)(c)** **OAR 340-041-0028(4)(a)** **OAR 340-041-0028(4)(b)** **OAR 340-041-0028(4)(c)** **OAR 340-041-0028(8)** **OAR 340-041-0028(11)(a)** **OAR 340-041-0028(11)(b)** **OAR 340-041-0028(12)(b)(B)**	*Water Quality Standards*: 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. 13.0°C during times and at locations of salmon and steelhead spawning. 16.0°C during times and at locations of core cold water habitat identification. 18.0°C during times and at locations of salmon and trout rearing and migration. Natural Conditions Criteria: Where the department determines that the natural thermal potential temperature of all or a portion of a water body exceeds the biologically-based criteria in section (4), the natural thermal potential temperatures are deemed the applicable criteria for that water body. Cold Water Protection – Spawning: Applies to point sources that discharge during spawning season into or above salmon and steelhead spawning waters that are colder than the spawning criterion. Application of this criteria to the Molalla-Pudding Subbasin is explained in the text of this document.. 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 degrees Fahrenheit) above the applicable criteria after complete mixing in the water body, and at the point of maximum impact. *Beneficial Uses*: Salmonid fish spawning and rearing, anadromous fish passage, resident fish and aquatic life are the most sensitive beneficial uses in the Molalla-Pudding Subbasin.
TMDL **Loading Capacity** **OAR 340-042-0040(4)(d)** **Excess Load** **OAR 340-042-0040(4)(e)** **Sources or Source Categories** **OAR 340-042-0040(4)(f)**	*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 ºC (0.5 ºF) increase at the point of maximum impact. The loading capacity is the heat load that corresponds to the applicable numeric criteria plus the 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 this temperature TMDL 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. *Sources or Source Categories*: Nonpoint source solar loading due to a lack of riparian vegetation from forestry, agriculture, rural residential, and urban activities. Channel form change due to hydrologic modification and current and historic stream area land use. Reduction in stream flow due to consumptive uses. Point source discharge of warm water to surface water.
Wasteload Allocations **OAR 340-042-0040(4)(g)** **Load Alloacations OAR 340-042-0040(4)(h)** **Surrogate Measures** **OAR 340-042-0040(5)(b)**	*Wasteload Allocations (NPDES Point Sources)*: The wasteload allocation (WLA) is the allowable heat load based on achieving no greater than a 0.3ºC stream temperature increase at the point of maximum impact. This is achieved by limiting the total stream temperature increase due to point sources to 0.2ºC, since a heat load equivalent to a 0.05ºC temperature increase is allocated to nonpoint sources and a heat load equivalent to 0.05ºC is kept for reserve capacity. The WLA for an individual source is calculated by the equation: $WLA = \Delta T * (Q_R + Q_e)C_F$, where ΔT = allowed temperature increase Q_R = stream flow of river Q_e = flow of effluent C_F = conversion factor to units of heat load

	Load Allocations (Nonpoint Sources): The load allocation is the background solar radiation loading based on system potential vegetation. An additional heat load based on a 0.05°C temperature increase at the point of maximum impact is available but is not explicitly allocated to individual sources. The following load allocations are applicable within the modeled corridor. Outside the modeled corridor, load allocations are addressed through surrogate measures. • Molalla River background solar radiation loading based on system potential vegetation is 281 MW-day/day. • Pudding River background solar radiation loading for August based on system potential vegetation is 159 MW-day/day. An additional heat load based on a 0.05°C temperature increase at the point of maximum impact is allocated to non-point sources but is not explicitly allocated to individual non-point sources. *Surrogate Measure to translate 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 an area's location and physical characteristics.
Margins of Safety OAR 340-042-0040(4)(i)	*Margins of Safety* are incorporated by making conservative critical condition assumptions for point source load calculations. Margins of safety are inherent in the methodology for determining nonpoint source loads, as these loads essentially target natural conditions.
Seasonal Variation OAR 340-042-0040(4)(j)	Peak temperatures typically occur in mid-July through mid-August and often exceed the salmon and trout rearing and migration criterion and core cold water criterion. Temperatures in late summer in the upper Molalla River and Table Rock Fork occasionally exceed the spawning criterion. The critical period in which WLAs apply is June 1 – September 30 for the Pudding River and May 1 – October 31 for the Molalla River. Point sources within the Pudding or Molalla watersheds, that discharge outside of those respective critical periods, receive an implicit heat load allocation sufficient to cover their current conditions of discharge. All portions of the TMDL except WLAs apply year round.
Reserve Capacity OAR 340-042-0040(4)(k)	A reserve capacity of 0.05˚C applicable to point sources is explicitly set aside. Where a heat load causing less than the allowed 0.2˚C stream temperature increase is used by point source discharges, the remainder is also set aside for reserve capacity. This allows for a maximum reserve capacity of 0.25 ˚C.
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.
Standards Attainment & Reasonable Assurance OAR 340-042-0040(4)(l) & (j)	Implementation of pollutant load reductions and limitations in the point source and non point source sectors will result in water quality standards attainment. Standards Attainment and Reasonable Assurance are addressed in the WQMP.

NAME AND LOCATION: WATERBODIES LISTED FOR TEMPERATURE

Stream segments were included on the 303(d) list based on the temperature criteria in place at the time the list was revised. Listings before 2004 were based on a temperature criterion of 17.8°C (64°F) for salmonid migration and rearing. The Environmental Quality Commission adopted new temperature criteria in December 2003 and the US Environmental Protection Agency (EPA) approved them in March 2004. The current temperature criterion for salmon and trout rearing and migration is 18.0°C (64.4°F). For waters considered core cold water habitat, the applicable criteria is 16ºC, and waters that support spawning must comply with the temperature criterion of 13ºC during spawning season.

The Molalla-Pudding Subbasin has five stream segments on the 303(d) list for exceeding the core cold water habitat criterion of 16ºC (Table 2 - 2). Four segments, all in the Pudding River portion of the Subbasin, violate the 18ºC rearing and migration criterion. Two segments, the upper Molalla River and the Table Rock Fork of the Molalla River, violate the spawning criterion of 13ºC. Two segments, Zollner Creek and the lower Molalla River, were listed in 1998 based on the temperature criterion applicable at the time, 17.8ºC.

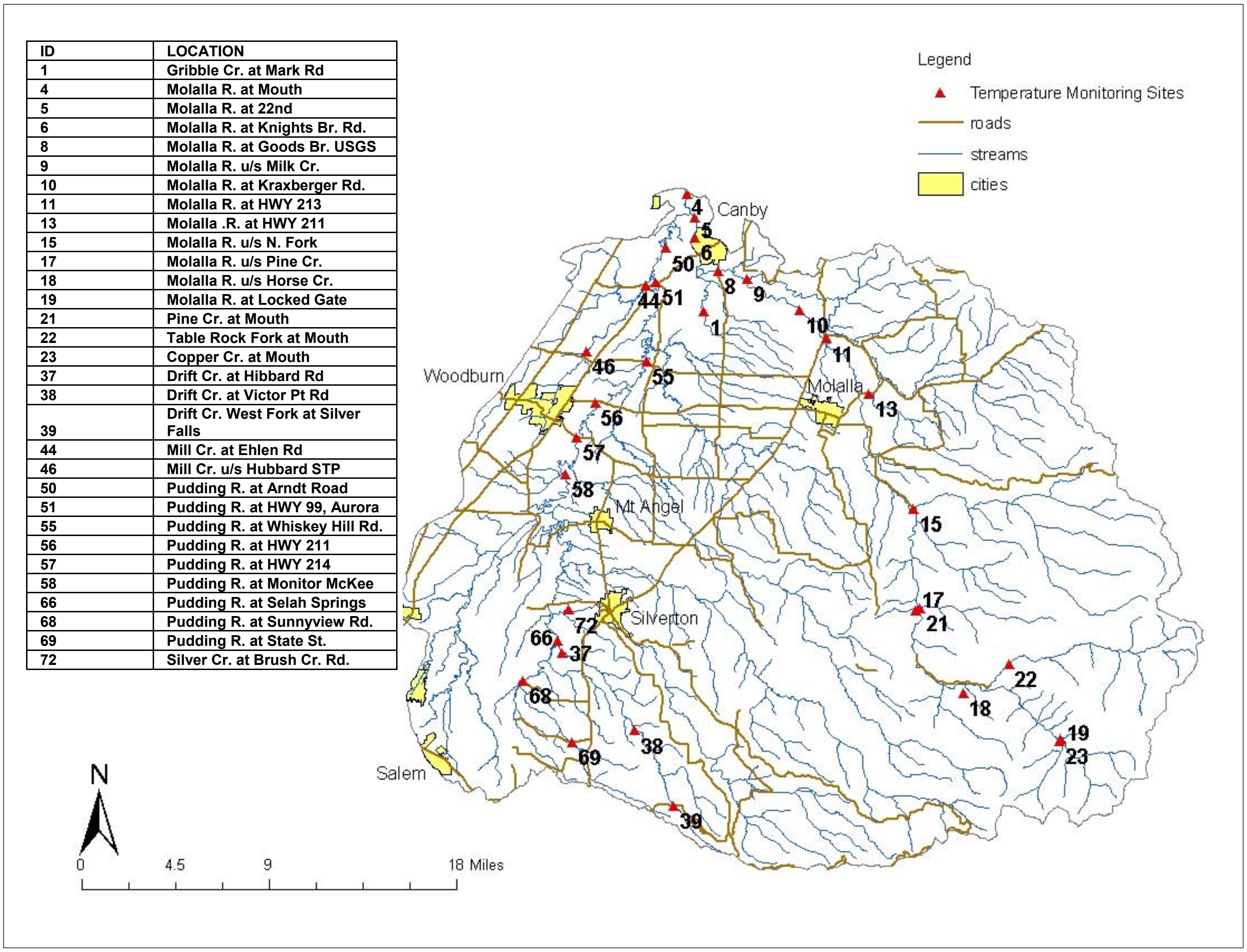
Molalla-Pudding Subbasin stream temperature TMDLs apply to all perennial and intermittent streams and tributaries in the subbasin, not only to those listed to date for temperature violations. This “watershed scale” application takes into account stream temperature being affected by heat loads from upstream as well as local sources. A watershed scale TMDL also eliminates the need to develop additional TMDLs in the subbasin if more temperature data later indicate that additional stream reaches or tributaries violate temperature criteria. Since the Molalla and Pudding Rivers are physically and geologically distinct systems, DEQ completed a separate model and temperature TMDL for each watershed.

Table 2 - 2: Molalla-Pudding Subbasin 303(d) Temperature Listed Stream Segments

Water Body	Listed River Mile	Parameter	Season – Criteria	Assessment Year
Pudding River Reaches and Tributaries				
Beaver Creek	0 to 6.8	Temperature	Year Around (Non-spawning) – Core cold water habitat: 16.0 ºC.	2004
Butte Creek	11.9 to 35.6	Temperature	Year Around (Non-spawning) – Core cold water habitat: 16.0 ºC.	2004
Drift Creek	0 to 9.5	Temperature	Year Around (Non-spawning) – Salmon and trout rearing and migration: 18.0 ºC.	2004
Pudding River	0 to 61.8	Temperature	Year Around (Non-spawning) Salmon and trout rearing and migration: 18.0 ºC.	2004
Silver Creek	0 to 5.9	Temperature	Summer -- Rearing: 17.8 ºC.	1998
South Fork Silver Creek	0 to 7	Temperature	Year Around (Non-spawning) - Salmon and trout rearing and migration: 18.0 ºC.	2004
Teasel Creek	0 to 6.3	Temperature	Year Around (Non-spawning) -- Salmon and trout rearing and migration: 18.0 ºC.	2004
Zollner Creek	0 to 7.8	Temperature	Summer -- Rearing: 17.8 ºC.	1998
Molalla River Reaches and Tributaries				
Molalla River	0 to 25	Temperature	Summer (former temperature criterion 17.8 ºC)	1998
Molalla River	19.7 to 44.7	Temperature	August 15 - June 15 -- Salmon and steelhead spawning: 13.0 ºC.	2004
Molalla River	18.2 to 48.3	Temperature	Year Around (Non-spawning) -- Core cold water habitat: 16.0 ºC.	2004
Table Rock Fork Molalla River	0 to 8.3	Temperature	August 15 - June 15 -- Salmon and steelhead spawning: 13.0 ºC.	2004
Table Rock Fork Molalla River	0 to 12	Temperature	Year Around (Non-spawning) -- Core cold water habitat: 16.0 ºC.	2004
Pine Creek	0 to 7.2	Temperature	Year Around (Non-spawning) -- Core cold water habitat: 16.0 ºC.	2004

DEQ monitored continuous stream temperatures between May and October 2004 at the locations indicated in Figure 2 - 1and Table 2 - 3. Continuous temperature recording devices were set to record temperature measurements hourly. In some cases, the thermisters were vandalized, or otherwise removed, resulting in mid-season deployments of a few units, noted in Table 2 - 3.

Table 2 - 3 also lists the maximum seven day average of maximum daily temperatures (7-DADM) over the deployment period. These averages indicate that temperatures measured at all sites monitored in the Molalla-Pudding subbasin in 2004, including tributaries and locations near stream headwaters, exceed the biologically based criteria of Oregon’s temperature standard.



ID	LOCATION
1	Gribble Cr. at Mark Rd
4	Molalla R. at Mouth
5	Molalla R. at 22nd
6	Molalla R. at Knights Br. Rd.
8	Molalla R. at Goods Br. USGS
9	Molalla R. u/s Milk Cr.
10	Molalla R. at Kraxberger Rd.
11	Molalla R. at HWY 213
13	Molalla .R. at HWY 211
15	Molalla R. u/s N. Fork
17	Molalla R. u/s Pine Cr.
18	Molalla R. u/s Horse Cr.
19	Molalla R. at Locked Gate
21	Pine Cr. at Mouth
22	Table Rock Fork at Mouth
23	Copper Cr. at Mouth
37	Drift Cr. at Hibbard Rd
38	Drift Cr. at Victor Pt Rd
39	Drift Cr. West Fork at Silver Falls
44	Mill Cr. at Ehlen Rd
46	Mill Cr. u/s Hubbard STP
50	Pudding R. at Arndt Road
51	Pudding R. at HWY 99, Aurora
55	Pudding R. at Whiskey Hill Rd.
56	Pudding R. at HWY 211
57	Pudding R. at HWY 214
58	Pudding R. at Monitor McKee
66	Pudding R. at Selah Springs
68	Pudding R. at Sunnyview Rd.
69	Pudding R. at State St.
72	Silver Cr. at Brush Cr. Rd.

Figure 2 - 1: Locations where DEQ measured continuous temperature in the Molalla-Pudding Subbasin in summer 2004.

Table 2 - 3: Seven day moving average daily maximum stream temperatures measured in the Molalla-Pudding subbasin in 2004.

Site #	Site Name	Approximate River Mile	Agency	7 Day Average Daily Max Date	7 Day Average Daily Max Temp ºC	Comment
10362	Pudding River at Arndt Road (Barlow)	4.0	ODEQ	7/29/2004	26.6	
10917	Pudding River at Hwy 99E (Aurora)	8.0	ODEQ	8/15/2004	25.9	data file starts on 8/3/2004
11528	Pudding River at Bernard Road (Whiskey Hill)	17.0	ODEQ	7/26/2004	26.6	probably exposed to air 7/27 - 8/22/2004
10640	Pudding River at Hwy 211 (Woodburn)	22.0	ODEQ	7/29/2004	27.2	probably exposed to air 8/14 - 8/22/2004
10641	Pudding River at Hwy 214 (downstream of cannery outfall)	27.0	ODEQ	7/29/2004	26.6	probably exposed to air 8/14 - 8/22/2004
11530	Pudding River at Monitor-Mckee Road	31.0	ODEQ	7/29/2004	27.2	
31878	Pudding River below Drift Creek	51.0	ODEQ	7/26/2004	23.2	
32056	Pudding River at Sunnyview Road	54.0	ODEQ	7/29/2004	27.1	
32055	Pudding River at State Street	58.0	ODEQ	7/28/2004	22.8	
31876	Mill Creek Ehlen Road	0.3	ODEQ	7/28/2004	22.5	
32060	Mill Creek upstream of Hubbard STP (Pudding River)	5.8	ODEQ	7/26/2004	20.7	
10646	Silver Creek at Brush Creek Road	1.0	ODEQ	8/14/2004	24.4	
32057	Drift Creek at Hibbard Road (Pudding River)	0.5	ODEQ	7/27/2004	26.4	
32054	Drift Creek at Victor Point Road	6.0	ODEQ	7/29/2004	20.7	
32053	Drift Creek, West Fork, at Hwy 214 (Silver Falls Hwy)	10.0	ODEQ	8/15/2004	27.6	
10636	Molalla River at mouth	0.1	ODEQ	7/29/2004	28.0	
32059	Molalla River at 22nd Avenue	1.0	ODEQ	7/30/2004	26.9	data file starts on 7/23/2004
10637	Molalla River at Knights Bridge Road (Canby)	1.5	ODEQ	7/30/2004	27.4	
32058	Molalla River at Canby-Marquam Hwy (Goods Bridge)	6.0	ODEQ	8/16/2004	26.7	data file starts on 7/23/2004
32061	Molalla River upstream of Milk Creek	8.0	ODEQ	7/29/2004	27.5	
32062	Molalla River north of Oak Grove Road	11.0	ODEQ	7/29/2004	28.0	
10881	Molalla River at Hwy 213 Bridge (Mulino)	15.0	ODEQ	7/30/2004	26.4	data file starts on 7/30/2004
10638	Molalla River at Hwy 211 Bridge (Molalla)	19.0	ODEQ	7/10/2004	23.6	probably exposed to air 7/21 - 8/16/2004
31871	Molalla River above North Fork LD	26.5	ODEQ	7/29/2004	24.0	
32051	Molalla River upstream of Pine Creek	33.0	ODEQ	7/29/2004	22.4	
32049	Molalla River upstream of Horse Creek	38.0	ODEQ	8/17/2004	21.0	
32046	Molalla River at River Mile 44	44.0	ODEQ	8/17/2004	18.8	
32052	Gribble Creek at Mark Road	1.0	ODEQ	7/28/2004	21.4	
32048	Table Rock Fork Molalla River at River Mile 1	0.1	ODEQ	8/16/2004	21.0	
32050	Pine Creek at mouth (Molalla River)	0.1	ODEQ	8/16/2004	19.3	
32047	Copper Creek at mouth (Molalla River)	0.1	ODEQ	8/18/2004	17.3	

Thermal Infra-red Radiometry (TIR) and visible video imagery data were collected for the Molalla and Pudding Rivers July 26 and August 11 -12, 2004, respectively, by Watershed Sciences, LLC. A description of the TIR data collection is included in Appendix A. TIR data collection was timed to capture daily maximum stream temperatures, typically occurring in middle to late afternoon.

The TIR snapshot of the Molalla River (Figure 2 - 2) reveals a stream in which temperatures near the mouth were approximately 10ºC warmer than those near the headwaters. Lower temperatures measured along the stream profile may indicate reaches where the stream is not heating as much (perhaps from better shading or a narrow stream width) or where springs and seeps contribute cooler water. TIR imagery of the Molalla River identified several cooler areas near stream banks that may indicate springs and seeps.

The TIR longitudinal profile of the Pudding River (Figure 2 - 3) indicates fluctuation within approximately two degrees C from the confluence with Silver Creek downstream to the mouth. The TIR measured greater temperature fluctuations upstream of Silver Creek, possibly resulting from impoundments in the main channel and less stream volume. Based on thermister data, Drift, Silver, Abiqua, and Butte Creeks generally enter the Pudding River within a degree, plus or minus, of the measured mainstem river temperature. Rock Creek and Mill Creek are several degrees cooler than mainstem temperatures.

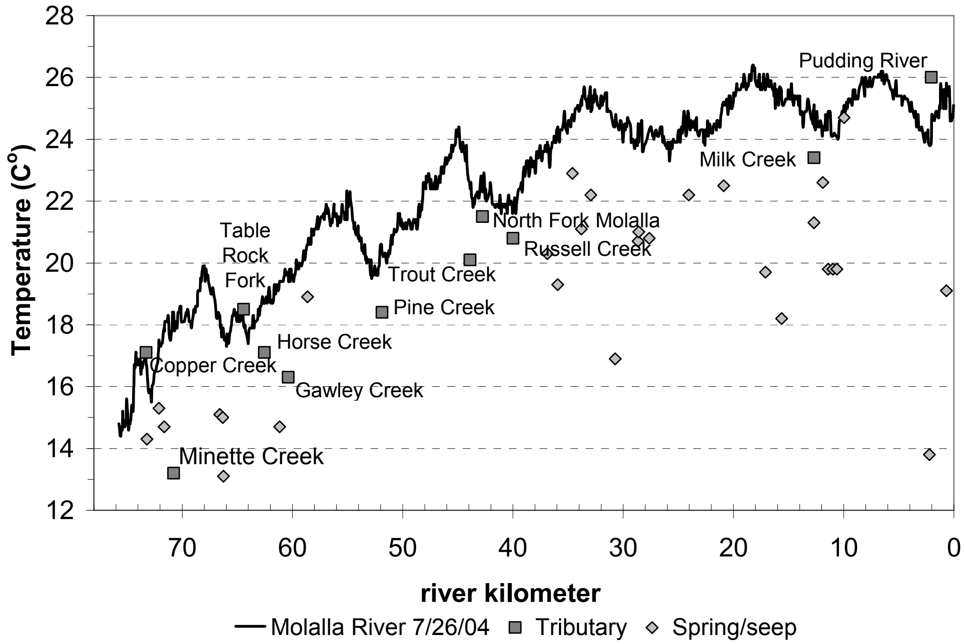


Figure 2 - 2: Longitudinal TIR median temperatures for the Molalla River on July 26, 2004.
River kilometers are calculated from the mouth. The figure also shows the location and names of tributary and other surface water inflows.

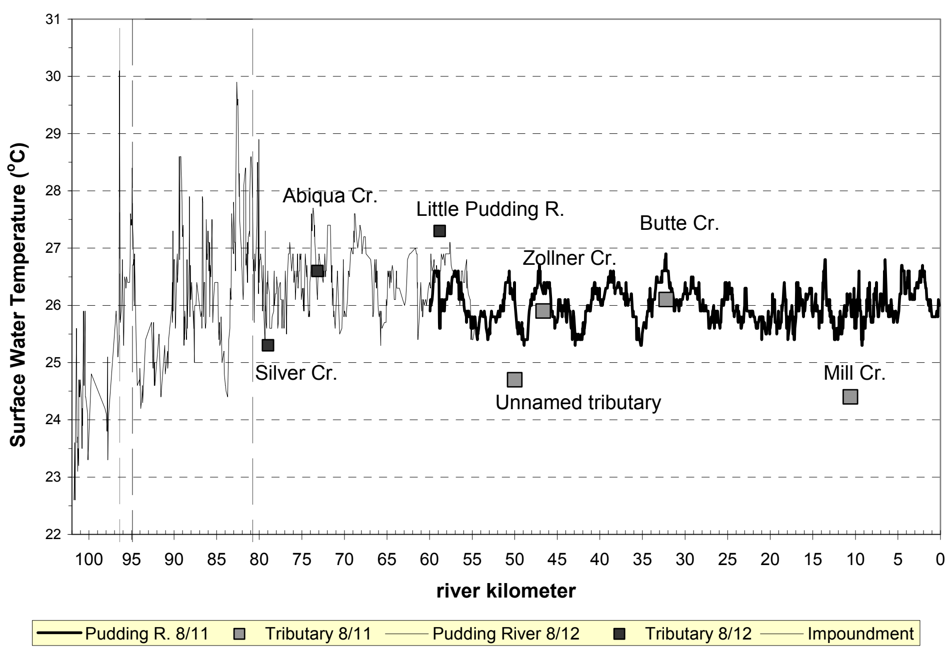


Figure 2 - 3: Longitudinal TIR median temperatures for the Pudding River on August 11 - 12, 2004.
River kilometers are calculated from the mouth. The figure also shows the location and names of tributaries.

POLLUTANT IDENTIFICATION

DEQ 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, influence the amount of solar radiation reaching the stream. The simulation of natural conditions incorporates reduced vegetation presence, density and tree height. This temperature TMDL addresses 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 Molalla-Pudding Subbasin.

WATER QUALITY STANDARDS AND BENEFICIAL USE

BENEFICIAL USE

Numeric and narrative water quality criteria are applied to protect the most sensitive beneficial uses. The most sensitive beneficial use to temperature in the Molalla-Pudding Subbasin is Fish and Aquatic Life (OAR 340-41-0340, Table 340A). Location fish uses in the Molalla-Pudding Subbasin, such as salmonid spawning, rearing and migration, are specified in Figures 340A and 340B of OAR 340-41-340 (accessible at http://www.deq.state.or.us/regulations/rules.htm).

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 stream temperatures are in the 21°C to 25°C (70°F to 77°F) range. The time period to death depends on the acclimation and life-stage of the fish. The cause of death is from the breakdown of physiological regulation, such as respiration and circulation, which are vital to fish health (Heath and Hughes, 1973). The third level is the most common and widespread cause of thermally induced fish mortality, termed indirect or sub-lethal limit and can occur weeks to months after the onset of stream temperatures stressful to fish. 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 (Brett, 1952; Bell, 1986; Hokanson, et al., 1977).

WATER QUALITY STANDARDS

Both narrative and numeric temperature criteria apply in the Molalla-Pudding Subbasin. Numeric criteria are listed in Table 2 - 1. Figure 2 - 4 and Figure 2 - 5 indicate where the salmonid spawning through fry emergence, salmonid rearing and migration, and the core cold water habitat criteria apply. For subbasin waters where fish uses are not identified, the applicable criteria are the same as the nearest downstream waterbody that is identified in fish use maps.

Table 2 - 4: Applicable temperature criteria in the Molalla-Pudding subbasin.
Stream temperature is calculated using the trailing average of seven consecutive daily maximum temperatures on a rolling basis (7-day average daily maximum – 7DADM).

Beneficial Use	Biologically Based Numeric Criteria
Salmon and Steelhead Spawning	13.0 °C (55.4 °F)
Core Cold Water Habitat	16.0 °C (60.8 °F)
Salmon and Trout Rearing and Migration	18.0 °C (64.4 °F)

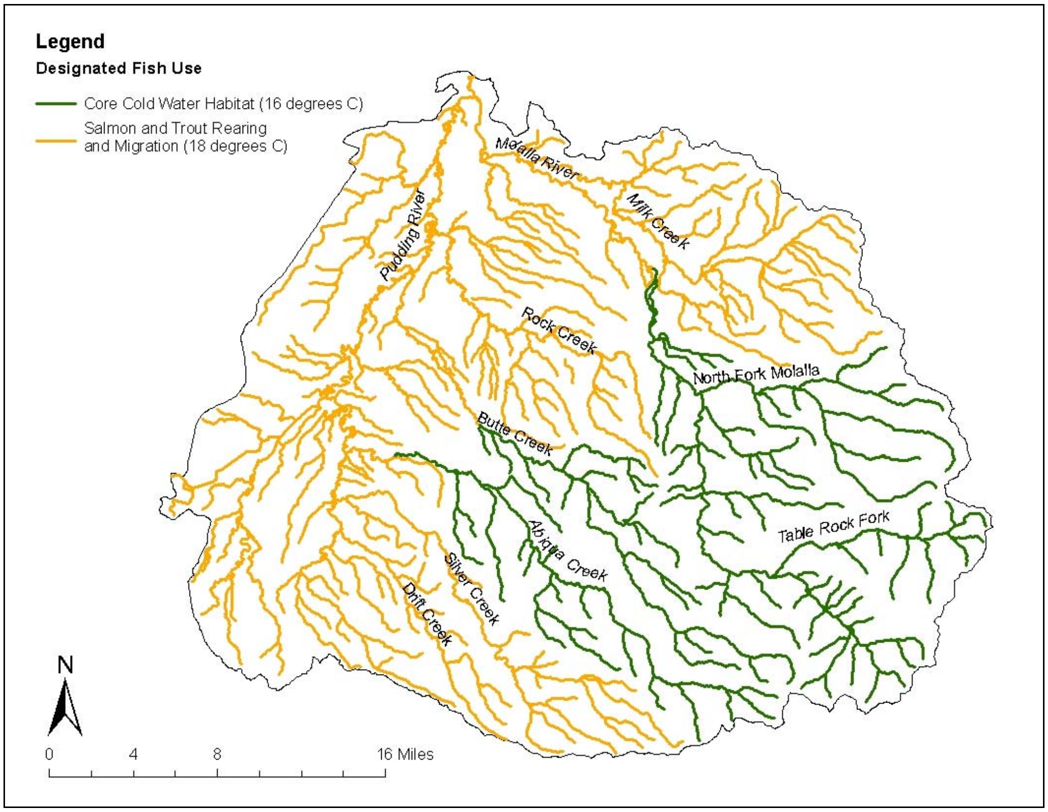


Figure 2 - 4: Molalla-Pudding Subbasin Designated Fish Use Distribution of Anadromous Salmonids

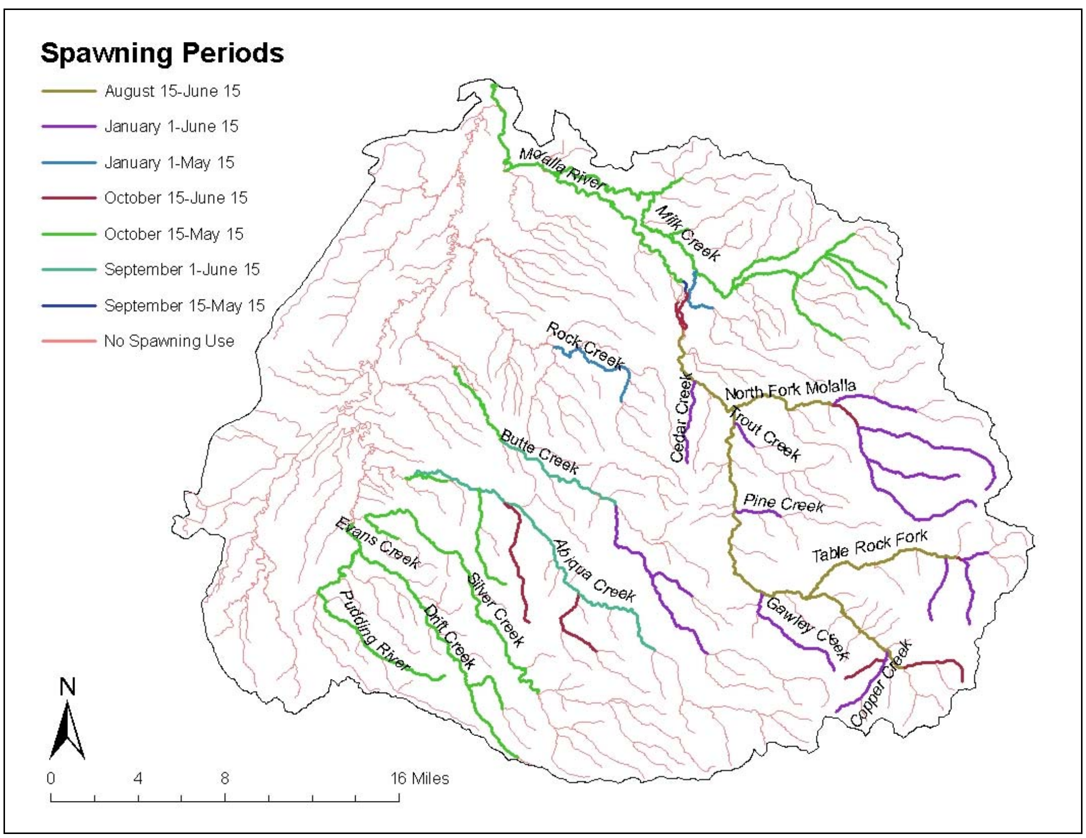


Figure 2 - 5: Molalla-Pudding Subbasin Designated Spawning Use Distribution of Anadromous Salmonids

The narrative criteria that apply to the Molalla-Pudding Subbasin describe the conditions under which biologically based numeric criteria may be superseded. The narrative criteria acknowledge that in some instances the biologically based numeric criteria may not be achieved because the natural stream temperature is warmer than the biologically based numeric criteria. A stream that is free from anthropogenic influence is considered to be under natural conditions. When the natural conditions temperature exceeds the appropriate biologically based criterion, the natural conditions temperature becomes the numeric temperature criterion for that specific stream or stream segment. Natural conditions criteria are applicable in the Molalla-Pudding Subbasin because modeling indicates that natural temperatures exceed the biologically based numeric criteria in the summer months on both the Pudding and Molalla Rivers and during early spawning season on the Molalla River. The derivation of natural conditions temperatures, also called natural thermal potential temperature (NTP) is detailed in Appendix E. Table 2 - 5 and Table 2 - 6 list the times and locations on the Molalla and Pudding Rivers, respectively, that natural conditions criteria apply.

Table 2 - 5: Natural conditions criteria applicable to the Molalla River.
Derivation of natural conditions criteria, also called natural thermal potential (NTP) temperatures, is explained in Appendix E. During time periods not listed in the table, biologically based numeric criteria apply.

Applicable Dates	Mouth to River Mile 19	River Mile 19.1 – 33	River Mile 33.1 - headwaters
July 1 – 14	18.8 ºC	17.1 ºC	Biologically based (16 ºC)
July 15 – 31	21.1 ºC	19.2 ºC	18.1 ºC
August 1 – 15	20.3 ºC	18.5 ºC	17.4 ºC
August 16 – 31	18.7 ºC	17.0 ºC	16.1 ºC
September 1 – 15	Biologically based (18 ºC)	15.1 ºC	14.3 ºC

Table 2 - 6: Natural conditions criteria applicable to the Pudding River.
Derivation of natural conditions criteria, also called natural thermal potential (NTP) temperatures, is explained in Appendix E. During time periods not listed in the table, biologically based numeric criteria apply.

Applicable Dates	Mouth to River Mile 22.5	River Mile 22.6 – headwaters
July 1 – 14	20.1 ºC	19.6 ºC
July 15 – August 31	21.6 ºC	20.9 ºC
September 1 - 15	18.2 ºC	Biologically based (18 ºC)

Criteria intended to protect cold water during spawning season (OAR 0340-41-0028(11)b) apply to the Molalla River because winter ambient stream temperatures are likely to be less than the spawning temperature criterion of 13 °C. A point source that discharges into or above salmon and steelhead spawning waters that are colder than the spawning criterion (13 °C) may not cause the water temperature in the spawning reach where the physical habitat for spawning exists, to increase more than:

- 0.5°C above the 60 day average if the rolling 60 day average maximum ambient water temperature between the dates of spawning use is 10 to 12.8°C; or

- 1.0°C above the 60 day average if the rolling 60 day average maximum ambient water temperature, between the dates of spawning use is less than 10°C.

Discharges from Molalla River point sources are unlikely to cause violations of the Protecting Cold Water criteria. The potential heat loading from Molalla River point sources that discharge during spawning season is evaluated in the Wasteload Allocations section.

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

LOADING CAPACITY

The loading capacity for this temperature TMDL is the greatest amount of heat loading that a water body can receive and not violate temperature criteria. The loading capacity may be allocated among point and nonpoint sources of stream heating, and a portion may also be set aside to account for future growth (i.e.

reserve capacity). The loading capacity depends on the available assimilative capacity of the receiving water. For water bodies whose natural thermal potential temperatures are at or above the temperature criterion, there is no available loading capacity – the loading capacity is consumed by non-anthropogenic sources.

The temperature rule does make allowance for human use (HUA) and specifies that wasteload allocations to point sources and load allocations to nonpoint sources may not cumulatively cause a stream temperature increase greater than 0.3ºC above applicable biologically based or natural conditions criteria after complete mixing in the water body (OAR 340-041-0028(12)).

Modeling of the Pudding and Molalla Rivers to derive the natural thermal potential temperatures shows that, in both cases, NTP temperatures exceed the biologically based criteria for several weeks between June 1 and September 30. Therefore, the loading capacity for both the Molalla and Pudding Rivers at such times is limited to heat loads which would cause no more than 0.3ºC of stream temperature increase above NTP temperatures. At times when the natural thermal potential temperatures are less than biologically based numeric criteria (e.g. early June and late September), the loading capacity may be greater than the heat load allowed by the HUA, provided the additional heat load does not result in violation of the temperature criterion downstream.

TEMPERATURE TMDL TECHNICAL APPROACH

Solar radiation is an important factor controlling stream temperature and riparian vegetation can block solar radiation from the water's surface. To derive a value for the heat load capacity of a stream, DEQ uses computer modeling to simulate stream effective shade[1] conditions with anthropogenic disturbances of vegetation eliminated – a condition DEQ terms System Potential Vegetation. System potential vegetation is the basis for deriving natural thermal potential temperatures, though point sources of heat and stream flow modification are also eliminated to simulate natural conditions.

In 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.*

The conceptual model used to simulate natural thermal potential in the Molalla and Pudding River systems is illustrated in Figure 2 - 6.

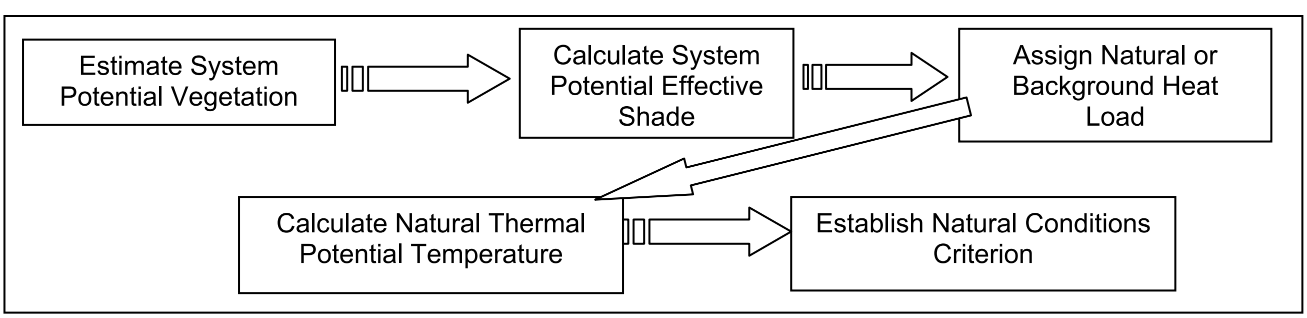


Figure 2 - 6: Conceptual model for developing Natural Thermal Potential and a natural conditions criterion.

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[1] The effective shade is the percent of daily solar radiation that is blocked from the water's surface.

SYSTEM POTENTIAL VEGETATION

System potential vegetation is vegetation that can grow and reproduce in a riparian area 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 –resource management (e.g. logging) and human disturbance (e.g. urban or agricultural uses) are not represented. System potential vegetation is not necessarily an estimate of pre-settlement conditions, but historic information can be an important element in the estimation of the natural thermal potential of a stream. System potential vegetation does include natural disturbance such as forest fires, wind throw, disease, and natural landslides; this disturbance is reflected as smaller tree heights and lower canopy densities in the calculation of shade levels.

The basis and background for DEQ's estimate of system potential vegetation in the Molalla-Pudding subbasin are included in Appendix B, "Potential Near-Stream Land Cover for Willamette Basin". In order to construct a representation of system potential vegetation, DEQ relied on U.S. Forest Service plant associations (Logan, et al., 1987), ODFW Willamette vegetation maps, and ecoregions that delineate native vegetation classes based on elevation, rainfall, temperature and geology (Pater, et al., 1998). To assess historical vegetation, DEQ referenced Nature Conservancy, Natural Heritage Program and General Land Office (1851 – 1865) records, mapping and surveys. The historical vegetation surveys included areas of savannah and prairie, even in areas currently supporting more densely growing trees. The savannahs and prairies represent natural disturbance, such as that caused by fires and flooding.

DEQ considered all this information in establishing relationships between the geomorphic surface covering an area and system potential vegetation. An area's geomorphology refers to the land forms, the surficial geologic material, and land-shaping processes (e.g. flooding, river deposition, erosion). Geomorphic surfaces have been mapped in most areas of the Molalla-Pudding Subbasin except approximately the upper half of the Molalla River watershed. In areas with mapped geomorphic surfaces, DEQ distributed forest, savannah, prairie vegetation characteristics over each geomorphic surface based on percentages in the 1850s vegetation surveys plus an assumption that current practice of fire suppression would result in a higher percentage of trees today. DEQ represented system potential vegetation in unmapped areas with an Upland Forest scenario, based on U. S. Forest Service plant associations (Logan, et al., 1987). The Upland Forest scenario represents a mature coniferous forest, but still accounts for some natural disturbance such as forest fires, wind throw, disease, and natural landslides.

To represent system potential vegetation in the model, DEQ assigned a vegetation height and density to each geomorphic surface and the Upland Forest areas, based on current forest inventory plots and the published literature. Varying canopy density estimates (e.g. 25%, 50%, 75%) distinguished between more and less disturbed areas, as well as between forest and savannah coverages.

QUANTITATIVE MODELING

The modeling used for this temperature TMDL simulates stream responses to changes in heat loads. The technical basis for the Molalla-Pudding temperature TMDL analysis and model calibration statistics are described in Appendix A.

DEQ used the Heat Source Model version 7 (Boyd and Kasper, 2004) to calculate Molalla River stream temperatures and effective shade at system potential vegetation. DEQ modeled Pudding River temperatures with Heat Source Version 8 (Boyd and Kasper, 2004). A description of the Heat Source model[2] is included in Appendix C. Heat Source quantifies heat exchange processes and simulates stream temperature response to changes in model variables such as stream flow and shade. Heat Source accounts for regional factors such as latitude and topography, that determine potential solar radiation, as well as local factors such as stream aspect, stream width and streamside vegetation characteristics that determine actual solar radiation loading to the stream. Streamside vegetation characteristics that determine effective shade are vegetation height, canopy density, overhang, setback or distance from the edge of the stream, and the width of the riparian buffer.

[2] An overview of Heat Source is also found on-line http://www.deq.state.or.us/wq/TMDLs/tools.htm

Thermal Infrared Radiometry (TIR) data provides a snapshot measurement of stream surface temperature. TIR data was collected along the mainstem Molalla River from near the headwaters to the mouth on July 26, 2004, between 2 and 4 p.m. and along the Pudding River on August 11 (4 to 6 p.m.) and August 12 (2 to 4 p.m.), 2004. The TIR process is more fully described in Appendix A.

DEQ calibrated the Heat Source model to the TIR data (spatial calibration) collected on July 26, 2004 (Molalla River), and August 11 and 12, 2004 (Pudding River), and the continuous temperatures (temporal calibration) measured at several locations on the Molalla and Pudding Rivers.

DEQ modeled the Molalla River from Copper Creek, approximately river mile 46 (river kilometer 76), to the mouth, its confluence with the Willamette River. The model period was 14 days from July 20 to August 2, 2004. The intent was to model the lowest stream flows that coincided with highest air and water temperatures. During the 14-day period that was modeled, the stream flow at Canby decreased from 125 to 85 cubic feet per second (cfs), so stream flows were approximately 3 to 5 times the calculated seasonal ten year low stream flow for the Molalla River (7Q10s). The average of daily maximum air temperatures during the model period was 31.3 ºC (88.4 ºF).

DEQ modeled the Pudding River from the confluence with Drift Creek at river mile 51 (river kilometer 84) to the mouth, the confluence with the Molalla River. The model period extended from August 1 to August 14, 2004. Stream flow at Aurora (river mile 8.1, river kilometer 12.5) during that time period decreased from 92 to 13 cfs. The average of daily maximum air temperatures during the model period was 30.2 ºC (86.4 ºF).

Derivation of the natural thermal potential temperatures involved simulating scenarios such as increased shading, natural streamflow, and reduced channel width (in the Molalla River model). The results from these modeled scenarios also serve as a sensitivity analysis, showing which factors have the greatest effects on reducing stream temperatures. Sensitivity analysis results are included in Appendix A.

EXCESS LOAD

The excess load is the difference between the actual pollutant load and the loading capacity of a water body. The difference between solar radiation loading for current and system potential vegetation conditions is the calculated anthropogenic loading for nonpoint sources. DEQ's analysis indicates that there is inadequate shade throughout the Molalla-Pudding subbasin, and that bankfull width and stream flow also affect heat loading to the streams.

Excess loads in the Molalla and Pudding River can be expressed as total excess solar radiation loading to the streams (Table 2-7) or excess heat load the streams under representative flow conditions (Table 2 - 8). Table 2-7 compares the model results for total solar radiation loading for current conditions and total solar radiation loading for system potential vegetation conditions. Seventeen percent of the current solar radiation loading to the Molalla River is excess loading due to anthropogenic sources, and 12% of the current solar radiation loading to the Pudding River is excess loading. Table 2 - 8 shows the excess load calculated at a particular location on each river based on the difference in 7 DADM temperatures (between current condition and system potential vegetation) and the 7Q10 low flow scenario. Note that the excess thermal load in the stream is much less than the excess solar radiation loading to the stream. This is because heat is not a conservative pollutant and much of the heat added by solar radiation dissipates though longwave radiation, conduction, convection, and evaporation. Figure 2 - 7 and Figure 2 - 8 show the solar radiation received by the Molalla and Pudding Rivers, respectively, for current conditions and for system potential vegetation conditions.

Table 2 - 7: Excess solar radiation loading to the Molalla and Pudding Rivers.

Source	Current Loading: Solar Radiation Received (million kcal/day)	System Potential Conditions: Solar Radiation Received (million kcal/day)	Excess Loading as Excess Solar Radiation (million kcal/day)
Molalla River[3]	6,983	5,798	1,185
Pudding River[4]	3,973	3,285	688

Table 2 - 8: Excess load based on difference in 7DADM temperature between current condition and system potential vegetation condition at 7Q10 flow.

Source	7DADM difference (T ºC)	7Q10 stream flow (cfs)	Excess Thermal Load (million kcal/day)
Molalla River RM 6.4 (km 10.4)	0.5	44	53.8
Pudding River RM 23.6 (km 38)	1.2	15	58.7

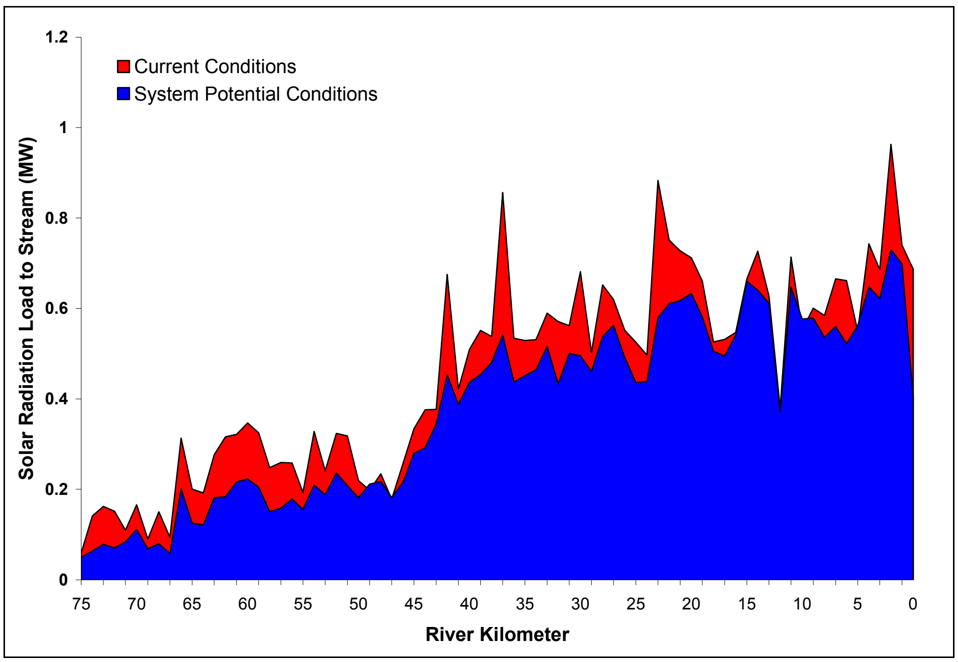

Figure 2 - 7: Comparison of solar radiation loading to the Molalla River under current conditions and system potential conditions, assessed at 100 m intervals.
The difference between the two conditions is the excess heat loading to the stream.

[3] Solar radiation to the Molalla River is the total solar radiation received by the stream in one representative day near the middle of the model period, July 26.

[4] Solar radiation loading to the Pudding River is the average solar radiation received by the stream for the August 1 -14, 2004 model calibration period.

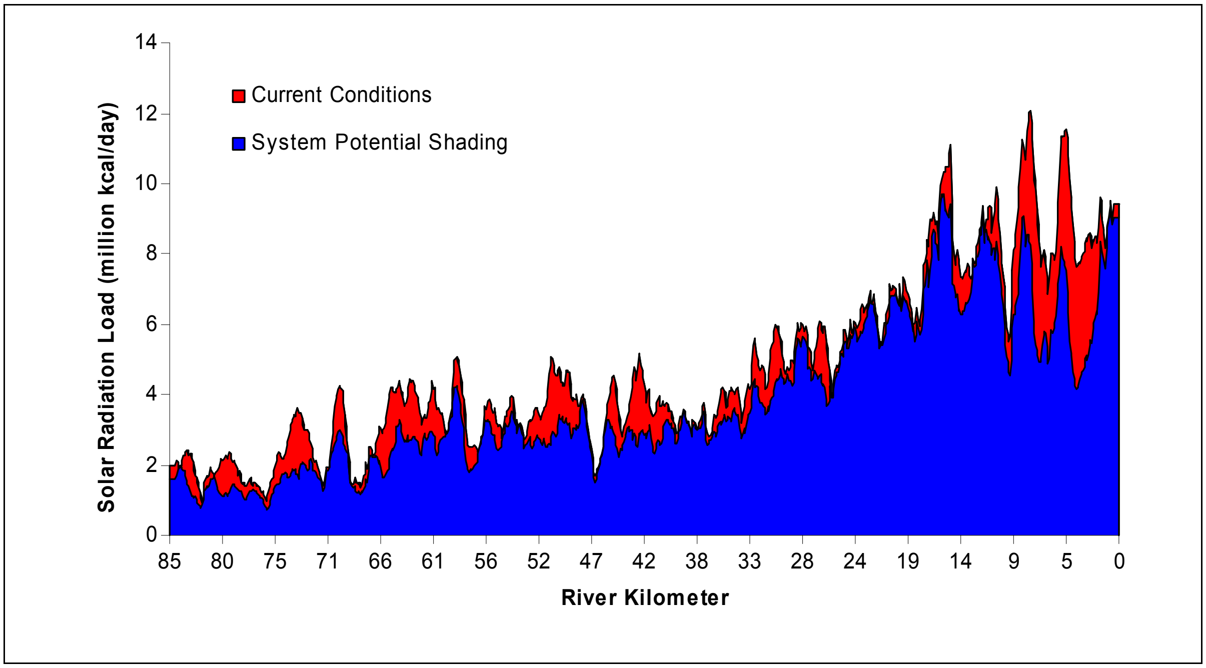

Figure 2 - 8: Comparison of solar radiation loading to the Pudding River under current and system potential shade conditions.
The difference between the two conditions is the excess heat loading to the stream.

SEASONAL VARIATION

This TMDL comprises allocations that apply year-round and explicit WLAs that apply for defined periods within the year. WLAs to point sources on the Pudding River and its tributaries apply from June 1 – September 30. WLAs to point sources on the Molalla River and its tributaries (except for the Pudding River) apply from May 1 – October 31. DEQ refers to these two periods as the critical periods for the Pudding and Molalla portions of the subbasin, respectively. Outside of the critical periods, temperature data collected in 2001, 2002, 2004, 2007 (Molalla River only), and 2008 (Molalla River only)[1] indicate no reasonable potential for temperature criteria to be exceeded. Point sources discharging outside of the applicable critical period are given an implicit heat load allocation sufficient to cover their current conditions of discharge. If future data were to indicate that temperature criteria were exceeded outside of the critical periods, WLAs to existing point sources would be extended through the end of the month of the last temperature criteria exceedance. DEQ would also calculate explicit WLAs for facilities given implicit heat load allocations for current conditions in this TMDL.

From mid June to mid September, stream temperatures in the Molalla-Pudding Subbasin exceed biologically based rearing and migration criteria. Between late June (potentially as early as mid May)[5] and mid October stream temperatures in the Molalla River portion of the subbasin exceed core cold water habitat criteria and spawning criteria. Maximum stream temperatures throughout the subbasin occur from late July to late August.

Mainstem Pudding River temperatures measured spring through fall 2004 (Figure 2 - 9, Figure 2 - 10, Figure 2 - 11) exceed the rearing and migration criterion by mid June and maintain that exceedance until mid September. Temperature patterns in a tributary to the upper Pudding River, Drift Creek, differ significantly upstream to down stream. At Victor Point Road (Figure 2 - 12), surrounded primarily by forestry land use, stream temperature does not exceed the criterion until mid July and falls below the criterion again by the end of August. Near the mouth of Drift Creek (Figure 2 - 13), the exceedance period is mid June through mid September. Stream temperatures measured in Silver Creek at Brush Creek Road (Figure 2 - 14) exceed the 18 ºC criterion between late June and mid September. The available data

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[5] City of Molalla's measured stream temperatures (Molalla River at approximately river mile 20) from May 2007 indicate 7-day averages of approximate daily maxima from 13.2 – 17.9 ºC. No 7-day averages of approximate maximum daily stream temperatures from May 2008 exceeded the spawning criteria of 13 ºC.

indicate that Mill Creek temperatures (Figure 2 - 15) exceed the criterion by late June, but drop below the criterion by early September.

For the Molalla River, although DEQ data were not collected into the latest of four applicable spawning seasons (i.e. after October 15), temperatures collected through October 12 indicate exceedance of the 13 ºC criteria in mid October is possible. Figure 2 - 16 through Figure 2 - 19 illustrate the summer 2004 temperature conditions in the Molalla River and two tributaries. By late June, the temperatures at the mouth of the Molalla River exceed the criterion by more than 5ºC. Upstream of the confluence with North Fork, temperatures in the Molalla River begin to climb above the criterion in late June remain well above the core cold water and spawning criteria until late September. Two tributaries to the Molalla River, Table Rock Fork (Figure 2 - 18) and Pine Creek (Figure 2 - 19), indicate a similar pattern, with temperatures beginning to exceed the core cold water criterion in mid July and remaining above the core cold water and spawning criteria until late September.

For many point sources the most challenging time to comply with the allocations in the TMDL will occur when low stream flow coincides with cooler applicable stream temperature criteria, usually in late summer to early fall. For nonpoint sources, allocations have no season-specific applicability because the activities that will lead to compliance with the TMDL (e.g. channel and riparian restoration) are on-going processes.

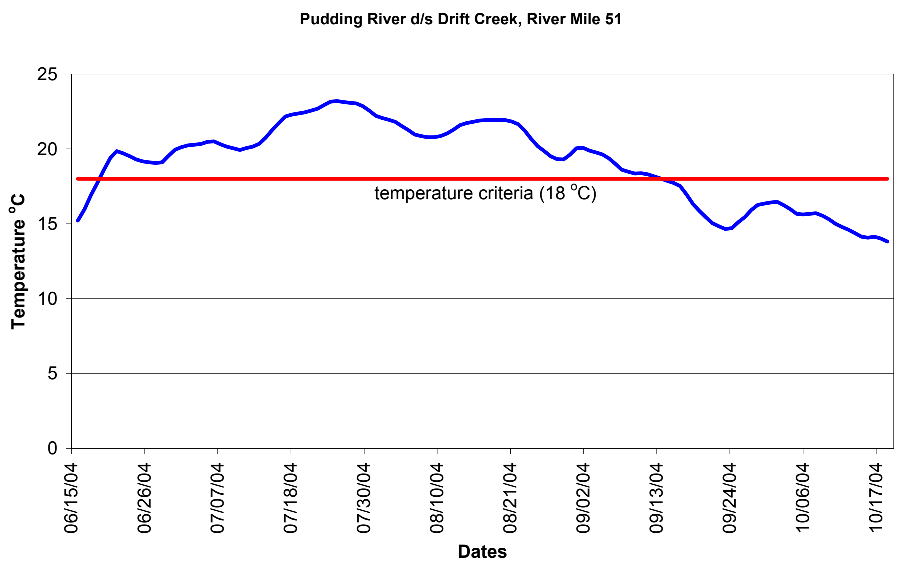

Figure 2 - 9: Moving seven day average of daily maximum temperatures measured in 2004 in the upper Pudding River.

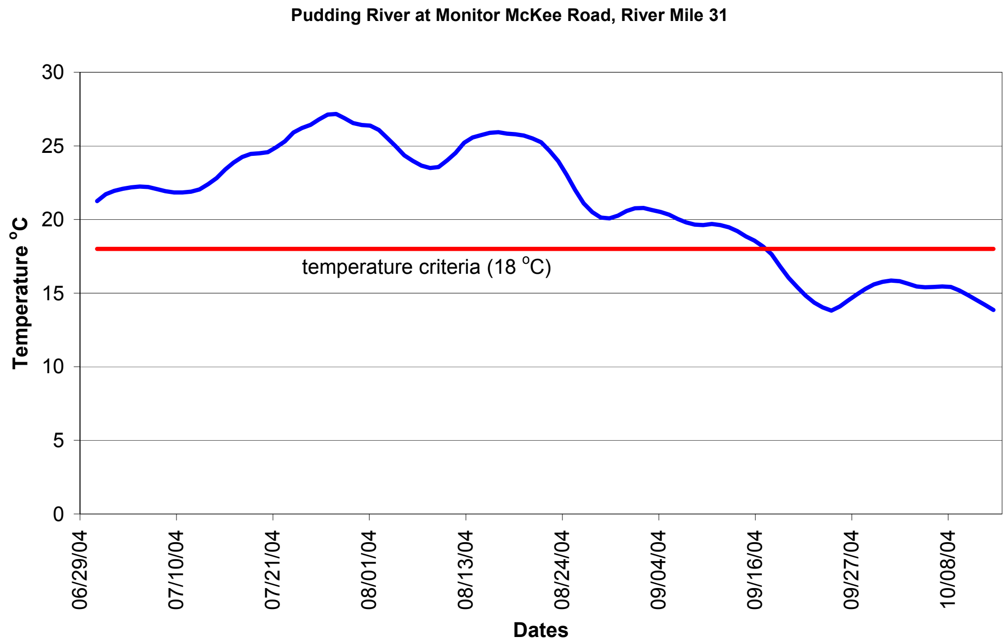

Figure 2 - 10: Moving seven day average of daily maximum temperatures measured in 2004 in the middle section of the Pudding River.

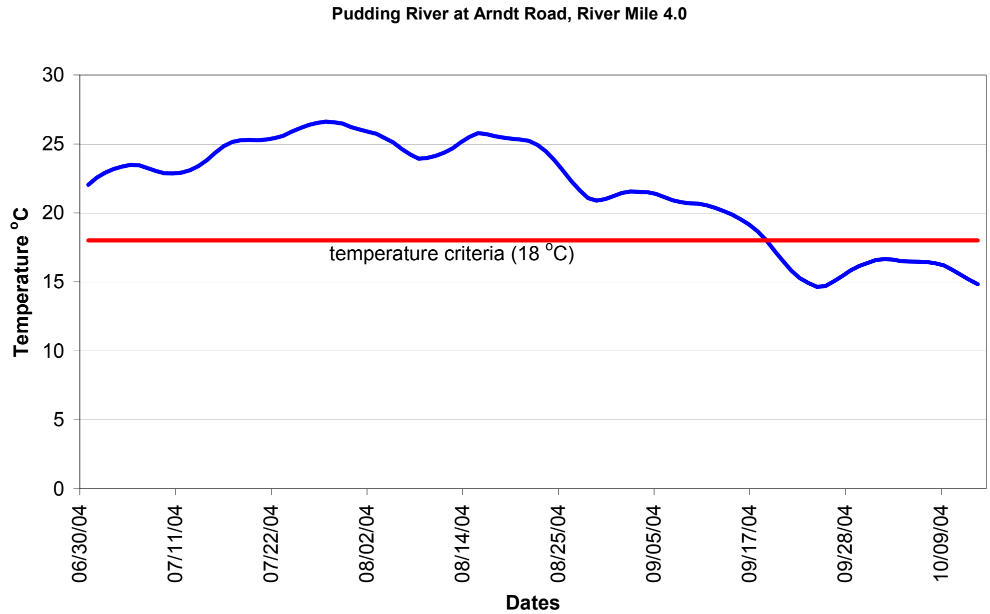

Figure 2 - 11: Moving seven day average of daily maximum temperatures measured in 2004 in the lower section of the Pudding River.

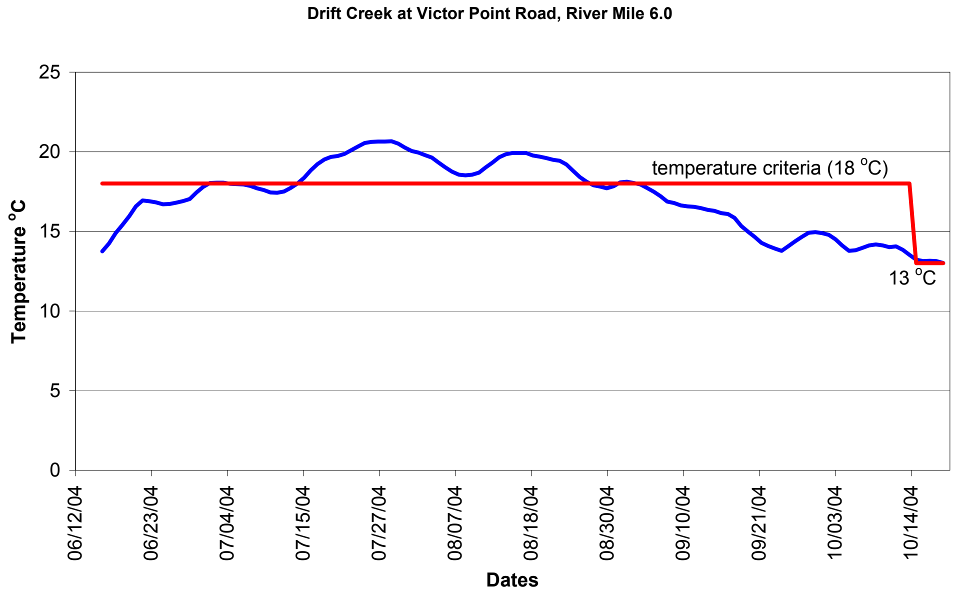

Figure 2 - 12: Moving seven day average of daily maximum temperatures measured in 2004 in the upper section of Drift Creek.

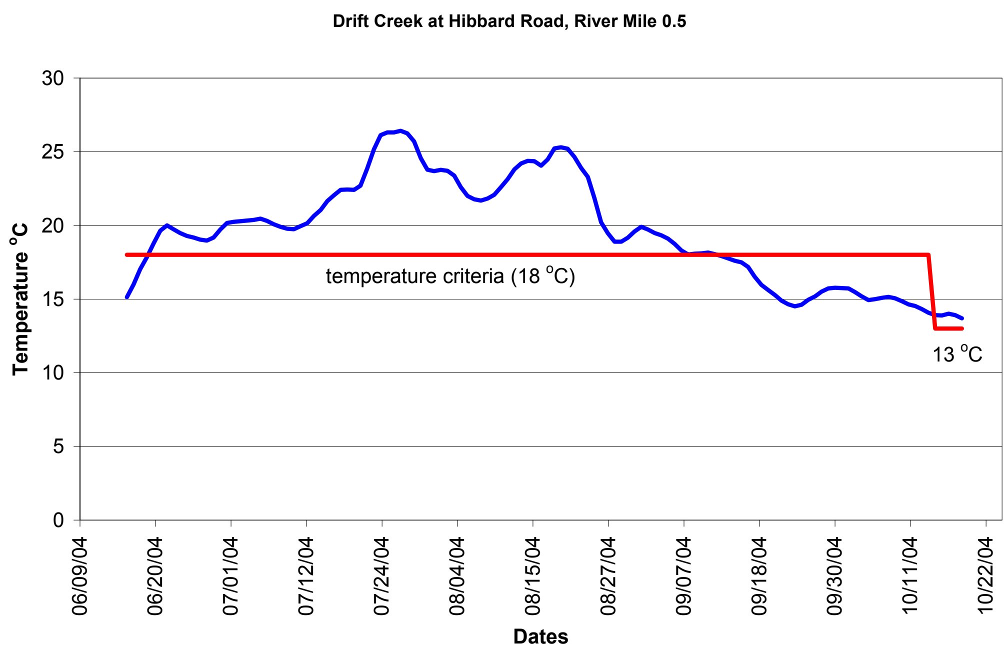

Figure 2 - 13: Moving seven day average of daily maximum temperatures measured in 2004 near the mouth of Drift Creek.

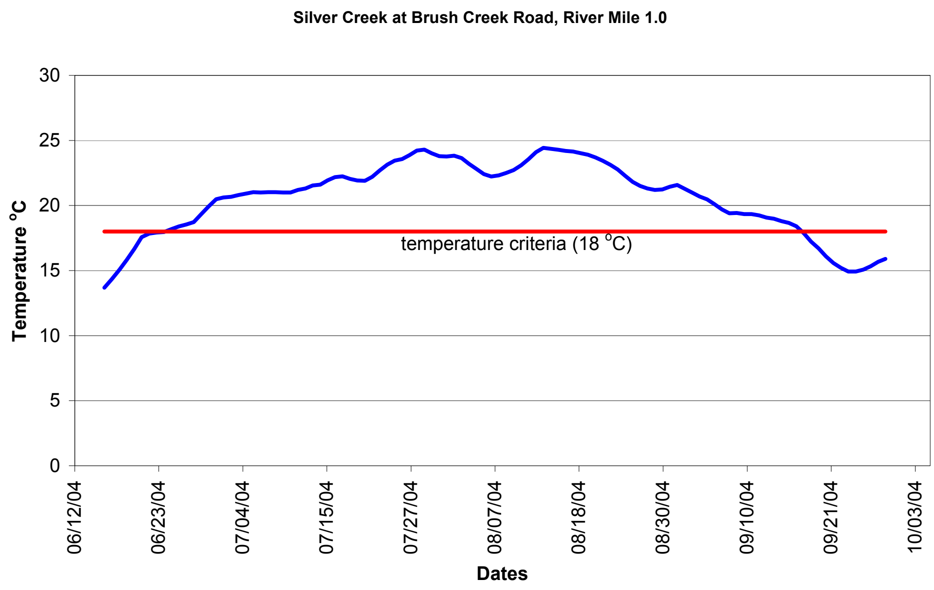

Figure 2 - 14: Moving seven day average of daily maximum temperatures measured in 2004 in Silver Creek.

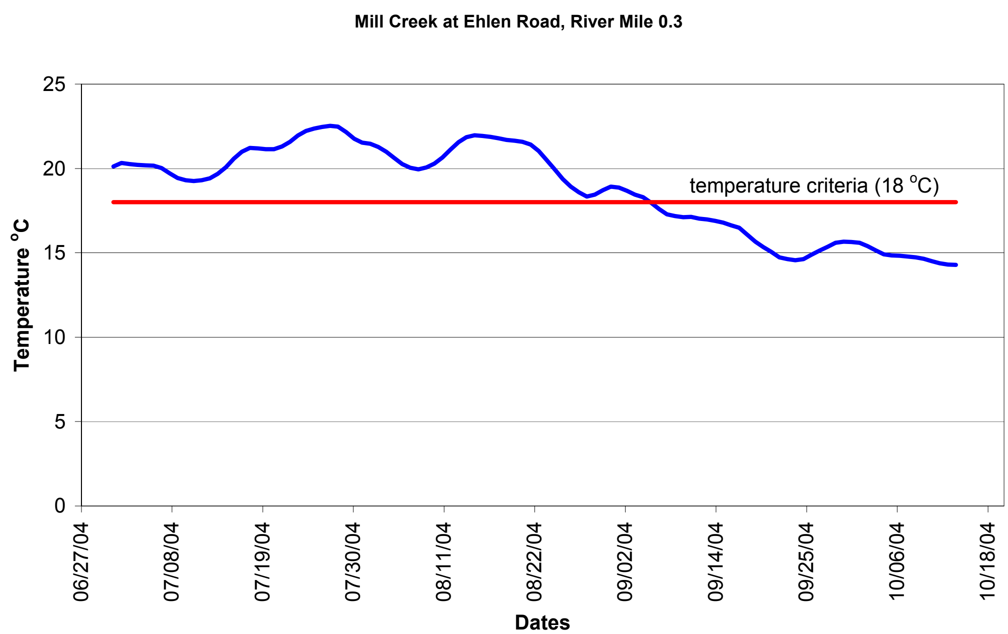

Figure 2 - 15: Moving seven day average of daily maximum temperatures measured in 2004 near the mouth of Mill Creek.

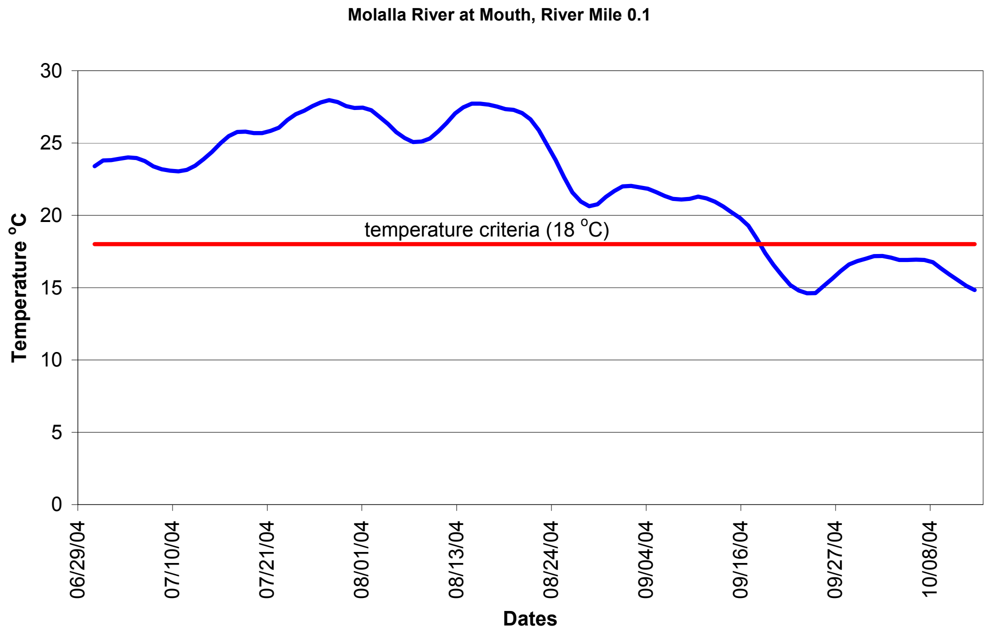

Figure 2 - 16: Moving seven day average of daily maximum temperatures measured in 2004 at the mouth of the Molalla River.

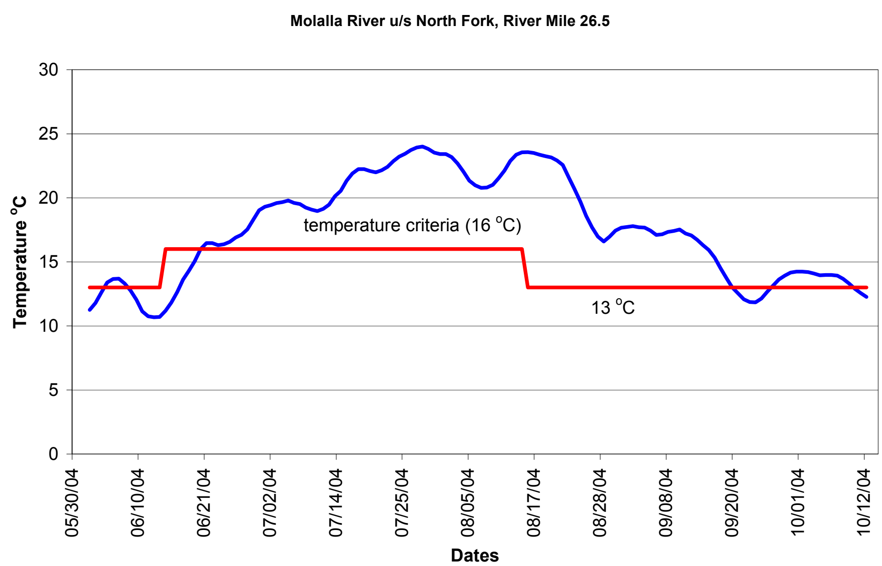

Figure 2 - 17: Moving seven day average of daily maximum temperatures measured in 2004 in the Molalla River upstream of North Fork Molalla.

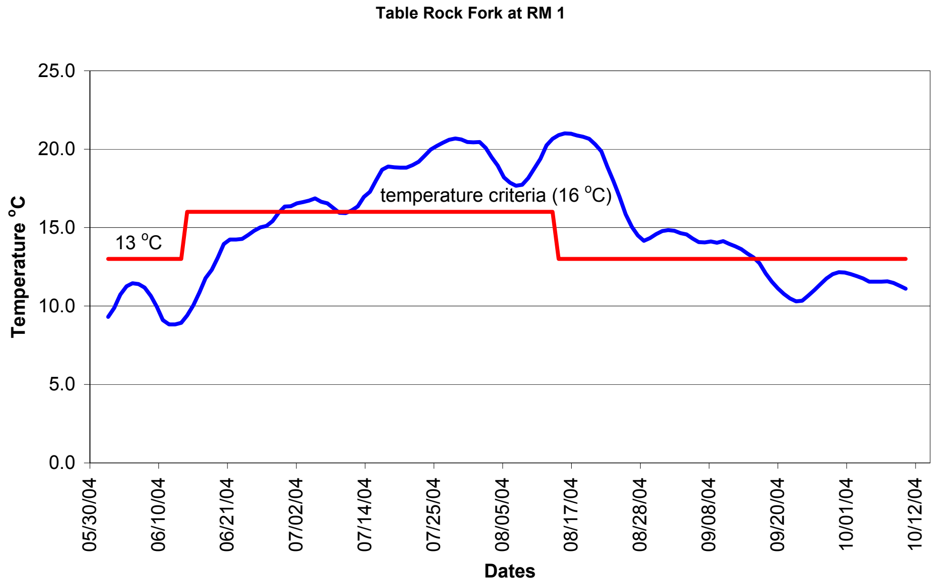

Figure 2 - 18: Moving seven day average of daily maximum temperatures measured in 2004 in Table Rock Fork, a tributary to the upper Molalla River.

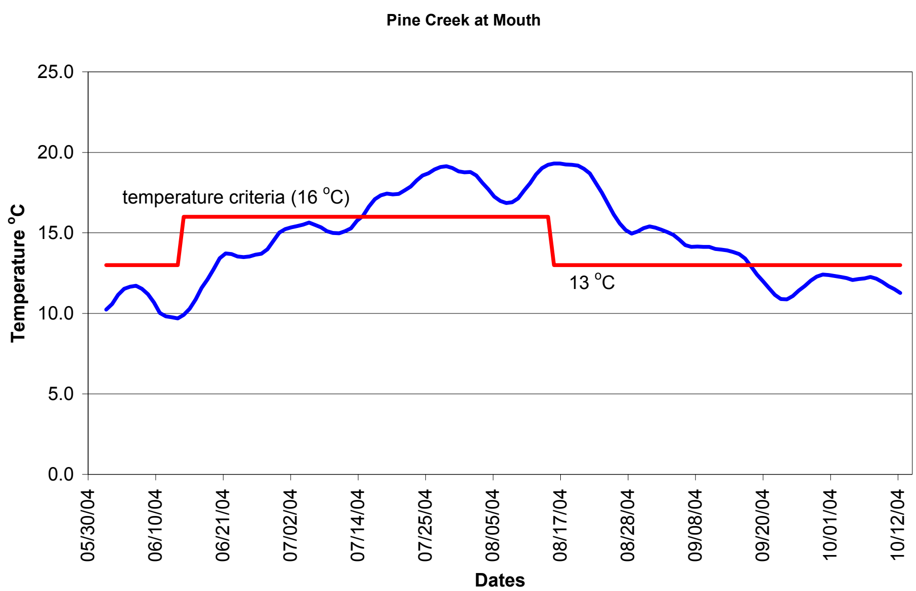

Figure 2 - 19: Moving seven day average of daily maximum temperatures measured in 2004 in Pine Creek, a tributary to the upper Molalla River.

SOURCES OR SOURCE CATEGORIES

Sources of heat pollution include nonpoint sources and point sources. Point sources of pollution enter the stream via a discrete human-made conveyance and are regulated by a permit. Nonpoint sources are generally more diffuse in nature and often cannot be traced back to a particular location. These sources are defined below in terms of land use. Dams and reservoir operations, when they are present, are also treated as nonpoint sources of pollution, in that they receive load allocations rather than waste load allocations. The effects of dams on water quality are generally more identifiable than dispersed land use nonpoint sources.

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 generally 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.

Channel modification resulting from historical logging and gravel mining may still be a non-point source of heat. Logging intensified in the Molalla River watershed after the World War II and often involved practices such as skidding logs in waterways, clear cutting in riparian zones, and splash dam construction (Cole, 2004). Human influenced runoff rates and other hydrologic modifications also influence channel morphology.

Hydrologic Modification, Dams and Ponds. The Molalla-Pudding Subbasin does not contain large-scale dams or reservoirs. Still, flow management, and smaller dams and ponds, which are prevalent in the Molalla-Pudding Subbasin, can affect stream temperature. Diverting or storing flows from natural channels during low flow periods may substantially diminish the assimilative capacity of the stream while also increasing solar loading to the stream because of greater travel times and increased surface area in ponded reaches. The release of water from reservoirs may increase or decrease down stream temperatures. The timing, duration and magnitude of such effects depend on reservoir characteristics such as surface area, depth, and withdrawal depth.

POINT SOURCES OF HEAT

There are approximately 75 stormwater permits, at the time of this writing, active in the Molalla-Pudding subbasin, including both construction and industrial permits. In previous TMDLs, including the Willamette Basin TMDL, DEQ has generally considered heat load from stormwater to have no reasonable potential to cause temperature criteria violations. For that reason, DEQ has not assigned explicit wasteload allocations (WLAs) for sources discharging only stormwater, but these sources receive implicit heat load allocations sufficient to cover current conditions of discharge.

Source locations, other than stormwater permits, are illustrated in Figure 2 - 20. In addition to stormwater permits, there are five individual and two general NPDES permitted sources in the Molalla watershed that are potential sources of heating (Table 2 - 9). There are nine individual and three general permitted sources in the Pudding watershed, but five of those sources do not discharge during the critical period in which explicit wasteload allocations apply, June 1 – September 30. Sources that do not discharge during the applicable critical periods are not assigned explicit wasteload allocations (WLAs), but rather receive implicit heat load allocations sufficient to cover current conditions of discharge. Those point sources that do not discharge during the critical periods[6], with one exception, are not described in this section. The Molalla Wastewater Treatment Plant (WWTP) does not discharge during the Molalla River critical period (May 1 – October 31), but the Protecting Cold Water criterion does apply during a portion of the spawning season when the WWTP does discharge. For that reason, the Molalla WWTP is described in this section and the potential heating effects of the WWTP are evaluated following the Wasteload Allocations section.

[6] DEQ defines the critical periods as June 1 – September 30 for the Pudding River and its tributaries, and May 1 – October 31 for the Molalla River and its tributaries.

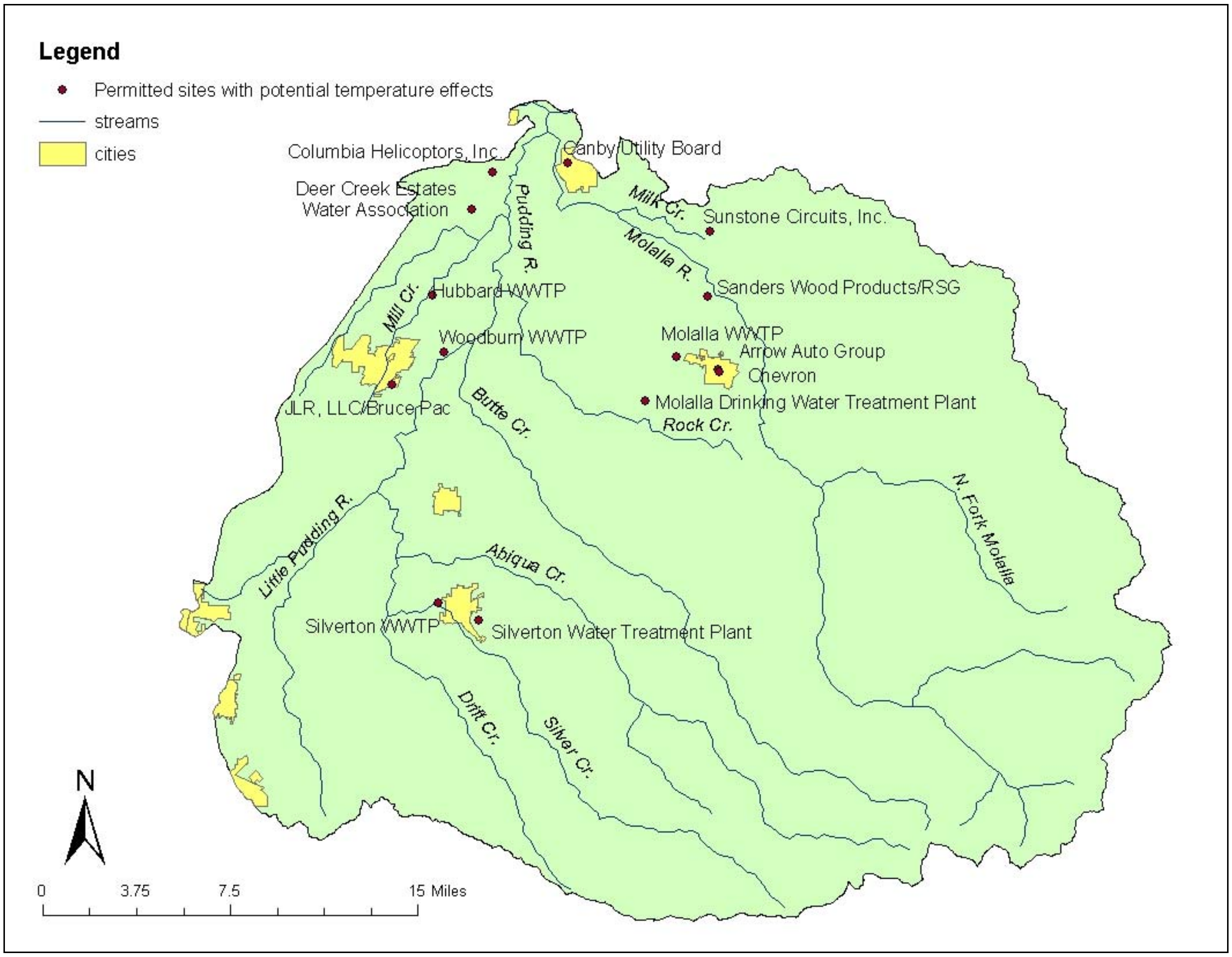

Figure 2 - 20: Molalla-Pudding Subbasin NPDES Permit Locations for identified discharges that may cause stream warming.

Table 2 - 9: NPDES permitted dischargers in the Molalla-Pudding Subbasin.
Gray cells indicate sources that do not discharge during the applicable critical periods.

Facility Name	Permit Type	Permit Description	Receiving Stream	River Mile	Season
Molalla Point Sources					
City of Molalla WWTP	NPDES-DOM-Da	Sewage disposal; less that 1 MGD with lagoons.	Molalla River	20	Nov. 1 – April 30
Molalla Municipal Water Treatment Plant	GEN02	Industrial wastewater; NPDES filter backwash	Molalla River	21.6	Year round
Canby Utility Board – Canby Water Treatment Plant	NPDES-IW-B16	Non-process wastewater; infiltration and filter gallery backwash	Molalla River	3.5	Year round
Sunstone Circuits, LLC	NPDES-IW-N	Process wastewater NEC (includes remediated groundwater)	Milk Creek	5.3	Year round
Sanders Wood Products, Inc. (RSG Forest Products)	NPDES-IW-B19	Timber and wood products – sawmills, log storage, instream log storage	Molalla River	17.3	Year round
Arrow Auto Group, Inc.	GEN17A	Industrial wastewater; NPDES wash water	Molalla River	10.2	Year round
Chevron Environmental Management Co.	NPDES-IW-B16	Non-process wastewater; groundwater remediation	Molalla River	20	Year round
Pudding Point Sources					
City of Silverton WWTP	NPDES-DOM-C1a	Sewage disposal; 5 MGD or more, less than 10 MGD	Silver Creek	2.4	Year round
City of Woodburn WWTP	NPDES-DOM-C1a	Sewage disposal; 5 MGD or more, less than 10 MGD	Pudding River (Mill Creek emergency overflows)	23.6	Year round
City of Hubbard WWTP	NPDES-DOM-Da	Sewage – less than 1 MGD	Mill Creek	5.3	Year round
JLR, LLC (Bruce Pac)	NPDES-IW-B	Food/beverage processing - Large and complex. Flow greater than or equal to 1 MGD for 180 days/year or more	Pudding River	27.2	Year round
Deer Creek Estates Water Association	GEN02	Industrial wastewater; NPDES filter backwash	Mill Creek	7.1	Year round
Silverton Water Treatment Plant	GEN02	Industrial wastewater; NPDES filter backwash	Abiqua Creek	3.9	Year round
Columbia Helicopters	NPDES-IW-B16	All facilities not elsewhere classified which dispose of non-process wastewaters	Pudding River	2	Year round
City of Aurora WWTP	NPDES-DOM-Db	Sewage disposal; less that 1 MGD with lagoons.	Pudding River	8.8	Nov. 1 – April 30
City of Gervais WWTP	NPDES-DOM-Db	Sewage disposal; less that 1 MGD with lagoons.	Pudding River	31.2	Nov. 1 – April 30
City of Mt. Angel WWTP	NPDES-DOM-Da	Sewage – less than 1 MGD	Pudding River	34	Nov. 1 – April 30
Lakewood Homeowners, Inc.	NPDES-DOM-Da	Sewage – less than 1 MGD	Mill Creek	3.9	Nov. 1 – April 30
Norpac Brooks Plant No. 5	NPDES-IW-N	Food/beverage processing - Medium. Flow between 0.1 MGD and 1 MGD, or flow greater than or equal to 1 MGD for less than 180 days/year	Pudding River	1.0	Nov. 1 – April 30

Molalla River Sources

City of Molalla Wastewater Treatment Plant

The City of Molalla Wastewater Treatment Plant discharges at approximately river mile 20 of the Molalla River between November 1 and April 30. This source outfall was relocated in 2006 from Bear Creek, a tributary to the Pudding River, to the Molalla River. Frequent violations of the bacteria standard in Bear Creek led to the relocation of the outfall approximately three miles east of Molalla.

This facility treats wastewater for a population of approximately 5,800 people. The average dry and wet weather design flow rates of the facility are 0.79 million gallons per day (MGD) and 1.92 MGD, respectively. The facility's discharge is limited via a dilution equation that takes into account the flow in the Molalla River. There are no thermal load limits set in the current, pre-TMDL permit because discharge only occurs during the winter season.

The treatment process is a preaerated lagoon system followed by dissolved air flotation and filtration. Effluent is chlorinated, dechlorinated and reaerated prior to discharge. The treated wastewater travels approximately three miles in a subsurface pipe from the treatment plant to the Molalla River outfall. The City continuously monitors effluent temperature.

During the summer, after screening, aeration in a lagoon, and additional treatment in the facultative/storage lagoons, wastewater is treated by dissolved air filtration (DAF) and chlorination. Dechlorination is not performed before the treated wastewater is irrigated on the facility site and other agricultural sites east of Molalla.

This facility is not assigned an explicit wasteload allocation because WWTP discharge does not occur during the Molalla River critical period (May 1 – October 31). This facility receives an implicit heat load allocation sufficient to cover current conditions of discharge. The heating potential of this source is evaluated in this TMDL because the Molalla River upstream of river mile 19 is listed for temperature violations during the spawning season which extends from August 15 to June 15, and because the Protecting Cold Water criterion applies during a portion of the spawning season.

Sunstone Circuits

This permit allows treated process wastewater from manufacturing circuit boards to be discharged into Milk Creek via an outfall diffuser at approximately river mile 5.3. Wastewater undergoes several chemical and physical treatment processes before being discharged. The design flow for the facility is 0.042 MGD and typical flow is 0.021 MGD. Typical summer temperatures in treated wastewater are approximately 18 – 20 ºC. The current, pre-TMDL permit includes an excess heat load limit of equivalent to 1.3 million kcal/day[7]. Effluent temperature is monitored daily. This facility is allocated a heat load in this TMDL based on an evaluation of the potential temperature increase to Milk Creek from currently permitted discharge. This heat load equates to a 0.04 ºC stream temperature increase in Milk Creek and applies May 1 – October 31.

Sanders Wood Products (RSG Forest Products)

This facility is a sawmill that processes logs into lumber. This facility uses pumped groundwater to cool the saw blades and remove sawdust and to cool a compressor. Shaker screens remove sawdust from the water before it leaves the building. Wastewater and stormwater from the facility flow to a pond with an oil water separator and then to a drainage ditch. Effluent flow reported on recent discharge monitoring reports ranges from 0.37 to 0.48 MGD, but this is measured at the outfall from the settling pond, which also includes stormwater. As water in the ditch flows northwest, the ditch alternately contributes to, and receives overflow from, farm ponds. The ditch into which the facility discharges does not visibly flow into the Molalla River, but ends in a low, ponded area. If surface flow in the ditch were to reach the Molalla River, for example during early season rains, the flow could contribute to a violation of the rearing and migration criteria (18 ºC) or the spawning criteria (13 ºC) that applies after October 14. The facility's current, pre-TMDL permit does not require temperature monitoring. This facility receives a heat load allocation equivalent to a stream temperature increase of 0.16 ºC which applies May 1 – October 31.

[7] The heat load limit in the permit is in units of megawatts (MW) -- 0.055 MW. 1 MW = 20.6 million kcal/day.

Canby Utilities
This facility is permitted for two outfalls that discharge infiltration gallery and filter gallery backwash to the Molalla River at approximately river mile 3.5. The second outfall, which on rare occasions transmitted overflow from the filter backwash ponds to the Molalla River, was eliminated in 2008 with expansion of the ponds and piping installed to recycle backwash water in the ponds back to the treatment plant. The treatment plant pumps raw water from a river infiltration gallery or surface water intake to clarifiers, filters the water with mixed media and dual filters, and disinfects the water with ultraviolet prior to chlorination.

Canby Utilities contracted operation of the Canby Water Treatment Plant to Veolia Water North America (VWNA) in April 2006. At that time, VWNA made some operational changes. Currently, untreated river water is used to backflush gravel and sediment that accumulates in the infiltration gallery, typically only in the winter months when river turbidity is higher. The former procedure had used treated water to backflush the infiltration gallery, and consequently, the permit contained both a chlorine limitation and a maximum period of discharge of 12 – 15 minutes, depending on river flow. The maximum flow rate the permit allows is 21 MGD[8].

The permit does not establish thermal load limits for the facility, but does require monitoring stream temperature upstream and downstream of the regulated mixing zone when discharges occur between July 1 and September 30. The permit also requires reporting plant effluent temperature during discharge, but the current operation (i.e. using raw river water to backflush the infiltration gallery) eliminates effluent discharge from the plant. This operational change was reported in a June 2006 letter report to DEQ that fulfilled a special condition of the permit to submit a report of operating procedures undertaken to reduce instream temperature increases during discharges.

Based on a review of the Canby Drinking Water plant 2006 operational changes, DEQ concludes that the facility does not have reasonable potential to heat the Molalla River. The facility no longer uses treated water from the plant to backflush the infiltration gallery. Raw river water passes through a caisson and pump before backflushing the infiltration gallery, but the several seconds of residence time in this apparatus is not sufficient to add a significant amount of heat. A second outfall, overflow from the filter backwash ponds, was eliminated in 2008 with the expansion of the filter backwash ponds and piping installed to recycle pond overflow back to the treatment plant. This facility does not receive an explicit wasteload allocation for heat but is allocated the negligible heat loading associated with current operating conditions.

City of Molalla Drinking Water Treatment Plant
The permit allows discharge of filter backwash and settling basin water to the Molalla River at river mile 21.6. The primary source of discharge at this facility is the backwashing of clarifier units. The average rate of filter cleaning is 6 to 8 times per month, and a typical discharge would be 45,000 gallons. Backwash occurs more frequently in the winter months when river water is more turbid. Solids cleaned from the filter material settle out in a backwash basin. From a review of the last five years of discharge monitoring reports, the highest recorded discharge was 0.0543 MGD (0.08 cfs). This facility operates under an extension to the expired NPDES General Permit 200J[9]. The permit requires a 30:1 dilution in the receiving stream during periods of discharge. The maximum reported discharge from this facility and the 7Q10 flow in the Molalla River at river mile 20 (18 cfs) would meet the dilution requirement. The highest temperature recorded over the previous five years, measured in the settling pond, was 26ºC. The settling pond drains into a ditch, which enters a slough. In the summer months, the drainage water tends to infiltrate, resulting in no visible surface discharge to the Molalla River. This facility receives a heat load allocation equivalent to a 0.02 ºC rise in ambient river temperature, applicable May 1 – October 31.

Arrow Auto Group
Based on the size of the discharge from Arrow Auto Group, DEQ considers the discharge to have no reasonable potential to increase stream temperature in the Molalla River. This business washes about 8 cars per day with cold water from a hose and discharges to a storm drain. Outfall from the storm drain

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[8] The permit flow rate limit is in terms of cubic meters/minute: 56.8 cubic meters/min.

[9] The 200J General Permit for discharge or land application of filter backwash expired in July 2002. The permit is scheduled to be revised in summer 2009. Until the permit is revised, sources continue to operate under the discharge limitations and requirements of the expired permit.

enters the Molalla River at approximately river mile 10. The permit does not require monitoring of effluent temperature or rate. Given discharge from a typical hose of 5 gallons per minute (0.01 cfs), an effluent temperature similar to room temperature (23 ºC), river temperature at the biologically based criteria (18 ºC or 13 ºC)and 7Q10 flows of the Molalla River in August (23 cfs) and October (25 cfs), the potential stream temperature increase from this discharge is less than 0.01 ºC. Because discharge from this facility does not have a reasonable potential to increase stream temperature, this facility does not receive an explicit wasteload allocation for heat, but is allocated the negligible heat loading associated with current operating conditions.

Chevron Environmental Management (Chevron/Texaco Service Station No. 211-517)
This is a groundwater remediation site. Groundwater is pumped, treated to remove petroleum hydrocarbon contaminants, and the treated groundwater is discharged to the Molalla River by way of the City of Molalla stormwater system, Creamery Creek, and Gribble Creek. The pumping and discharge is intermittent from 0.029 to 0.057 MGD. The permit holder is not required to measure temperature in the effluent, but they report the median groundwater temperature as 14.8ºC and the maximum as 19.9ºC, based on all measurements taken. The permit holder estimates that the maximum temperatures of the discharge, after a short residence time in the treatment system, are 20ºC in the summer and 18ºC in the winter. This facility receives a heat load allocation equivalent to a 0.02 ºC stream temperature increase applicable May 1 – October 31.

Pudding River Sources

City of Woodburn Wastewater Treatment Plant
The City of Woodburn discharges treated and dechlorinated wastewater to the Pudding River at river mile 23.6. Effluent exits through a primary outfall into the Pudding River except when discharge flows at the facility exceed 12 MGD. Then, effluent overflows an internal weir and exits from a second outfall at approximately the same river mile. The facility serves approximately 25,000 people and treats sewage with screening, primary clarification, activated sludge, secondary clarification, effluent filtration and ultraviolet disinfection. The average dry weather design is 3.3 MGD and the average wet weather flow is 4.8 MGD. The facilities planning effort currently underway defines the long-term average dry weather design flow as 5.9 MGD and the average wet weather design flow as 8.6 MGD. Three emergency pump stations may have overflows to Mill Creek or two Mill Creek tributaries only in the case of storm events surpassing a one-in-five-year (Nov. 1 – May 21) or one-in-ten-year (May 22 – October 31) 24-hour duration storm.

The permit sets an excess thermal load from May 1 – October 31 of 9.2 million kcal/day (0.44 MW). The permit also sets limits on TSS, CBOD, *E. coli*, pH, and ammonia year round. TSS and CBOD have distinct summer and winter standards, and ammonia depends of both river flow and season. A minimum dissolved oxygen standard applies between June 1 – October 31.

Level III effluent can also be irrigated on 88 acres of a poplar plantation. Additional acreage, up to 240 acres, can be added as needed. Biosolids are stored in facultative lagoons for approximately 3 years before being removed or applied to the poplar plantation.

This facility receives an allocated heat load equivalent to a 0.2 ºC stream temperature increase, applicable June 1 – September 30, when the discharge is fully mixed with the Pudding River.

JLR, LLC (Bruce Pac)
This discharge from this facility enters the Pudding River at river mile 27. The facility currently cooks and processes meat. Wastewater from washing the plant and equipment is treated by filtering, aeration, clarification, chlorination, lagoon storage, and dechlorination/reaeration. The facility also treats domestic wastewater and the treated process water and treated domestic wastewater comingle before being discharged to the Pudding River. In 2003, JLR, LLC purchased the facility previously owned and operated by Agripac as a fruit and vegetable processing facility. JLR intends to grow their operations to a maximum design flow of 2 MGD by 2024. Current discharge design flow is 0.5 MGD and permit limits are also calculated based on this flow as well as a projected design flow of 1.35 MGD.

The facility currently does not discharge in the summer months, but irrigates adjacent agricultural land, separate parcels for the treated domestic wastewater and treated process water. Land application is covered under the same permit as the surface water discharge. Reclaimed wastewater is treated to Level

II standards (as defined in OAR340-55). Land application is also described in the required Operations Monitoring and Management Plan.

Summer effluent temperatures have not been collected because the facility is only required to monitor effluent temperature if they are discharging to the Pudding River. The temperature management plan, completed as part of the permit, calculates the potential heating effect from an estimated effluent temperature of 72ºF(22.2ºC) on the Pudding River if the river were at the temperature criterion. The current thermal load limit in the pre-TMDL is 13 million kcal/day (0.63 MW-day/day). In this TMDL, this facility is allocated a heat load equivalent to a 0.01 ºC stream temperature increase when fully mixed with the Pudding River, applicable June 1 – September 30. Modeling shows that the effect from this heat load will dissipate upstream of the Woodburn WWTP, so the temperature effects from the allocated heat loads to these two facilities will not be cumulative.

City of Silverton Wastewater Treatment Plant

The City of Silverton wastewater treatment plant serves approximately 10,000 people. Current average wet and dry weather design flows to the facility are 4.6 MGD and 2.5 MGD, respectively. The facility treats wastewater with an activated sludge procedure and ultraviolet disinfection. Between May and October, based on a review of 2006 data, between 13 and 75% (54% average) of the discharge, post treatment, is pumped to several wetland cells in the Oregon Garden. The remainder flows by gravity to Silver Creek at river mile 2.4.

The portion of the finished effluent pumped to the Oregon Garden enters a series of wetlands. Some is diverted from the first wetland complex for irrigation. After passing through two more wetland complexes, the water is discharged to Brush Creek. The Garden can accept all the effluent the WWTP generates in excess of what is permitted to discharge to Silver Creek between July and September. The Garden does not accept effluent from the WWTP in the winter months because the effluent may contain higher concentrations of CBOD (carbonaceous biochemical oxygen demand), TSS (total suspended solids), and ammonia than the permit allows in the summer months. The effluent the Oregon Garden accepts meets the permit requirements for discharge to Silver Creek and is not allowed a mixing zone in the Garden wetlands.

Thermal load limits currently set in the pre-TMDL permit are 5.2 million Kcal/day (0.25 MW-day/day) between May 16 and October 14, and 21 million kcal/day (1.0 MW) from October 15 to May.15. The permit states that upon completion of a TMDL, the permit may be re-opened to include new or revised thermal load limits. The City continuously monitors effluent temperature for wastewater discharged to Silver Creek as well as that discharged to the Oregon Garden wetlands. Starting in 2005, the City also started monitoring temperature of the outflow from the Oregon Garden wetland to Brush Creek. They also have monitoring locations in Silver Creek, the Oregon Garden wetlands, and Brush Creek where grab samples are collected and temperature is measured every two weeks.

In 2006, the City of Silverton completed an update of the wastewater and collection system master plan. The plan includes increasing the area at the Oregon Garden to be used for irrigation with treated wastewater. The plan is intended to outline the needs and plans for the facility for 20 years.

This facility receives an allocated heat load in this TMDL equivalent to a 0.2 ºC stream temperature increase when fully mixed with Silver Creek, applicable June 1 – September 30.

City of Hubbard Wastewater Treatment Plant

This facility discharges wastewater treated with an activated sludge process to Mill Creek at river mile 5.3. Wastewater is screened, aerated for approximately three days, and clarified before ultraviolet disinfection. In 2005, DEQ approved engineering plans and specifications for plant modifications to address recent operational problems. The current permit regulates BOD, pH, *E. coli*, TSS, and temperature. Monitoring requirements include dissolved oxygen, ammonia and nutrients. The permit also requires the permittee to evaluate the use of effluent for reclaimed water or other non-discharging alternatives in the summer period and submit a report to DEQ by October 31, 2008.

Thermal limits in the current, pre-TMDL permit are calculated from weekly average dry weather design flow (0.51 MGD) and maximum measured summer effluent temperature (24 ºC). The current, pre-TMDL thermal limit is 1 million kcal/day (0.48 MW-day/day). In this TMDL, this facility is allocated a heat load equivalent to a 0.2 ºC stream temperature increase when fully mixed with Mill Creek, applicable June 1 – September 30.

Deer Creek Estates
Deer Creek Estates is a mobile home association that treats groundwater for drinking water. An oxidizer, potassium permanganate, is added to extract iron and manganese. A sand filter treats about 100,000 gallons/day and generates about 2,400 gallons in a daily backwash. Filter backwash is allowed to settle and is discharged along with wastewater from the water treatment filter tanks to Deer Creek at river mile 0.4. Estimated concentration of iron and manganese oxide in discharge water is 19.35 mg/L and 6.9 mg/L, respectively.

Few data are available to evaluate the potential thermal effects from the Dee Creek Estates Water Association discharge into Deer Creek. Neither temperature nor discharge information have been submitted to DEQ since 1996 and it is not certain that the facility still discharges to surface water. A 1978 permit application indicates a potential daily discharge of 2,400 gallons. Because of the uncertainty associated with this discharge and the likelihood of no reasonable potential to increase stream temperature in the Pudding River, this facility does not receive an explicit wasteload allocation for heat, but is allocated the negligible heat loading associated with current operating conditions.

City of Silverton Drinking Water Treatment Plant
The City of Silverton drinking water treatment plant discharges wastewater from filter backwash and reservoir cleaning water to Abiqua Creek at river mile 3.9. Wastewater first enters a storm sewer system, daylights in a drainage ditch through a partially developed industrial area, and flows into a constructed pond of approximately 20 acres and10 feet in depth (Webb Pond). The pond acts as a settling basin. Overflow from the pond enters a drainage ditch which discharges to Abiqua Creek. Aluminum sulfate, sodium hydroxide, sodium silicoflouride, and chlorine are added during drinking water processing. Residual chlorine, pH, and settleable solids are regulated by the discharge permit. Typical average monthly discharge reported between 2000 and 2007 ranges from 0.02 to 0.05 MGD. This facility receives an allocation equivalent to a 0.2 ºC stream temperature increase when fully mixed with Abiqua Creek, applicable June 1 – September 30.

Columbia Helicopters, Inc.
This helicopter leasing and maintenance facility has a permit that allows for treated wastewater discharge into a storm drain on Airport Road in Aurora. The storm drain outfalls at approximately river mile 2 on the Pudding River. Past practices at the site have contaminated the groundwater with volatile organic compounds (VOCs) and groundwater remediation has been on-going since 1992.

Discharged wastewater includes treated groundwater, stormwater, penetrant dye wastewater, vehicle/aircraft washwater, and transmission washwater. Five groundwater extraction wells reach depths of approximately 40 feet. Pumped groundwater goes to an air stripping tower for VOC removal and is discharged at a rate of approximately 0.144 MGD. Domestic water used for the dye process is treated with carbon filtration before discharge. Cold domestic water is also used for vehicle and transmission washing at rate of about 800 gallons per day and goes to a settling basin before discharge.

Oil and grease, pH, some metals, and volatile organic compounds are regulated by the permit as is the requirement for a stormwater pollution control plan. DEQ considers wastewater from the site to have no reasonable potential to increase stream temperature in the Pudding River, but discharging treated groundwater may contribute metals such as iron and manganese. While the permit limits and monitoring do not currently incorporate iron and manganese, stormwater best management practices, erosion control, and limits on other metals are likely to limit the iron and manganese contribution from stormwater. This facility does not receive an explicit wasteload allocation for heat but is allocated the negligible heat loading associated with current operating conditions.

ALLOCATIONS

Loading capacity is allocated among point sources as wasteload allocations and to nonpoint sources as load allocations. The temperature rule specifies that after a TMDL is completed,[10] in waters that exceed the applicable temperature criteria, heat loading from point and nonpoint sources may not increase stream temperature more than a "human use allowance" of 0.3˚C when fully mixed with a stream and at the point of maximum impact.[11] The actual allocation of heat within the human use allowance is not specified in the temperature rule.

DEQ has allocated the allowable heat load in the Molalla-Pudding Subbasin TMDL in a manner consistent with the Willamette Basin temperature TMDL (DEQ, 2006)[12]: DEQ allocated among all point sources on a stream, heat loads that yield a cumulative increase in stream temperature no more than 0.2˚C. To all combined nonpoint sources, DEQ allocated a heat load causing no more than a 0.05 ˚C increase in stream temperature. A heat load equivalent to a 0.05˚C increase in stream temperature is held as reserve capacity. Where the maximum allowable discharge from a facility causes less than the 0.2˚C cumulative increase in stream temperature, the remaining heat load is allocated to reserve capacity. These allocations are expressed in energy units such as kilocalories per day (or equivalent SI power units megawatt-day/day, MW-day/day). The specific methods and equations used to develop wasteload allocations are described in this section and in Appendix D.

WASTELOAD ALLOCATIONS

A wasteload allocation (WLA) is the portion of the loading capacity allocated to point sources. DEQ provides waste load allocations to all NPDES facilities with reasonable potential to warm the receiving stream above the applicable criteria. Equation 1 calculates the maximum allowable increase in stream temperature (ΔT) for a given thermal discharge.

In most cases for this TMDL, a WLA is expressed as a flow-based formula (Equation 2). Using the formula as the wasteload allocation captures varying flow conditions, both effluent and in-stream, up to and including the design flow of the facility. This method allows facilities to increase discharge and still be within receiving water requirements. Waste load allocations for temperature are expressed as heat load limits (kcal/day or equivalent SI units MW-day/day) by multiplying the allowable stream temperature increase (not more than 0.2 ºC) by the combined flow of the point source and the receiving stream. This form of wasteload allocation is referred to as excess thermal load (ETL). Where in-stream and effluent flow information are sufficient, DEQ assigns flow-based ETLs, such that the allowable heat load varies with the flow of the stream and the point source. If daily stream discharge information is not readily available or attainable, DEQ calculates a fixed ETL based on an estimated 7Q10 flow of the stream and the design flow of the facility.

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[10] Before development of a TMDL, the temperature rule (OAR 340-041-0028) allows a point source to discharge a heat load that may cause as much as a 0.3˚C increase in stream temperature when mixed with ¼ of the receiving stream flow or the volume of the temperature mixing zone (whichever is more restrictive).

[11] The point of maximum impact is defined as the point in the stream where the maximum difference in temperature between natural thermal potential temperature and current temperatures occurs. DEQ estimated the natural thermal potential of the Pudding and Molalla Rivers through modeling. The modeling is described in the Natural Thermal Potential Development Methodology section as well as Appendix E.

[12] The Willamette River TMDLs Council was an advisory stakeholder group composed of representatives from industry, state and federal agencies, municipalities, tribes, agriculture, forestry, and environmental advocacy and other non-profit organizations. The group met and conferred over several years during development of the Willamette Basin TMDLs. The Council recommended that in allocating heat loads resulting in no more than a 0.3 ºC stream temperature increase, that heat loading equivalent to 0.05 ºC be reserved for future growth (reserve capacity), heat loading equivalent to a stream temperature increase of 0.05 ºC be allocated to non-point sources, and the remaining heat load, resulting in no more than 0.2 ºC stream temperature increase, be allocated among all point sources.

$$\Delta T = \left(\frac{Q_e}{Q_e + Q_R}\right)(T_e - T_c) \quad \text{(Equation 1)}$$

where:

Q_R = river flow rate

Q_e = effluent flow rate

T_c = applicable river temperature criteria

T_e = effluent temperature

In terms of dilution factor, D_F

$$\Delta T = \frac{T_e - T_c}{D_F}$$

where:

$$D_F = \frac{Q_e + Q_R}{Q_e}$$

$$\text{ETL} = (\Delta T)(Q_R + Q_e)C_F \quad \text{(Eq. 2)}$$

where:

ETL = Excess thermal load, $kcal/day$

ΔT = allowable temperature increase, ^oC

Q_R = river flow rate, upstream, m^3/s

Q_e = effluent flow rate, m^3/s

C_F = conversion factor

$$C_F = 86.4 \text{ x } 10^6 \frac{kcal \cdot s}{^oC \cdot m^3 \cdot day}$$

Alternatively, for flow as cfs:

Q_R, Q_e units: ft^3/s

$$C_F = 2{,}446{,}665 \frac{kcal \cdot s}{^oC \cdot ft^3 \cdot day}$$

The current excess thermal load (ETL) from a point source can be quantified with Equation 3 by calculating the difference between the effluent temperature and applicable stream temperature criterion – either the biologically based numeric temperature criterion or the natural thermal potential temperature at the location of the discharge. Since applicable criteria are based on 7-day average daily maximum (7DADM) values, generally all calculations should be performed using trailing 7-day averages, with 7-day average daily maximum values used for effluent temperature (T_e) and 7-day average values used for effluent flow (Q_e).[13] Effluent temperatures and effluent flows that correspond with a particular excess thermal load (ETL) can be calculated with Equations 3a and 3b. DEQ estimated the target criteria (natural thermal potential temperatures) at point source locations on both the Pudding and Molalla Rivers with methods described in the following section and Appendix E . Also, in the following section, the heat loading equivalent to 0.2 ºC of the human use allowance is apportioned among the facilities, based in part on simulations of cumulative thermal effects from neighboring sources. Example tables of effluent temperatures and effluent flows within a point source's allocated ETL are included in Appendix D.

[13] However, the exact statistics used for compliance purposes will be specified in each of the NPDES permits.

$$\mathrm{ETL} = Q_e(T_e - T_c)C_F \qquad \text{(Equation 3)}$$

$$T_e = \frac{ETL}{Q_e C_F} + T_c \qquad \text{(Eq. 3a)}$$

$$Q_e = \frac{ETL}{(T_e - T_c)C_F} \qquad \text{(Eq. 3b)}$$

where:

$ETL = $ Excess thermal load, $kcal/day$

Pudding River Wasteload Allocations

Permitted discharges to the Pudding River portion of the subbasin are listed in Table 2 - 10. The facilities most likely to contribute significant heat loads to the Pudding River or tributary are the City of Woodburn WWTP, JLR, LLC/Bruce Pac, Hubbard WWTP and Silverton WWTP.

Table 2 - 10: Potential heat discharges to the Pudding River.

Facility Name	Permit Type	Permit Description	Receiving Stream	River Mile	Season
City of Silverton WWTP	NPDES-DOM-C1a	Sewage disposal; 5 MGD or more, less than 10 MGD	Silver Creek	2.4	Year round
City of Woodburn WWTP	NPDES-DOM-C1a	Sewage disposal; 5 MGD or more, less than 10 MGD	Pudding River	23.6	Year round
City of Hubbard WWTP	NPDES-DOM-Da	Sewage – less than 1 MGD	Mill Creek	5.3	Year round
JLR, LLC/Bruce Pac	NPDES-IW-B	Food/beverage processing - Large and complex. Flow greater than or equal to 1 MGD for 180 days/year or more	Pudding River	27.2	Year round
Silverton Water Treatment Plant	GEN02	Industrial wastewater; NPDES filter backwash	Abiqua Creek	3.9	Year round

Cumulative Effects Analysis

Because wasteload allocations are based on cumulative influences from thermal discharges, modeling was performed to quantify potential overlap of heat inputs from the four likely significant heat discharges to the Pudding River and tributaries. The simulations assumed a conservative, worst-case scenario, that each point source discharged a heat load equivalent to a 0.2 ºC increase in the 7 DADM temperature of the receiving stream. This is a hypothetical scenario, since the JRL facility does not currently discharge in summer and since JRL has been given a wasteload allocation of only 0.01oC, not 0.20oC. Additional assumptions are listed below. These are conservative assumptions in that they simulate low flow, but not additional anthropogenic heat loads.

- Natural stream flow rates correspond to a Little Abiqua Creek 7Q10 flow rate of 1.7 cfs.[14]
- Consumptive uses, via diversions from tributaries to the Pudding River and directly from the Pudding River, correspond to conditions for which Pudding River flow rates equal 7Q10 low flow rates of 15 cfs at the gage near Woodburn (USGS gage number 14201340) and 25 cfs at the gage at Aurora (USGS gage number 14202000).
- Vegetative shade is at system potential levels (with natural disturbance).
- Tributary temperatures do not exceed the 7DADM temperature criterion of 18.0^{o}C.

[14] Little Abiqua Creek flows were used as reference flows because the stream has no surface water diversions.

All discharges were modeled with pure heat loads (negligible flow) so that calculated temperature increases (ΔT) would not be influenced by changes in time of travel. Model calculated temperatures and ΔT impacts are shown in Figure 2 - 21 and Figure 2 - 22.

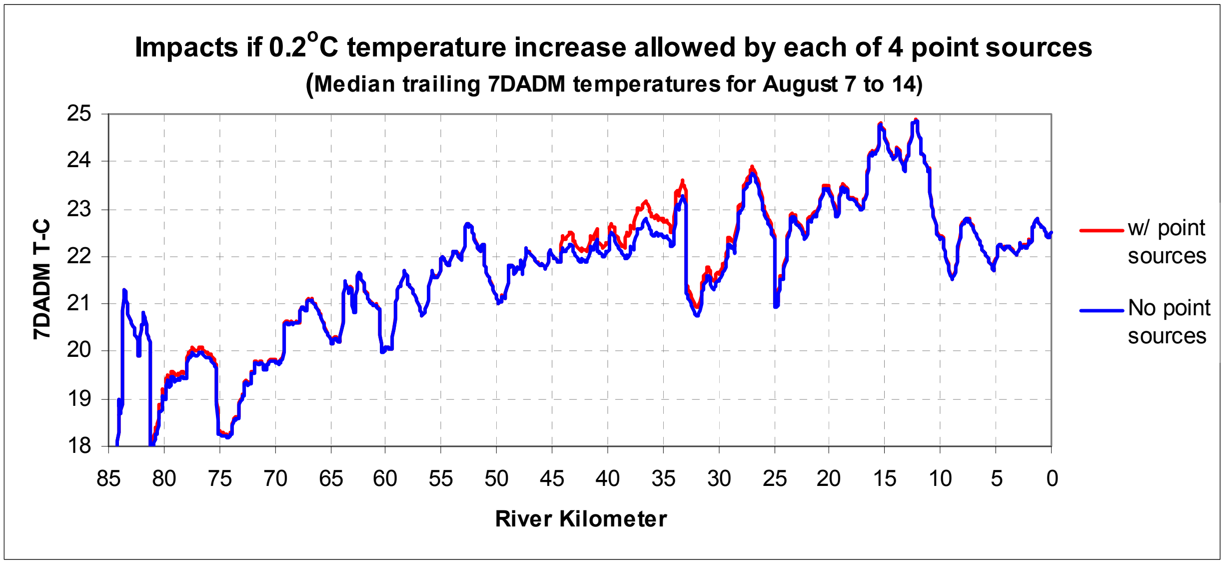


Figure 2 - 21: Pudding River temperature simulation illustrating cumulative effects of heat loads.

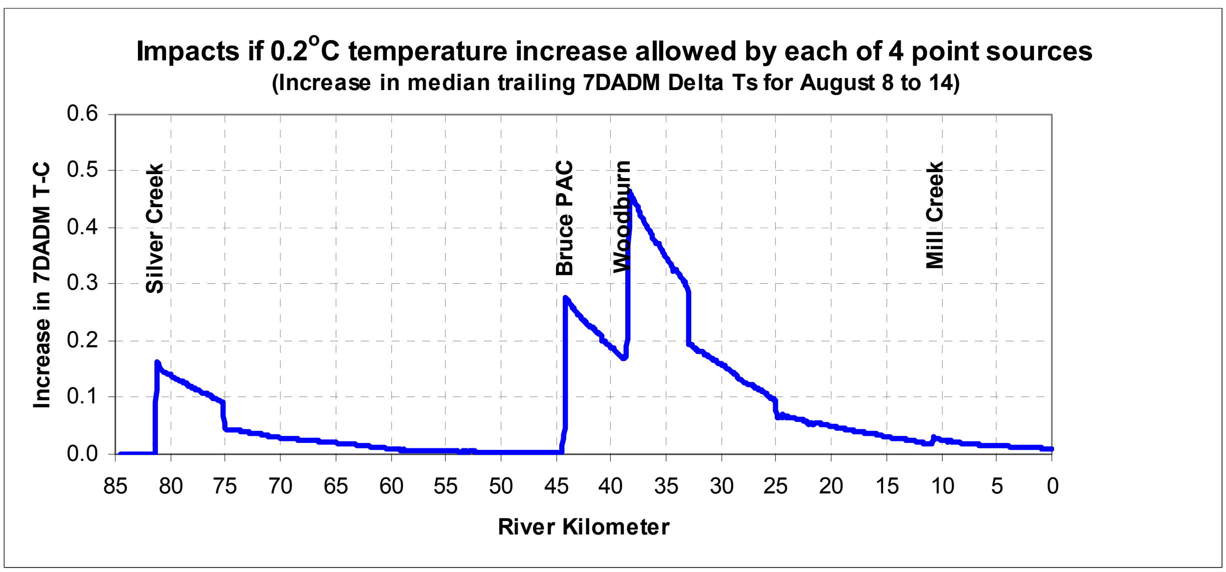


Figure 2 - 22: Pudding River temperature simulation illustrating temperature increases attributable to four dischargers.

As shown (Figure 2 - 22), the model calculates that a 0.2°C increase in Silver Creek 7DADM temperature results in an increase in Pudding River 7DADM temperature of about 0.17°C. The increase is relatively large because, in this area, the Pudding River consists mostly of flow from Silver Creek. Conversely, a 0.2°C increase in Mill Creek 7DADM temperatures results in only a small increase in Pudding River temperature. The increase is small because Pudding River flow is much greater in this area.

The temperature increase due to Silver Creek largely dissipates by location River Kilometer 60 and is negligible at the locations where JLR, LLC/Bruce Pac and Woodburn discharges are located (RKm 44 and 38). Since there is no cumulative effect via the Pudding River, the point sources to Silver and Mill Creeks can each be allowed heat loads equivalent to a stream temperature increase of 0.2 ºC (the portion of the human use allowance allowed for point sources).

Conversely, the model shows that the temperature effects of JLR, LLC/Bruce Pac and Woodburn discharges are cumulative (Figure 2 - 23)[15]. About two-thirds of the temperature increase caused by JLR, LLC/Bruce Pac remains at the Woodburn discharge location. Therefore, if more than a negligible portion of the heat load allowed by the HUA is allocated to JLR, LLC/Bruce Pac, then a reduction in the Woodburn wasteload allocation would be required. The allocation to each of these sources is discussed later in the Wasteload Allocations section.

Derivation of Applicable Temperature Criteria for Seasons of Concern

In order to derive wasteload allocations for point sources, applicable temperature criteria must be derived for each discharge location. When NTP temperatures exceed biologically based numeric criteria, NTP temperatures are the applicable criteria. When NTP temperatures are less than biological criteria, the biological criteria are the applicable criteria.

Available data do not indicate that the 18°C biological criterion is exceeded prior to June 1 or after September 30. Therefore, wasteload allocations for the Pudding River apply from June 1 to September 30. Because the discharges take place during and outside of the two-week model period, maximum NTP values, with appropriate margins-of-safety, must be estimated between June 1 and September 30. The details of DEQ's NTP analysis are presented in Appendix E and are summarized in this section.

DEQ estimated NTP between June 1 and September 30 at the Pudding River point source locations and three locations in the vicinity of the point sources (site numbers 11530, 10641, and 10640), as follows. First, DEQ reviewed three years (2001, 2002, 2004) of continuous temperature data collected from the Pudding River at Aurora (site number 10917, river mile 8, river km 12.9) to differentiate time periods having similar 7 day average maximum temperatures (7DADM) (Figure 2 - 23). The differentiated time periods are:

- June 1 – 15
- June 16 – 30
- July 1 – 14
- July 15 – August 31
- September 1 – September 15
- September 16 – September 30

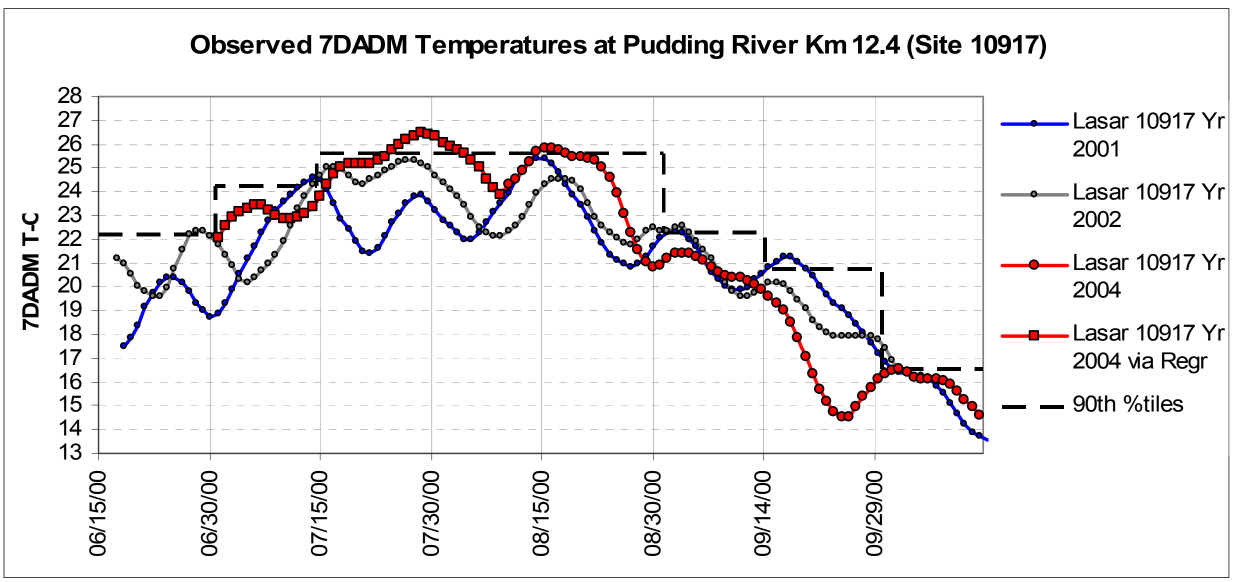


Figure 2 - 23: Time periods with similar 7-day average daily maximum temperatures based on three years of continuous temperature data collection from Pudding River at Aurora.

15 The Heat Source model slightly over-calculates the impact of point source heat loads – for example, Figure 42 indicates a temperature increase greater than 0.2 ºC from the simulated Bruce Pac discharge. DEQ has been unable to identify the cause of the over calculation, but since excess thermal load allocations calculated using the model would be slightly conservative, considers the error negligible.

The temperature data from Pudding River at Aurora was also regressed with data collected in 2004 from the three sites in the vicinity of the point sources to establish predictive relationships. DEQ then determined the average differences between current calibrated condition (CCC) model temperatures and NTP temperatures for the model period. Those differences (CCC – NTP) (Line 3 in Table 2 - 11) were then subtracted from the estimated 90th percentile ambient temperatures (Table 2 - 11, Row 4) to derive estimated 90th percentile NTP temperatures for the monitoring sites (Table 2 - 11, Row 5). Using the 90th percentile NTP temperatures provides a greater margins-of-safety than using maximum NTP temperatures. NTP temperatures at the effluent discharge locations (JLR, LLC/Bruce Pac and Woodburn WWTP) were then estimated via linear interpolation (Table 2 - 11, Row 5). Since these values of 20.9 and 21.6^{o}C exceed the 18^{o}C biologically-based numeric criteria, they become the applicable criteria. If derived NTP values are less than the biological criterion, the biological criterion applies.

Table 2 - 11 summarizes the values derived for the longest and warmest time period, July 15 – August 31. Tables with NTP values derived for other periods between June 1 – September 30 are included in Appendix E. Figure 2 - 24 illustrates the temperature criteria that apply at the location of the Pudding River at the Woodburn WWTP discharge. Table 2 - 12 and Table 2 - 13 summarize the temperature criteria that apply at the locations of the Woodburn WWTP and JLR, LLC/Bruce Pac discharges, respectively.

Table 2 - 11: Applicable NTP temperatures – July 15 to August 31.

		River km 51.7 (Site 11530)	JLR, LLC/Bruce PAC	River km 43.7 (Site 10641)	City of Woodburn WWTP	River km 36.2 (Site 10640)
1	Average model calculated CCC temperatures (T ^{o}C)	23.68	23.63	23.75	23.89	23.72
2	Average model calculated NTP temperatures (T ^{o}C)	19.44	19.61	19.71	19.89	19.84
3	CCC – NTP (7DADM) T ^{o}C	-4.24	-4.03	-4.04	-4.00	-3.88
4	90th %tile observed 7DADM July 15 to August 31 Temperature	25.26	NA	24.90	NA	25.47
5	7DADM NTP Temperatures	21.02	**20.9**	20.86	**21.6**	21.59

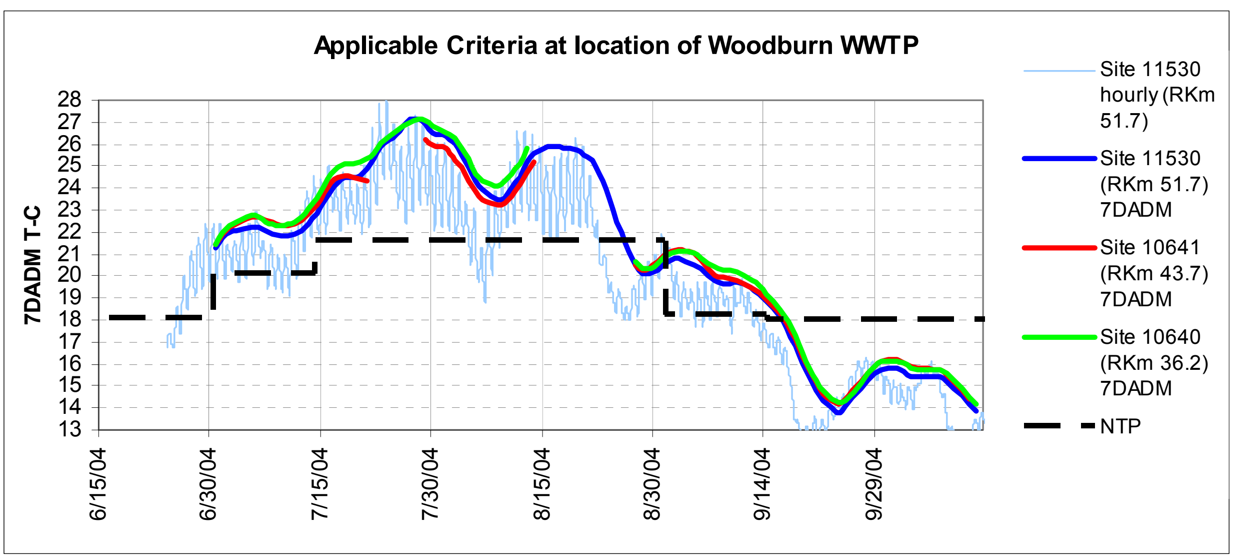


Figure 2 - 24: Applicable criteria for Pudding River at location of City of Woodburn discharge.

Table 2 - 12: Applicable temperature criteria for the Pudding River at the site of the Woodburn WWTP discharge. To simplify compliance DEQ combined the June 1 – 15 (18.0C) and June 16 – June 30 (18.1 C) periods.

Time period	**Applicable Criteria, T_c (°C)**
June 1 to June 30	18.0
July 1 to July 14	20.1
July 15 to August 31	21.6
September 1 to September 15	18.2
September 16 to September 30	18.0

Table 2 - 13: Applicable temperature criteria for the Pudding River at the site of the JLR, LLC/Bruce Pac discharge.

Time period	**Applicable Criteria, T_c (°C)**
June 1 to June 30	18.0
July 1 to July 14	19.6
July 15 to August 31	20.9
September 1 to September 30	18.0

DEQ did not model Silver Creek but did derive an estimated NTP by applying the 4.0°C difference between ambient and NTP temperatures derived for the Pudding River to the current Silver Creek temperatures. DEQ allowed an implicit margin-of-safety when applying the Pudding River model results to Silver Creek to account for greater uncertainty and make sure that derived Silver Creek NTP temperatures do not exceed actual NTP temperatures: Since only one year of continuous temperature data on Silver Creek is available and 90th percentiles may not provide sufficient margins-of-safety, DEQ based estimated Silver Creek NTPs on the median of current 7DADM temperatures (Figure 2 - 25). Based on median current temperatures, the NTP temperature for July 15 to August 31 is 19.1°C. Estimated NTP temperatures for other time periods are less than biologically-based numeric criteria so the biological criteria are the applicable criteria outside July 15 through August 31 (Table 2 - 14). The reach of Silver Creek which receives the City of Silverton WWTP discharge is also designated for Salmon and Steelhead Spawning from October 15 to May 15 when the biologically-based numeric criteria is 13°C.

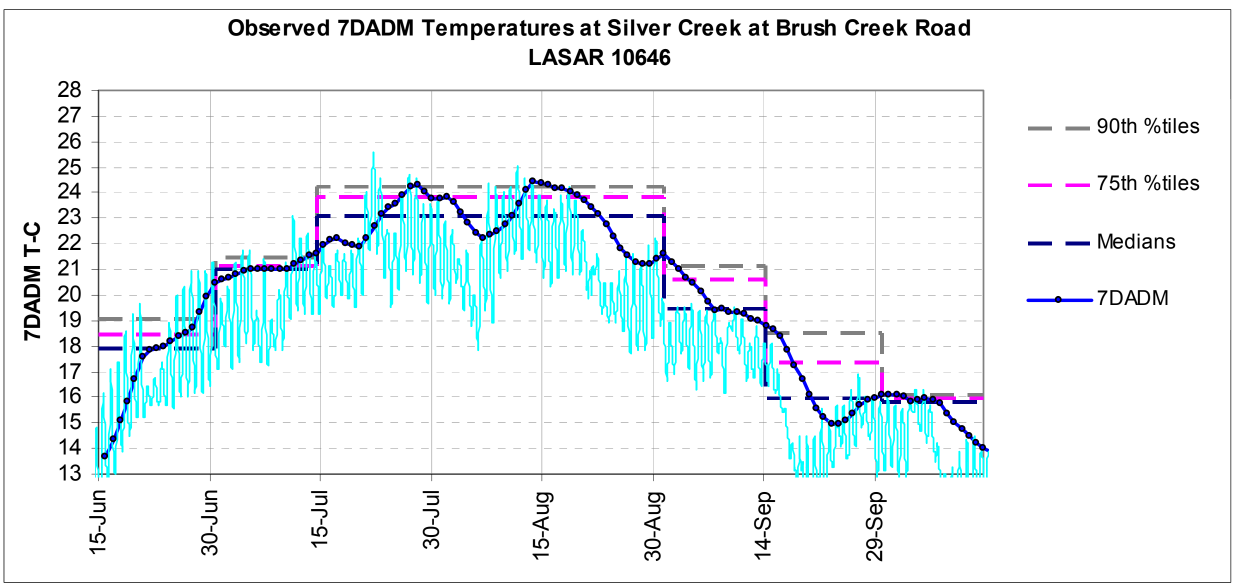


Figure 2 - 25: Measured temperatures at Silver Creek at Brush Creek Road from 2004.

Table 2 - 14: Applicable river temperature criteria, T_c, Silver Creek.

Time period	**Applicable Criteria, T_c (°C)**
June 1 to July 15	18.0
July 15 to August 31	19.1
September 1 to September 30	18.0

Excess Thermal Load Allocation for JLR, LLC/Bruce Pac

JLR, LLC/Bruce Pac and City of Woodburn WWTP temperature increases to the Pudding River are cumulative. If the heat load allocated to JLR, LLC/Bruce Pac is negligible, however, the heat load will dissipate in the 3.6 miles between JLR, LLC/Bruce Pac and the Woodburn WWTP. DEQ's modeling indicates that JLR, LLC/Bruce Pac's heat load would be negligible at the Woodburn WWTP discharge site as long as JLR, LLC/Bruce Pac's allocation does not cause a stream temperature increase greater than 0.01°C. Since JLR, LLC/Bruce Pac currently does not discharge to the Pudding River during the summer (June 1 to September 30), the allocation for JLR, LLC/Bruce Pac will be a heat load equivalent to a 0.01°C increase in stream temperature in the Pudding River, applicable between June 1 and September 30. This allocation will still allow a heat load equivalent to a 0.20°C stream temperature increase in the Pudding River to be allocated to the City of Woodburn WWTP. Outside of the critical period (June 1 – September 30), the facility does not receive an explicit wasteload allocation but rather an implicit heat load allocation sufficient to cover current conditions of discharge.

If a future decision is made to allocate a larger heat load to JLR, LLC/Bruce Pac, then the wasteload allocation for the City of Woodburn WWTP may need to be recalculated. The TMDL contains a reserve capacity allocation. Increases for future growth or expanded sources could be allocated from this reserve capacity. If this is insufficient, then revised wasteload allocations could be developed as part of a future TMDL. In this case, for every unit of the human use allowance allocated as heat load to JLR, LLC/Bruce Pac, at least a 2/3 unit reduction would be required in the portion of the HUA allocated as heat load to Woodburn to account for thermal overlap. In addition, since the temperature increases of the two point sources are cumulative, and since effluent heat loading effects are carried downstream more rapidly at high stream flow rates than at low stream flow rates, allowed temperature increases (ΔTs) for the facilities will need to be reduced for higher stream flow rates. Such relationships between allowed ΔT and stream flow rates can be derived through modeling.

The allowable ETL is flow-based and is calculated by Equation 4. Equation 4 defines the ETL allocation for JLR, LLC/Bruce Pac for any given effluent and river flow combination, up to and including the facility's design flow. Note that the Pudding River gage at Woodburn is located downstream from the JLR, LLC/Bruce Pac discharge so Q_R is the total river flow downstream from the discharge location. Therefore Equation 4 does not include an effluent flow rate term. Examples of ETL allocations for various river flow rates are shown in Table 2 - 15, also calculated using Equation 4.

The variable allowable heat loads (Table 2 - 15) derived from the flow-based ETL formula are less than the ETL in JLR, LLC/Bruce Pac current permit. Though the term "ETL" is used both in this TMDL and the current permit, "ETL" has different meanings and is derived differently in the two documents:

- The ETL assigned in this TMDL is flow-based and variable, whereas the ETL in the current permit is a not-to-exceed cap set in 2003 with the expectation that the facility would submit a temperature management plan and reduce temperatures in accordance with the plan.
- The ETL assigned in this TMDL is based on meeting a water quality criterion. The ETL in the current permit was not calculated to meet a water quality criterion.

The current permit specifies an ETL limitation (i.e. a cap) of 31 million kcals/day (May 1 – October 31), which the Permit Evaluation (September 4, 2003) defines as the amount of heat in the potential facility discharge above 64 ºF (17.8 ºC), the temperature criterion at the time the permit was issued. The ETL for JLR, LLC/Bruce Pac in this TMDL applies for a shorter period (June 1 – September 30). JLR, LLC/Bruce Pac does not currently discharge to surface water in the summer months, so the ETL is this TMDL is an increase over current discharge conditions. While the facility must comply with the receiving water requirements (i.e. not increasing the stream temperature more than 0.01 ºC above the applicable criterion), the flow-based ETL allows the facility flexibility to increase or decrease their discharge based on river flow. In addition, this TMDL analysis has shown the NTP at this location to exceed the biologically-based temperature criterion, which allows the facility a slightly warmer discharge or a greater quantity than if the 18ºC criteria applied.

$$\text{ETL} = 0.01 \cdot Q_R \cdot C_F \qquad \text{(Equation 4)}$$

where:

ETL = Excess Thermal Load, $kcal/day$

0.01 = allowable temperature increase, ^oC

Q_R = stream flow rate at gage Pudding River at Woodburn, cfs

$$C_F = 2{,}446{,}665 \frac{kcal \cdot s}{^oC \cdot ft^3 \cdot day}$$

Table 2 - 15: JLR, LLC/Bruce Pac Excess Thermal Load (ETL) allocations (million kcal/day) and (MW-day/day) - June 1 to September 30.

Woodburn gage flow rate (cfs):	**≤15**	**20**	**25**	**30**	**35**	**40**
	ETL	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**
Million Kcal/day	0.37	0.49	0.61	0.73	0.86	0.98
MW-day/day	0.0179	0.0237	0.0296	0.0354	0.0417	0.0475

Woodburn gage flow rate (cfs):	**50**	**60**	**70**	**80**	**90**	**100**
	ETL	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**
Million Kcal/day	1.22	1.47	1.71	1.96	2.20	2.45
MW-day/day	0.0591	0.0712	0.0829	0.0950	0.1066	0.1187

Excess Thermal Load Allocation for City of Woodburn WWTP

DEQ allocates a heat load equivalent to a 0.20 °C stream temperature increase in the Pudding River to the City of Woodburn WWTP. Since stream temperature increases are not cumulative if the JLR, LLC/Bruce Pac heat load is negligible, the allowed 0.20 °C does not need to be reduced for stream flow rates greater than the 7Q10 low flow rate. The ETL is flow-based and is calculated by Equation 5. Equation 5 defines the ETL for the City of Woodburn WWTP for any given effluent and river flow combination up to and including the facility's design flow. The Pudding River at Woodburn gage is located just upstream from the City of Woodburn discharge so $Q_R + Q_e$ is the total river flow downstream of the discharge.   ETL allocations for various river and effluent flow rate combinations are shown in Table 2 - 16 also calculated with Equation 5. Outside of the critical period (June 1 – September 30), the facility does not receive an explicit wasteload allocation, but rather an implicit heat load allocation sufficient to cover current conditions of discharge.

The facility's current permit specifies an Excess Thermal Load limitation of a weekly average of 9.2 million kcals/day (May 1 – October 31). This limit was based on the design flow of the facility, one-quarter of the 7Q10 flow in the Pudding River, maximum reported effluent temperature, and a 0.3ºC stream temperature increase above the biological criteria. The ETL for the City of Woodburn WWTP in this TMDL is flow-based and applies for a shorter period (June 1 – September 30) than the ETL in their current permit. A review of recent facility discharge records and associated stream flows indicates that the heat load in typical summer discharge from the City of Woodburn WWTP would be within the ETL set in this TMDL except for a period in mid September. The flow-based ETL allows the facility flexibility to increase or decrease their discharge based on river flow. In addition, this TMDL analysis has shown the NTP at this location to exceed the biologically-based temperature criterion between July 1 and September 15, which allows the facility a slightly warmer discharge or a greater quantity than if the 18ºC criteria applied.

$$\text{ETL} = 0.20(Q_R + Q_e)C_F \qquad \text{(Equation 5)}$$

where:

ETL = Excess Thermal Load, $kcal/day$

0.2 = allowed temperature increase, ^oC

Q_R = stream flow rate at gage Pudding River at Woodburn, cfs

Q_e = City of Woodburn WWTP effluent flow rate, cfs

$$C_F = 2{,}446{,}665 \frac{kcal \cdot s}{^oC \cdot ft^3 \cdot day}$$

Table 2 - 16: Woodburn WWTP Excess Thermal Load (ETL) allocations (million kcal/day) for various river and effluent flow combinations – June 1 to September 30.
Million kcal/day may be converted to MW-day/day by multiplying by 0.04846.

Woodburn gage flow rate (cfs):	**≤15**	**20**	**25**	**30**	**35**	**40**
Q_e (MGD)	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**
0.1	7.42	9.86	12.31	14.76	17.20	19.65
0.2	7.49	9.94	12.38	14.83	17.28	19.72
0.3	7.57	10.01	12.46	14.91	17.35	19.80
0.5	7.72	10.17	12.61	15.06	17.51	19.95
0.7	7.87	10.32	12.76	15.21	17.66	20.10
1	8.10	10.54	12.99	15.44	17.88	20.33
1.5	8.48	10.92	13.37	15.82	18.26	20.71
2	8.85	11.30	13.75	16.19	18.64	21.09
2.5	9.23	11.68	14.13	16.57	19.02	21.47
3	9.61	12.06	14.50	16.95	19.40	21.84
4	10.37	12.81	15.26	17.71	20.15	22.60
5	11.12	13.57	16.02	18.46	20.91	23.36

Woodburn gage flow rate (cfs):	**50**	**60**	**70**	**80**	**90**	**100**
Q_e (MGD)	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**
0.1	24.5	29.4	34.3	39.2	44.1	49.0
0.2	24.6	29.5	34.4	39.3	44.2	49.1
0.3	24.7	29.6	34.5	39.4	44.3	49.2
0.5	24.8	29.7	34.6	39.5	44.4	49.3
0.7	25.0	29.9	34.8	39.7	44.6	49.5
1	25.2	30.1	35.0	39.9	44.8	49.7
1.5	25.6	30.5	35.4	40.3	45.2	50.1
2	26.0	30.9	35.8	40.7	45.6	50.4
2.5	26.4	31.3	36.1	41.0	45.9	50.8
3	26.7	31.6	36.5	41.4	46.3	51.2
4	27.5	32.4	37.3	42.2	47.1	52.0
5	28.3	33.1	38.0	42.9	47.8	52.7

Excess Thermal Load Allocation for City of Silverton WWTP

DEQ allocates a heat load equivalent to a 0.20 °C increase in stream temperature of Silver to the City of Silverton WWTP. Since this facility is the only point source on Silver Creek, the 0.20°C allowed temperature increase (ΔT) need not be reduced for stream flow rates greater than the 7Q10 low flow rate. The ETL is calculated by Equation 6, which defines the ETL for any given effluent and river flow combination. The Silver Creek at Silverton stream gage is located upstream from the City of Silverton discharge so $Q_R + Q_e$ is the total river flow downstream of the discharge.

ETL allocations apply from June 1 to September 30. Outside of the critical period (June 1 – September 30), the facility does not receive an explicit wasteload allocation but an implicit heat load allocation sufficient to cover current conditions of discharge. Data are not available before May 15 or after October 20, but the pattern of temperature increase and decrease indicates that temperature criteria are probably met during spawning periods (Figure 2 - 26). Because a trailing 7-day moving average determines compliance, only 7DADM temperature exceedances of the 13°C criterion after October 22 are considered criterion exceedances.

Flow-based ETL allocations, calculated using Equation 6, for various river and effluent flow rate combinations are shown in
Table 2 - 17. The 7Q10 low flow rate for Silver Creek is 3.5 cfs at USGS gage Silver Creek at Silverton (14200300) based on all available data (1964 to 1979). The City of Silverton resumed maintenance of and data collection from the gage in 2004 and will need to continue this maintenance in order to take advantage of an ETL that varies with flow. If stream flow is unknown, then Q_R should be set to the 7Q10 flow condition of 3.5 cfs for all ETL calculations. In this case, only the first column in
Table 2 - 17 would apply.

The facility's current permit specifies two Excess Thermal Load limitations: a weekly average of 5.2 million kcals/day (May 16 – October 14) and a weekly average of 21 million kcal/day (October 15 – May 15). The summer limit was based on the design flow of the facility, one-quarter of the 7Q10 flow in Silver Creek, maximum reported effluent temperature, and a 0.3ºC stream temperature increase above the biological criteria. The ETL for the City of Silverton WWTP in this TMDL is flow-based and applies for a shorter period (June 1 – September 30) than the summer ETL in their current permit. A review of the recent facility discharge records and associated stream flows indicates that the City of Silverton WWTP under current operation would rarely meet the ETL in the summer months. Operational changes will likely be required to meet receiving water requirements (i.e. not increasing the stream temperature more than 0.2 ºC above the applicable criterion). While the flow-based ETL allows the facility flexibility to increase or decrease their discharge based on stream flow, the flow in Silver Creek rarely exceeds the 7Q10 flow in the summer months. This TMDL analysis estimated the NTP at this location to exceed the biologically-based temperature criterion between July 15 and August 31, which allows the facility a slightly warmer discharge or a greater quantity than if the 18ºC criteria applied.

$$\mathrm{ETL} = 0.20(Q_R + Q_e)C_F \qquad \text{(Equation 6)}$$

where:

$\mathrm{ETL} =$ Excess Thermal Load, $kcal/day$

$0.20 =$ allowed temperature increase, ^{o}C

$Q_R =$ stream flow rate at gage Silver Creek at Silverton, cfs

$Q_e =$ City of Silverton WWTP effluent flow rate, cfs

$C_F = 2{,}446{,}665 \dfrac{kcal \cdot s}{^{o}C \cdot ft^3 \cdot day}$

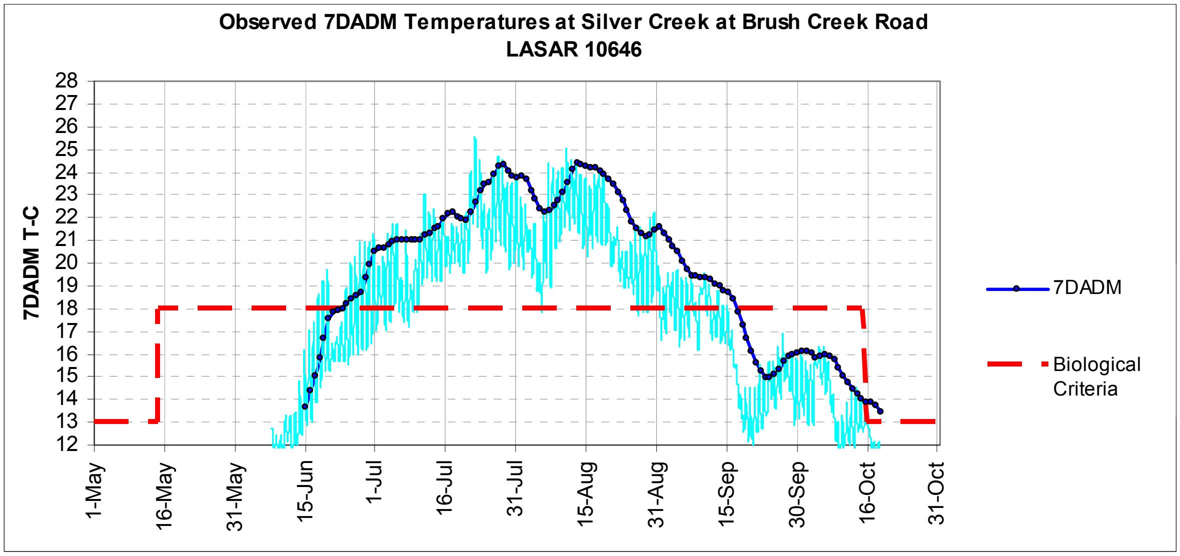


Figure 2 - 26: Measured temperatures at Silver Creek at Brush Creek Road. Monitoring at this site was performed from June 9 to October 20, 2004.

Table 2 - 17: Silverton WWTP Excess Thermal Load (ETL) allocations (million kcal/day) for various river and effluent flow combinations – June 1 to September 30.
Million kcal/day may be converted to MW-day/day by multiplying by 0.04846.

Silver Creek at Silverton flow rate (cfs):	**≤3.5**	**5**	**7.5**	**10**	**12.5**	**15**
Q_e (MGD)	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**
0.1	1.79	2.52	3.75	4.97	6.19	7.42
0.2	1.86	2.60	3.82	5.04	6.27	7.49
0.3	1.94	2.67	3.90	5.12	6.34	7.57
0.4	2.02	2.75	3.97	5.20	6.42	7.64
0.5	2.09	2.83	4.05	5.27	6.50	7.72
0.7	2.24	2.98	4.20	5.42	6.65	7.87
1.0	2.47	3.20	4.43	5.65	6.87	8.10
1.5	2.85	3.58	4.81	6.03	7.25	8.48
2.0	3.23	3.96	5.18	6.41	7.63	8.85
2.5	3.61	4.34	5.56	6.79	8.01	9.23
3.0	3.98	4.72	5.94	7.16	8.39	9.61
4.0	4.74	5.47	6.70	7.92	9.14	10.37

Silver Creek at Silverton flow rate (cfs):	**17.5**	**20**	**22.5**	**25**	**27.5**	**30**
Q_e (MGD)	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**
0.1	8.6	9.9	11.1	12.3	13.5	14.8
0.2	8.7	9.9	11.2	12.4	13.6	14.8
0.3	8.8	10.0	11.2	12.5	13.7	14.9
0.4	8.9	10.1	11.3	12.5	13.8	15.0
0.5	8.9	10.2	11.4	12.6	13.8	15.1
0.7	9.1	10.3	11.5	12.8	14.0	15.2
1.0	9.3	10.5	11.8	13.0	14.2	15.4
1.5	9.7	10.9	12.1	13.4	14.6	15.8
2.0	10.1	11.3	12.5	13.7	15.0	16.2
2.5	10.5	11.7	12.9	14.1	15.3	16.6
3.0	10.8	12.1	13.3	14.5	15.7	17.0
4.0	11.6	12.8	14.0	15.3	16.5	17.7

Excess Thermal Load Allocation for City of Hubbard WWTP

Mill Creek is not included on the 303(d) List for temperature, but available DEQ continuous temperature data collected from Mill Creek upstream from Hubbard WWTP suggests that the 18°C criterion is exceeded during the summer (Figure 2 - 27). In addition, the stream contributes to temperature standard violations in the Pudding River. The designated fish use of Mill Creek is Salmon and Trout Rearing and Migration, with no spawning use. Therefore, the biologically-based numeric criterion is 18°C year-round. Since Mill Creek affects temperatures in the Pudding River, wasteload allocations apply for the same summer period (June 1 to September 30) as do direct discharges to the Pudding River. Outside of the critical period (June 1 – September 30), the facility does not receive an explicit wasteload allocation but an implicit heat load allocation sufficient to cover current conditions of discharge.

DEQ allocates a heat load equivalent to a stream temperature increase of 0.20°C in Mill Creek to the City of Hubbard WWTP. Since this facility is the only point source on Mill Creek, discharging during the critical period, the 0.20°C allowed temperature increase (ΔT) need not be reduced for stream flow rates greater than the 7Q10 low flow rate. The flow-based ETL is calculated by Equation 7, which defines the ETL for any given effluent and river flow combination up to an including the facility design flow. ETL allocations for various river and effluent flow rate combinations are shown in Table 2 - 18, calculated using Equation 7. Mill Creek upstream from the Hubbard WWTP discharge is currently ungaged, although an inactive gage is reportedly available approximately 300 feet downstream of the City of Hubbard WWTP discharge. The City of Hubbard will need to install or resume measurements at a stream gage to take advantage of an ETL that varies with flow. If no gage is installed and flow is unknown, then Q_R should be set to the 7Q10 flow condition of 2.39 cfs for all ETL and allowable effluent flow and temperature calculations. In this case, only the first column in Table 2 - 18 would apply. The 7Q10 low flow rate for Mill Creek is 2.39 cfs, based on an assumption that Mill Creek is 10% of the Pudding River flow at Aurora (DEQ Western Region permit evaluation report). Such a ratio is consistent with stream flow that DEQ measured at the mouth of Mill Creek in August 2004 and August 2007.

The facility's current permit specifies an Excess Thermal Load limitation of a weekly average of 1.0 million kcals/day (May 1 – October 31). The limit was based on the design flow of the facility, one-quarter of the estimated 7Q10 flow in Mill Creek, maximum reported effluent temperature, and a 0.3ºC stream temperature increase above the biological criteria. The ETL for the City of Hubbard WWTP in this TMDL is flow-based and applies for a shorter period (June 1 – September 30) than the ETL in their current permit. A review of the recent facility discharge records indicates that the City of Hubbard WWTP under current operation would rarely meet the ETL in the summer months. Operational changes will likely be required to meet receiving water requirements (i.e. not increasing the stream temperature more than 0.2 ºC above the applicable criterion). The flow-based ETL allows the facility flexibility to increase or decrease their discharge based on stream flow.

$$\mathrm{ETL} = 0.20(Q_R + Q_e)C_F \qquad \text{(Equation 7)}$$

where:

ETL = Excess Thermal Load, $kcal/day$

0.20 = allowed temperature increase, ^{o}C

Q_R = stream flow rate of Mill Creek u/s from Hubbard, cfs

Q_e = City of Hubbard WWTP effluent flow rate, cfs

$C_F = 2{,}446{,}665 \dfrac{kcal \cdot s}{^{o}C \cdot ft^3 \cdot day}$

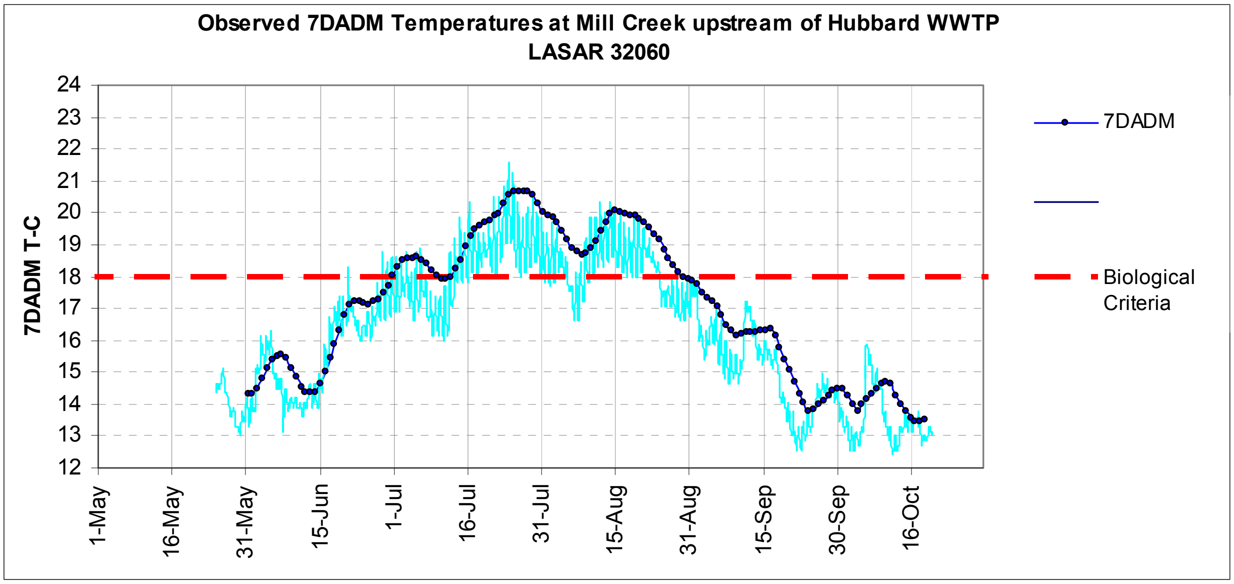


Figure 2 - 27: Measured temperatures at Mill Creek upstream of City of Hubbard WWTP.

Table 2 - 18: Hubbard WWTP Excess Thermal Load (ETL) allocations (million kcal/day) for various river and effluent flow combinations – June 1 to September 30.
Million kcal/day may be converted to MW-day/day by multiplying by 0.04846.

Mill Creek flow rate (cfs):	**≤2.39**	**2.5**	**3**	**4**	**5**	**6**
Q_e (MGD)	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**
0.08	1.23	1.28	1.53	2.02	2.51	3.00
0.10	1.25	1.30	1.54	2.03	2.52	3.01
0.12	1.26	1.31	1.56	2.05	2.54	3.03
0.14	1.28	1.33	1.57	2.06	2.55	3.04
0.16	1.29	1.34	1.59	2.08	2.57	3.06
0.18	1.31	1.36	1.60	2.09	2.58	3.07
0.20	1.32	1.37	1.62	2.11	2.60	3.09
0.22	1.34	1.39	1.63	2.12	2.61	3.10
0.24	1.35	1.41	1.65	2.14	2.63	3.12
0.26	1.37	1.42	1.66	2.15	2.64	3.13
0.28	1.38	1.44	1.68	2.17	2.66	3.15
0.30	1.40	1.45	1.70	2.18	2.67	3.16

Mill Creek flow rate (cfs):	**8**	**10**	**12.5**	**15**	**20**	**25**
Q_e (MGD)	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**
0.08	3.98	4.95	6.18	7.40	9.85	12.29
0.10	3.99	4.97	6.19	7.42	9.86	12.31
0.12	4.01	4.98	6.21	7.43	9.88	12.32
0.14	4.02	5.00	6.22	7.45	9.89	12.34
0.16	4.04	5.01	6.24	7.46	9.91	12.35
0.18	4.05	5.03	6.25	7.48	9.92	12.37
0.20	4.07	5.04	6.27	7.49	9.94	12.38
0.22	4.08	5.06	6.28	7.51	9.95	12.40
0.24	4.10	5.08	6.30	7.52	9.97	12.42
0.26	4.11	5.09	6.31	7.54	9.98	12.43
0.28	4.13	5.11	6.33	7.55	10.00	12.45
0.30	4.14	5.12	6.34	7.57	10.01	12.46

Wasteload Allocation to City of Silverton Drinking Water Treatment Plant

The City of Silverton Drinking Water Treatment Plant (DWTP) is permitted by a general permit to discharge filter backwash to Abiqua Creek. Abiqua Creek is not included on the 303(d) list for temperature, but 2005 and 2006 continuous temperature data collected by the Marion SWCD indicate that the 18 ºC criteria is violated at river mile 2 in the summer months. The treatment plant discharge is located at river mile 3.9, where the core cold water criterion (16 ºC) applies from June 16 – August 30, and the spawning temperature criterion (13 ºC) applies from September 1 – June 15.

A number of uncertainties exist with this discharge: the general permit does not require temperature monitoring, the measured discharge reported on the discharge monitoring reports (DMRs) is not necessarily the discharge flowing from the settling pond, and the settling pond is a mix of drinking water plant discharge and stormwater. DEQ estimated the potential temperature increase to Abiqua Creek in both summer and spawning season (Table 2 - 19) with the following assumptions:

- The effluent flow is the maximum reported on recent DMRs during the summer or spawning period.
- The estimated 7Q10 is the flow DEQ measured in Abiqua Creek in August 2007. The same value was used for both summer and spawning periods to evaluate the temperature effects at the beginning of spawning season, in September.

- Effluent temperatures are assumed to be similar to the maximum temperatures measured at the Molalla DWP, which also discharges from settling ponds.

With Equation 1, DEQ obtained the results in Table 2 - 19 which indicate a potential temperature increase to Abiqua Creek from the Silverton DWTP discharge. Given the low summer flows in Abiqua Creek, the likelihood of a violation of the temperature criteria, the potential for heating the facility's discharge in the settling pond, and the relatively consistent discharge year-round from the facility, DEQ will assign an allocation to the Silverton DWTP.

The City of Silverton DWTP is the only point source on Abiqua Creek and may be allowed a 0.2ºC temperature increase. Since impacts are not cumulative, the 0.20°C allowed need not be reduced for stream flow rates greater than the 7Q10 low flow rate. The ETL is calculated with Equation 8. Because there is no operational stream flow gage on Abiqua Creek, DEQ has assigned an allocation based on the 7Q10 flow of Abiqua Creek and the maximum recent reported discharge from the facility (0.095 MGD, 0.147 cfs). The allocation is listed in Table 2 - 20.

This facility operates under an extension to the expired NPDES General Permit 200J[16]. The permit requires a 30:1 dilution in the receiving stream during periods of discharge. The maximum reported discharge from this facility (0.147 cfs) and the 7Q10 flow in Abiqua Creek (5 cfs) would meet the dilution requirement. If the facility complies with the 200J permit requirements, no operational changes appear to be necessary for the facility's discharge to meet the WLA.

$$\mathrm{ETL} = 0.20(Q_R + Q_e)C_F \qquad \text{(Equation 8)}$$

where:

ETL = Excess Thermal Load, $kcal/day$

0.20 = allowed temperature increase, ^{o}C

Q_R = estimated 7Q10 stream flow rate of Abiqua Creek d/s from Silverton DWP cfs

Q_e = City of Silverton DWP effluent flow rate, 0.147 cfs

$$C_F = 2{,}446{,}665 \frac{kcal \cdot s}{^{o}C \cdot ft^3 \cdot day}$$

Table 2 - 19: Potential heating effects Silverton DWP effluent discharge at river mile 3.9 on Abiqua Creek. DEQ has assumed maximum effluent temperatures as no effluent temperature data are available.

Season	**Point Source Discharge (cfs)**	**Maximum Temperature (°C)**	**Stream Discharge (cfs)**	**Rearing/migration or Spawning Temperature Criteria (°C)**	**Effect on River Temperature at 100% mix (° C)**
June 16 – August 30	0.131	23 (73.4 °F)	5	16 (60.8 °F)	0.17 (0.30 °F)
September 1 – June 15	0.147	21 (69.8°F)	5	13 (55.4 °F)	0.20 (0.36 °F)

Table 2 - 20: Excess Thermal Load allocated to Silverton Drinking Water Treatment Plant.

Allocated ΔT (ºC)	**Stream Flow (7Q10) (cfs)**	**Effluent Flow (design flow) (cfs)**	**ETL (million kcal/day)**	**ETL (MW)**
0.2	5	0.095	2.493	0.12

[16] The 200J General Permit for discharge or land application of filter backwash expired in July 2002. The permit is scheduled to be revised in summer 2009. Until the permit is revised, sources continue to operate under the discharge limitations and requirements of the expired permit.

Molalla River Wasteload Allocations

DEQ evaluated or calculated wasteload allocations for facilities with potential heating effects on the Molalla River (Table 2 - 21). DEQ allocated only the heat load that conservative calculations indicated the facilities would contribute under presumed worst-case conditions (e.g. maximum discharge and effluent temperatures). DEQ did not complete a cumulative effects analysis for Molalla River point sources because the two point sources (Molalla Municipal Drinking Water Treatment Plant and Sanders Wood Products) that are permitted to discharge to the Molalla River during the critical period (May 1 – October 31) are small relative to 7Q10 stream flows, and the discharge from the facilities may not even reach surface water for most or all of the applicable TMDL period. The potential discharge quantities of these sources relative to stream flow and calculations of potential stream heating are included in the following descriptions of the WLAs for each of these sources.

DEQ estimated the maximum NTP values for the Molalla River before and after the two-week model period by the same method as for the Pudding River model, but with a larger margin-of-safety. The larger margin of safety takes into account the larger uncertainty associated with the Molalla River model[17] and that only two years of continuous stream temperatures were available (2002 and 2004) to estimate current conditions. Rather than subtracting the average differences between current calibration condition (CCC) temperatures and NTP temperatures (for the model period) from the 90th percentile of observed current temperatures, DEQ subtracted the maximum difference between CCC modeled temperatures and NTP temperatures from the median of observed temperatures. Table 2 - 22 summarizes the NTP temperatures derived at three locations on the Molalla River where continuous stream temperatures were measured and presents examples of two interpolated values at river mile 17 and 21.6, where point sources are located. The details of the analysis and NTP temperatures estimated for other time periods are presented in Appendix E.

Table 2 - 21: Sources DEQ evaluated for potential heat loads to the Molalla River.

Facility Name	Permit Type	Permit Description	Receiving Stream	River Mile	Season
City of Molalla WWTP	NPDES-DOM-Da	Sewage disposal; less that 1 MGD, with lagoons.	Molalla River	20	Nov. 1 – April 30
Molalla Municipal Drinking Water Treatment Plant	GEN02	Industrial wastewater; NPDES filter backwash	Molalla River	21.6	Year round
Sanders Wood Products, Inc. (RSG Forest Products)	NPDES-IW-B19	Timber and wood products – sawmills, log storage, instream log storage	Molalla River	17.3	Year round
Sunstone Circuits, LLC	NPDES-IW-N	Process wastewater, Not Elsewhere Classified	Milk Creek	5.3	Year round

Table 2 - 22: Molalla River applicable NTP temperatures August 1 - 15.

	Molalla River at Hwy. 213 (RM 15)	**Molalla River Mile 17**	**Molalla River at Hwy. 211 (River Mile 19)**	**Molalla River Mile 21.6**	**Molalla River u/s North Fork (River Mile 26.5)**
Maximum difference CCC – NTP (T °C)	2.8	NA	2.8	NA	2.8
median observed 7DADM August 1 - 15 Temperature (T °C)	23.9	NA	23.1	NA	21.3
7DADM NTP Temperatures August 1 -15 (T °C)	**21.1**	**20.7**	**20.3**	**19.7**	**18.5**

[17] Model calibration and error statistics are presented in Appendix A.

Excess Thermal Load Allocation for Sanders Wood Products, Inc.

Effluent from the Sanders/RSG facility does not visibly flow into the Molalla River during the dry season. If connection of the drainage ditch with the Molalla River were to occur during late summer rains, for example, temperature in the drainage ditch surface water would likely be influenced by overflow from agricultural ponds, as well. Despite an uncertain connection of facility discharge to the Molalla River and uncertainty about temperature measurements in the facility effluent, DEQ will assign an allocation for the Sanders/RSG facility because of potential temperature effects from the facility during the late summer/early fall when rains begin and Molalla River flow is still low. The allocation applies May 1 – October 31. Outside of the critical period (May 1 – October 31), the facility does not receive an explicit wasteload allocation, but rather an implicit heat load allocation sufficient to cover current conditions of discharge.

DEQ used Equation 1 to evaluate potential heating effects from the facility's discharge. Time periods evaluated are late summer and early fall when there is a more likely connection between the drainage ditch into which the facility discharges and the Molalla River. Since the maximum reported discharge on recent discharge monitoring reports includes stormwater, DEQ based the maximum discharge of process wastewater on personal communication with the facility's plant operation manager (July 31, 2008). The facility is not required to report effluent temperatures, but temperatures at the settling pond (which also contains stormwater) are measured. In the analysis of the facility's potential heating effects, DEQ used the measured temperatures from the settling pond during the months when overflow into the drainage ditch is more likely. Where the estimated NTP exceeded the biologically based criteria, DEQ used the NTP in the calculation (Table 2 - 23). Table 2 - 24 shows the potential heating to the Molalla River based on those assumptions.

While the estimated potential heating effect of the facility is less than 0.1 °C, there is uncertainty about the discharge quantity of process wastewater. Even if process wastewater discharge were as high as the maximum reported discharge (0.48 MGD, including stormwater), the calculated temperature increase to the Molalla River would be 0.16 °C. To account for the large uncertainty, this facility receives an allocated heat load equivalent to a stream temperature increase of 0.16 ºC. The ETL from this allocation is calculated with Equation 9. Example ETLs for various effluent and river flow conditions are shown in Table 2 - 25.

The facility's current permit does not have an Excess Thermal Load limitation. The WLA is based on potential heat loading from current operating conditions and no operational changes appear to be necessary for the facility's discharge to meet the WLA.

Table 2 - 23: Summary of applicable temperature criteria at river mile 17 on the Molalla River.

Time period	**Applicable Criteria, T_c (°C)**
October 15 – May 15	13.0
May 16 to June 30	18.0
July 1 to July 15	19.2
July 16 to July 31	21.5
August 1 - 15	20.7
August 16 - 31	19.1
September 1 to October 14	18.0

Table 2 - 24: Potential heating effects of Sanders Wood Products effluent discharge at river mile 17 on the Molalla River.
DEQ has assumed maximum effluent temperatures as no effluent temperature data are available.

Month Evaluated	**Point Source Discharge (cfs)**	**Maximum Temperature (ºC)**	**Monthly 7Q10 Stream Discharge or Minimum Flow Requirements (cfs)**	**Applicable Temperature Criteria (ºC)**	**Effect on River Temperature at 100% mix (ºC)**
August	0.155 (0.1 MGD)	24 (75.2 ºF)	23	20.7 (69.3 ºF)	0.02 (0.04 ºF)
September	0.155 (0.1 MGD)	23 (73.4 ºF)	19	18.0 (64.4 ºF)	0.04 (0.07 ºF)
October	0.155 (0.1 MGD)	20 (68 ºF)	25	13.0 (55.4 ºF)	0.04 (0.07 ºF)
September	0.65 (0.48 MGD)	23 (73.4 ºF)	19	18.0 (64.4 ºF)	0.16 (0.3 ºF)

$$\text{ETL} = 0.16(Q_R + Q_e)C_F \qquad \text{(Equation 9)}$$

where:

$\text{ETL} = \text{Excess Thermal Load}, \ kcal/day$

$0.16 = \text{allowed temperature increase}, \ ^{o}C$

$Q_R = \text{stream flow rate at gage Molalla River at Canby} * 0.64, \ cfs$

$Q_e = \text{Sanders/RSG effluent flow rate}, \ cfs$

$$C_F = 2{,}446{,}665 \frac{kcal \cdot s}{^{o}C \cdot ft^3 \cdot day}$$

Table 2 - 25: RSG/Sanders Excess Thermal Load (ETL) allocations (million kcal/day) for various river and effluent flow combinations – May 1 – October 31.
Million kcal/day may be converted to megawatt-day/day (MW-day/day) by multiplying by 0.04846.

Molalla R. at Canby gage * 0.64 flow rate (cfs):	**≤18**	**30**	**50**	**75**	**100**	**200**
Q_e (MGD)	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**
0.1	7.107	11.805	19.634	29.421	39.207	78.354
0.2	7.168	11.865	19.694	29.481	39.268	78.414
0.3	7.228	11.926	19.755	29.542	39.328	78.475
0.5	7.349	12.047	19.876	29.663	39.449	78.596
0.7	7.470	12.168	19.997	29.784	39.571	78.717
1	7.652	12.350	20.179	29.966	39.752	78.899

Molalla R. at Canby gage * 0.64 flow rate (cfs):	**300**	**400**	**500**	**600**	**800**	**1000**
Q_e (MGD)	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**
0.1	117.500	156.647	195.794	234.940	313.234	391.527
0.2	117.561	156.708	195.854	235.001	313.294	391.588
0.3	117.622	156.768	195.915	235.062	313.355	391.648
0.5	117.743	156.889	196.036	235.183	313.476	391.769
0.7	117.864	157.010	196.157	235.304	313.597	391.890
1	118.046	157.192	196.339	235.485	313.779	392.072

Excess Thermal Load Allocation for Molalla Drinking Water Plant

The Molalla Drinking Water plant discharges filter backwash after solids have settled out in a settling pond. Although discharge to the Molalla River via the drainage ditch and slough, is not likely during the summer months, the permit would allow discharge year-round. For that reason, DEQ evaluated potential effects during both core cold water (16 ºC) and spawning seasons. The spawning criterion (13 ºC) applies October 15 – June 15 at the location of the drinking water treatment plant outfall (river mile 21.6).

To evaluate the potential heating effects (ΔT) from the plant's discharge of filter backwash water, DEQ used Equation 1. The discharge flow (Q_e) used in the calculation is the maximum measured and reported in monitoring reports submitted since 2002 and the river flow (Q_r) is the monthly 7Q10 flow. The effluent temperature entered into the calculation is the maximum measured and reported for a given month (Table 2 - 26). The temperature criteria used (Table 2 - 27) are the lowest applicable for the month, as calculated for river mile 19, or the biologically based criterion.

The analysis suggests that the Molalla drinking water treatment plant discharge may raise Molalla River temperature less than 0.025 ºC (Table 2 - 28). The greatest temperature increases are most likely during late summer and early fall, when temperature criteria are lower and stream flow is still low. This facility receives an excess thermal load equivalent to an increase of 0.02 ºC in ambient stream temperature. The allocation applies May 1 – October 31. The ETL is calculated with Equation 11. Example ETLs for various effluent and river flow conditions are shown in Table 2 - 29.

This facility operates under an extension to the expired NPDES General Permit 200J[18]. The permit requires a 30:1 dilution in the receiving stream during periods of discharge. The maximum reported discharge from this facility (0.08 cfs) and the 7Q10 flow in the Molalla River at river mile 20 (18 cfs) would meet the dilution requirement. If the facility complies with the 200J permit requirements, no operational changes appear to be necessary for the facility's discharge to meet the WLA.

Table 2 - 26: Greatest monthly effluent temperatures reported on discharge monitoring reports, 2002 – 2008.

Month	**Highest Reported TºC (2002 – 2008)**
June	25
July	26
August	23
Sept	21
October	19

Table 2 - 27: Applicable temperature criteria at Molalla River, river mile 21.6.

Dates	**Applicable Criteria T ºC**
June 16 – June 30	16.0
July 1 to July 15	18.2
July 16 to July 31	20.4
August 1 - 15	19.7
August 16 - 31	18.1
Sept. – October 14	16.0
October 15 – June 15	13.0

Table 2 - 28: Potential temperature increase to the Molalla River from City of Molalla drinking water treatment plant discharge.

Month Evaluated	**Point Source Discharge (cfs)**	**Maximum Temperature (ºC)**	**Monthly 7Q10 Stream Discharge (cfs)**	**Applicable Temperature Criteria (ºC)**	**Effect on River Temperature at 100% mix (º C)**
June	0.08	25 (77 ºF)	85	13.0 (55.4 ºF)	0.010 (0.02 ºF)
July	0.08	26 (78.8F)	39	18.2 (64.6 ºF)	0.016 (0.03 ºF)
August	0.08	23 (73.4 ºF)	23	18.1 (64.6 ºF)	0.017 (0.03 ºF)
September	0.08	21 (69.8 ºF)	20	16.0 (60.8 ºF)	0.022 (0.04 ºF)
October	0.08	19 (66.2 ºF)	25	13.0 (55.4 ºF)	0.022 (0.04 ºF)

[18] The 200J General Permit for discharge or land application of filter backwash expired in July 2002. The permit is scheduled to be revised in summer 2009. Until the permit is revised, sources continue to operate under the discharge limitations and requirements of the expired permit.

$$\text{ETL} = 0.02(Q_R + Q_e)C_F \qquad \text{(Equation 10)}$$

where:

ETL = Excess Thermal Load, $kcal/day$

0.02 = allowed temperature increase, ^{o}C

Q_R = stream flow rate at gage Molalla River at Canby * 0.64, cfs

Q_e = City of Molalla drinking water treatment plant effluent flow rate, cfs

$$C_F = 2{,}446{,}665 \frac{kcal \cdot s}{^{o}C \cdot ft^3 \cdot day}$$

Table 2 - 29: City of Molalla Drinking Water Treatment Plant example Excess Thermal Load (ETL) allocations (million kcal/day) for various river and effluent flow combinations.
Million kcal/day may be converted to megawatt-day/day (MW-day/day) by multiplying by 0.04846.

Molalla R. at Canby gage * 0.64 flow rate (cfs):	**≤18**	**30**	**50**	**75**	**100**	**200**
Q_e (MGD)	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**
0.01	0.882	1.469	2.447	3.671	4.894	9.787
0.02	0.882	1.470	2.448	3.672	4.895	9.788
0.03	0.883	1.470	2.449	3.672	4.896	9.789
0.05	0.885	1.472	2.450	3.674	4.897	9.790
0.08	0.886	1.473	2.452	3.675	4.899	9.792
0.1	0.888	1.476	2.454	3.678	4.901	9.794

Molalla R. at Canby gage * 0.64 flow rate (cfs):	**300**	**400**	**500**	**600**	**800**	**1000**
Q_e (MGD)	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**	**ETL**
0.01	14.681	19.574	24.467	29.361	39.147	48.934
0.02	14.682	19.575	24.468	29.361	39.148	48.935
0.03	14.682	19.576	24.469	29.362	39.149	48.936
0.05	14.684	19.577	24.470	29.364	39.150	48.937
0.08	14.685	19.579	24.472	29.365	39.152	48.939
0.1	14.688	19.581	24.474	29.368	39.154	48.941

Excess Thermal Load Allocation for Sunstone Circuits

DEQ based calculation of the potential effects from the Sunstone Circuits discharge (Equation 1) on an estimated 7Q10 flow in Milk Creek of 10.5 cfs (DEQ Mixing zone study, 1993). DEQ also used this flow estimate for the spawning season calculation, since no other flow data were available for Milk Creek. Spawning season extends from October 15 – May 15 in Milk Creek. The effluent flow used in the calculation is the design flow of the facility. The effluent temperatures used in the calculation were the maximum measurements reported on recent discharge monitoring reports in both the spawning and rearing/migration seasons. Sunstone discharge could raise the temperature of Milk Creek approximately 0.04 ºC (Table 2 - 30).

DEQ assigns a wasteload allocation of 0.04 ºC to Sunstone Circuits. Since Milk Creek does not have a stream measurement gage, DEQ assigns an ETL based on the 7Q10 flow and the design flow of the facility (Equation 12). The ETL is 1.034 million kcal/day (0.050 MW-day/day) (Table 2 - 31). This wasteload allocation applies May 1 – October 31. Outside of the critical period (May 1 – October 31), the facility does not receive an explicit wasteload allocation, but rather an implicit heat load allocation sufficient to cover current conditions of discharge.

The ETL from this TMDL is similar to the ETL in the current permit (1.3 million kcal/day or 0.055 MW-day/day). The WLA is based on potential heat loading from current operating conditions and no operational changes appear to be necessary for the facility's discharge to meet the WLA.

Table 2 - 30: Potential temperature increase to Milk Creek from Sunstone Circuits discharge.

Season	Point Source Discharge (cfs)	Maximum Temperature (°C)	Stream Discharge (cfs)	Rearing/migration or Spawning Temperature Criteria (°C)	Effect on River Temperature at 100% mix (° C)
May 16 – October 14	0.065	24.9 (76.1 °F)	10.5	18 (64.4 °F)	0.04 (0.07 °F)
October 15 – May 15	0.065	20 (68 °F)	10.5	13 (55.4 °F)	0.04 (0.07 °F)

$$\text{ETL} = 0.04(Q_R + Q_e)C_F \qquad \text{(Equation 11)}$$

where:

$$\text{ETL} = \text{Excess Thermal Load, } {kcal}/{day}$$

$$0.04 = \text{allowed temperature increase, } ^{o}C$$

$$Q_R = \text{7Q10 stream flow , 10.5 } cfs$$

$$Q_e = \text{Sunstone Circuits, design flow rate, 0.06 cfs (0.042 MGD)}$$

$$C_F = 2{,}446{,}665 \frac{kcal \cdot s}{^{o}C \cdot ft^3 \cdot day}$$

Table 2 - 31: Excess Thermal Load allocated to Sunstone Circuits.
Million kcal/day may be converted to megawatt-day/day (MW-day/day) by multiplying by 0.04846.

Allocated ΔT (ºC)	Stream Flow (7Q10) (cfs)	Effluent Flow (design flow) (cfs)	ETL (million kcal/day)	ETL (MW-day/day)
0.04	10.5	0.065	1.034	0.050

Excess Thermal Load Allocation for Chevron/Texaco Service Station No. 211-517

To calculate the potential heating effects (ΔT) from the discharge of treated groundwater from this facility, DEQ used a discharge flow (Q_e) that is the maximum reported by the permit holder, 0.09 cfs. The effluent temperature entered into the calculation is the maximum estimated by the permit holder for summer (20 ºC) and winter (18 ºC). The temperature criteria used in the calculation are the biologically based criteria.

The potential temperature increase to the Molalla River from the Chevron site discharge is 0.02 ºC (Table 2 - 32). This facility receives an excess thermal load equivalent to an increase of 0.02 ºC in ambient stream temperature that applies from May 1 - October 31. The ETL is calculated with Equation 11. Example ETLs for various river flow conditions are shown in Table 2 - 33. Outside of the critical period (May 1 – October 31), the facility does not receive an explicit wasteload allocation, but rather an implicit heat load allocation sufficient to cover current conditions of discharge.

The facility's current permit does not have an Excess Thermal Load limitation. However, the WLA is based on potential heat loading from current operating conditions and no operational changes appear to be necessary for the facility's discharge to meet the WLA.

Table 2 - 32: Potential temperature increase to the Molalla River from Chevron/Texaco service station discharge.

Month Evaluated	Point Source Discharge (cfs)	Maximum Temperature (°C)	Monthly 7Q10 Stream Discharge (cfs)	Core Cold Water and Spawning Temperature Criteria (°C)	Effect on River Temperature at 100% mix (° C)
August	0.09	20 (68 °F)	23	16 (60.8 °F)	0.02 (0.04 °F)
October	0.09	18 (64.4F)	25	13 (55.4 °F)	0.02 (0.04 °F)

$$\text{ETL} = 0.02(Q_R + Q_e)C_F \qquad \text{(Equation 11)}$$

where:

ETL = Excess Thermal Load, $kcal/day$

0.02 = allowed temperature increase, ^{o}C

Q_R = stream flow rate at gage Molalla River at Canby * 0.64, cfs

Q_e = groundwater treatment system effluent flow rate, cfs

$$C_F = 2{,}446{,}665 \frac{kcal \cdot s}{^{o}C \cdot ft^3 \cdot day}$$

Table 2 - 33: Chevron/Texaco service station example Excess Thermal Load (ETL) allocations (million kcal/day) for various river flows.
Million kcal/day may be converted to megawatt-day/day (MW-day/day) by multiplying by 0.04846.

Molalla R. at Canby gage * 0.64 flow rate (cfs):	≤18	30	50	75	100	200
Q_e (MGD)	ETL	ETL	ETL	ETL	ETL	ETL
0.06	0.885	1.472	2.451	3.674	4.898	9.791

Molalla R. at Canby gage * 0.64 flow rate (cfs):	300	400	500	600	800	1000
Q_e (MGD)	ETL	ETL	ETL	ETL	ETL	ETL
0.06	14.685	19.578	24.471	29.364	39.151	48.938

Molalla Wastewater Treatment Plant Evaluation

The City of Molalla wastewater treatment plant is only permitted to discharge between November 1 and April 30, when the upper Molalla River spawning temperature criterion is 13°C. The Molalla River critical period extends from May 1 – October 31, and for that reason, DEQ has not assigned an explicit wasteload allocation to this source. Still, the upper Molalla River is listed during the whole spawning season (August 15 – June 15), and the WWTP discharges during the spawning season, so the likely effect on Molalla River temperature is evaluated in this section. DEQ's calculations indicate that the discharge from the WWTP has no reasonable potential to increase ambient river temperature to the point of non-compliance with temperature criteria. While the facility does not receive an explicit wasteload allocation, DEQ does recognize an implicit heat load allocation sufficient to cover current conditions of discharge between November 1 and April 30.

Based on an estimate of the average of daily stream temperatures measured in January, February, March and April 2007[19], the Protecting Cold Water criterion applies to this location on the Molalla River, in addition to the spawning criterion. This TMDL does not address compliance with the Protecting Cold Water criterion, but the potential ambient river temperature increases from WWTP discharge are evaluated in comparison to both the protecting cold water criterion as well as the spawning criterion.

The most likely times for the WWTP discharge to affect stream temperature are late April, when effluent temperatures are starting to warm, and early November, when the Molalla River may still be experiencing low flow. Since DEQ did not model the natural thermal potential for those two time periods, the likely effect of the Molalla WWTP discharge during those time periods was evaluated with Equation 12 and by assuming that the river temperature would be at the temperature criterion of 13°C (Table 2 - 34). To be conservative, the calculation is based on mixing the effluent into only one-quarter the flow of the Molalla River (DEQ's practice for calculating heat loading before a TMDL is developed).

The permit issued to the Molalla WWTP also limits effluent discharge by a dilution equation that assures that dissolved oxygen criteria are met. The permit estimates flow at river mile 20 on the Molalla River at 0.64 *stream flow measured at the Canby gauge (correcting for drainage area). The dilution equation (Equation 13) calculates how much discharge would be allowed based on estimated stream flow at river mile 20.

DEQ calculated the 7Q10 flow[20] based on 64 years of stream flow measured at Canby or estimated at Canby from another Molalla River gauge, and converted that flow to flow at river mile 20 by multiplying by 0.64. The 7Q10 flow in November at river mile 20 is 73 cfs and in April is 345 cfs. The allowable effluent flow from the Molalla WWTP based on those two flow scenarios is 0.32 MGD (0.49 cfs) and 2.33 MGD (3.6 cfs). The treatment plant typically does not discharge less than 1 MGD and will continue to hold or irrigate wastewater until Molalla River flows are sufficient to discharge 1 MGD. By current permit requirements, in order to discharge 1 MGD (1.5 cfs), the flow at the Molalla River at Canby gauge would have to be at least 278 cfs, which equates to approximately 178 cfs at river mile 20. In the calculation, DEQ used the maximum effluent temperatures reported on discharge monitoring reports for the months of April and November between 2004 and 2008.

$$\Delta T = \left(\frac{Q_e}{Q_e + Q_R(0.25)} \right)(T_e - T_c) \quad \text{(Equation 12)}$$

where:

Q_R = river flow rate at river mile 20

Q_e = effluent flow rate

T_c = applicable river spawning temperature criteria

T_e = effluent temperature

Equation 13:

$$DR_{DO} = 481.42\,(Q_{R20})^{-0.2765}$$

and

$$Q_{PS} = \frac{Q_{R20}}{DR_{DO}}$$

[19] The Molalla WWTP began measuring daily ambient stream temperature in the Molalla River in January 2007. 60 continuous days of daily temperature data were not available. The average of 40 days of daily ambient stream temperature collected in January and February 2007 is 6.2 ºC. The average of daily ambient stream temperatures measured in March 2007 was 7.8 ºC. The average of 43 daily ambient stream temperatures measured in April 2007 and March 2007 average is 8.7 ºC.

[20] Average flow for various recurrence intervals was calculated with Therminator. a DEQ-written, Microsoft© Excel program.

Where:

DR_{DO}: Dilution ratio to comply with dissolved oxygen requirements
Q_{R20}: River flow discharge at river mile 20
Q_{PS}: Point source effluent discharge flow volume (cfs)

Table 2 - 34: Potential heating effects from Molalla WWTP discharge to the Molalla River at river mile 20.
*The dilution requirements in the permit would not allow 1 MGD discharge unless the river flow at the discharge point were at least 178 cfs. The November 7Q10 flow for the Molalla River at this location is 73 cfs.

Month Evaluated	Point Source Discharge (cfs)	Maximum Temperature (°C)	Monthly 7Q10 Stream Discharge or Minimum Flow Requirements (cfs)	Spawning Temperature Criteria (°C)	Effect on River Temperature at 25% mix (°C)
April	3.6 (2.33 MGD)	18 (64.4 ºF)	345	13 (55.4 ºF)	0.2 (0.36 ºF)
November	1.5 (1 MGD)	14 (57.2 ºF)	178*	13 (55.4 ºF)	0.03 (0.06 ºF)

Because the moving 60-day average of ambient stream temperature during the spawning period is likely to be less than 10 ºC, the source is restricted from contributing a heat load that would increase the 60-day average of stream temperature more than 1 ºC (protecting cold water criterion). An estimate of the potential increase in stream temperature is based on Equation 1, with effluent mixed into 100% of the river flow. DEQ's temperature IMD[21] directs that this calculation use the 60Q2 flow (the 60-day average of low flow with a recurrence interval of 1 in 2 years). The 60Q2 flow[22] of the Molalla River at Canby is 85 cfs, which is approximately 54.4 cfs at river mile 20, but this flow would not allow the practical minimum discharge of 1 MGD from the WWTP. As a conservative estimate, DEQ completed the calculation with an effluent flow of 1.5 cfs (1 MGD), a river flow of 54 cfs, and a 60-day average ambient river temperature of 6.2 °C (the January – February 2007 average). The results of the calculation are presented in Table 2 - 35 and indicate that under these conservative assumptions the potential ambient stream temperature increase could be 0.2 ºC. Under more realistic effluent and river flow conditions, the potential ambient stream temperature increase is 0.1 ºC. There is no reasonable potential that the treatment plant discharge would increase river temperature more than 1 ºC during spawning season.

Table 2 - 35: Potential effect on ambient stream temperature from Molalla WWTP discharge during spawning season.
*The current permit would not allow 1 MGD effluent discharge with only 54 cfs river flow – this is presented as a conservative scenario to evaluate the potential effect on ambient stream temperature.

Point Source Discharge (cfs)	Maximum Temperature (oC)	Stream Discharge or Minimum Flow Requirements (cfs)	60-day average ambient stream temperature (oC)	Effect on River Temperature at 25% mix (o C)
1.5 (1 MGD)	18 (64.4 ºF)	54*	6.2 (43.2 ºF)	0.2 (0.36 ºF)
1.5 (1 MGD)	18 (64.4 ºF)	178	6.2 (43.2 ºF)	0.1 (0.18 ºF)
6.2 (4 MGD)	18 (64.4 ºF)	525	6.2 (43.2 ºF)	0.14 (0.25 ºF)

[21] Temperature Water Quality Standard Implementation -- A DEQ Internal Management Directive, can be found on the DEQ website: http://www.deq.state.or.us/wq/pubs/imds/Temperature.pdf

[22] Calculated with DFLOW, U.S. EPA low flow analysis tool, found at this location: http://epa.gov/waterscience/models/dflow/

SUMMARY OF WASTELOAD ALLOCATIONS

A summary of the wasteload allocations for each of the permitted facilities is presented in Table 2 - 36.

Table 2 - 36: Wasteload Allocations to permitted facilities in Molalla-Pudding Subbasin.
cfs = cubic feet per second C_F = 2,446,665 kcal * sec/(ºC * ft_3* day) Q_e = Effluent flow in ft_3/sec

Facility Name	Receiving Stream	River Mile	Q_R measurement location	Wasteload Allocation	Applicable Period
Molalla Municipal Water Treatment Plant	Molalla River	21.6	Molalla River at Canby * 0.64	0.02 ºC *(Q_R + Q_e)C_F	May 1 – October 31
Sunstone Circuits, LLC	Milk Creek	5.3	7Q10 Milk Creek = 10.5 cfs	1.034 million kcal/day (0.05 MW-day/day)	May 1 – October 31
Sanders Wood Products, Inc. (RSG Forest Products)	Molalla River	17.3	Molalla River at Canby * 0.64	0.16 ºC *(Q_R + Q_e)C_F	May 1 – October 31
Chevron Environmental Management Co.	Molalla River	20	Molalla River at Canby * 0.64	0.02 ºC *(Q_R + Q_e)C_F	May 1 – October 31
City of Silverton WWTP	Silver Creek	2.4	Silver Creek at Silverton	0.20 ºC *(Q_R + Q_e)C_F	June 1 – September 30
City of Woodburn WWTP	Pudding River	23.6	Pudding River at Woodburn	0.20 ºC *(Q_R + Q_e)C_F	June 1 – September 30
City of Hubbard WWTP	Mill Creek	5.3	7Q10 Mill Creek = 2.39 cfs	0.20 ºC *(Q_R + Q_e)C_F	June 1 – September 30
JLR, LLC (Bruce Pac)	Pudding River	27.2	Pudding River at Woodburn	0.01 ºC * Q_R * C_F	June 1 – September 30
Silverton Water Treatment Plant	Abiqua Creek	3.9	7Q10 flow of Abiqua Creek = 5 cfs	0.20 ºC *(Q_R + Q_e)C_F	June 1 – September 30

LOAD ALLOCATIONS

Load Allocations compose the nonpoint source portion of the loading capacity and can be divided among natural, current anthropogenic, and future anthropogenic nonpoint pollutant sources. Background heat loading i.e. solar radiation that would reach the stream's surface in the absence of anthropogenic disturbance, is the allocated condition and was calculated using the Heat Source Temperature Model version 7 (Molalla River) and version 8 (Pudding River). This background condition is based on system potential vegetation and, in the case of the Molalla River, a narrowed stream channel. The derivation of system potential vegetation characteristics, which accounts for natural disturbance by reducing vegetation height and shading density in the model, is detailed in Appendix B. The relationships below were used to determine solar radiation heat loads for the system potential condition (Figure 2 - 28). Table 2 - 37 shows the result of this computation for both the Molalla and Pudding Rivers. The background solar radiation load at system potential is the load allocation.

DEQ also apportions 0.05˚C of the HUA to non-point sources. 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 heat loading (such as riparian management) or for human disturbance that may not easily be addressed (e.g. presence of a road near a stream that would limit shading).

Total Solar Radiation Heat Load from <u>All Nonpoint Sources,</u>

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

Solar Radiation Heat Load from <u>Background Nonpoint Sources (*System Potential*),</u>

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

Solar Radiation Heat Load from <u>Anthropogenic Nonpoint Sources,</u>

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

where,

$H_{Total\ NPS}$: Total Nonpoint Source Heat Load (kcal/day) or (MW-day/day)

$H_{SP\ NPS}$: Background Nonpoint Source Heat Load based on System Potential Vegetation (kcal/day) or (MW-day/day)

$H_{Anthro\ NPS}$: Anthropogenic Nonpoint Source Heat Load (kcal/day) or (MW-day/day)
$\Phi_{Total\ Solar}$: Total Daily Solar Radiation Flux (kcal cm^{-2} day^{-1}) or (W m^{-2})
$\Phi_{SP\ Solar}$: Background Daily Solar Radiation Flux based on *System Potential* (kcal cm^{-2} day^{-1}) or (W m^{-2})
$\Phi_{Anthro\ Solar}$: Anthropogenic Daily Solar Radiation Flux (kcal cm^{-2} day^{-1}) or (W m^{-2})
A: Stream Surface Area - calculated at each 100 m stream segment node (m^2)

Figure 2 - 28: Solar Radiation Heat Load Calculation Diagram.

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

Table 2 - 37: Load allocation for nonpoint sources in the Molalla and Pudding Rivers.
Million kcal/day may be converted to MW-day/day by multiplying by 0.04846.

Stream	Background Solar Radiation Load at System Potential (million kcal/day)
Molalla River nonpoint sources	5,798 (281 MW-day/day)
Pudding River nonpoint sources	3,286 (159 MW-day/day)

Surrogate Measures
The Load Allocation (e.g. background solar radiation at system potential vegetation) applies to all streams in the Molalla-Pudding subbasin but cannot be expressed explicitly for streams that were not modeled. DEQ uses a surrogate measure to express the load allocation for unmodeled streams. Percent effective shade is a surrogate measure used to represent nonpoint source heat loads. As well, percent effective shade may be used as a surrogate for the load allocation to the mainstem Pudding and Molalla Rivers.

Percent effective shade is straightforward to monitor and calculate and 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. Removal or disturbance of riparian vegetation is the primary nonpoint source activity that affects stream temperatures since shading from vegetation limits the amount of solar radiation that reaches the stream. The principal means of achieving system potential shading is through protection and restoration of riparian vegetation, though additional measures will also likely improve summer temperatures. For example, water conservation would improve summer stream flows and decrease stream temperatures through an increase in load capacity. Stream restoration that reduces channel width will improve the effectiveness of existing vegetation to shade the stream surface.

Figure 2 - 29 and Figure 2 - 30 show the site specific (by mainstem river kilometer) percent effective shade calculated for current conditions versus system potential vegetation conditions on the Molalla and Pudding Rivers, respectively, averaged over a 1 km (0.6 miles) distance. System potential vegetation could increase shading from an average 27% currently to 41% on the Molalla River. On the Pudding River, system potential vegetation could increase shading from an average 47% currently to an average of 58%.

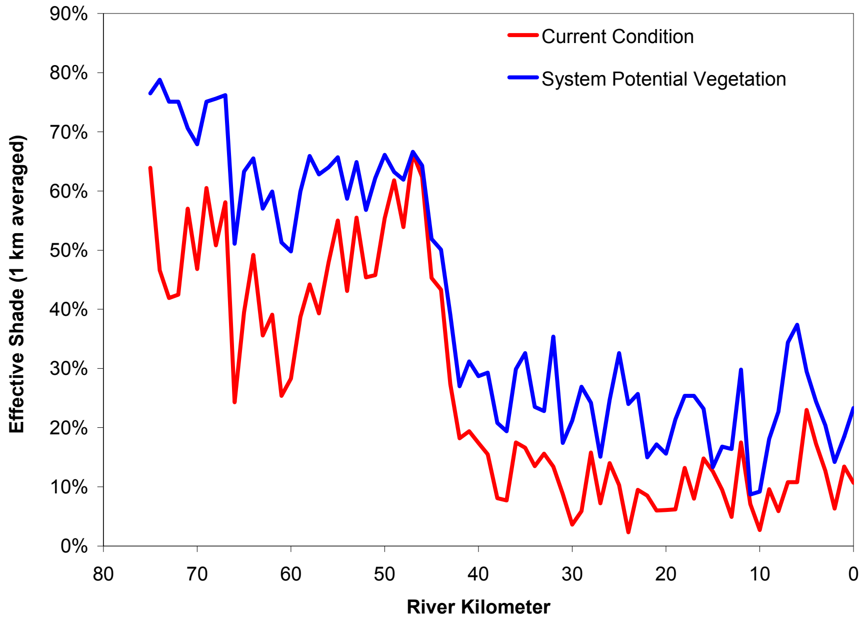


Figure 2 - 29: Molalla River current and system potential effective shade, averaged over a 1 km distance. System potential vegetation in the upper half of the watershed is modeled as a mature coniferous forest with natural disturbance. System potential vegetation in the lower half of the watershed is modeled as a randomly distributed mixture of forest, savannah, and prairie. The notable decrease in effective shade at approximately river kilometer 45 corresponds with the North Fork Molalla confluence and channel widening.

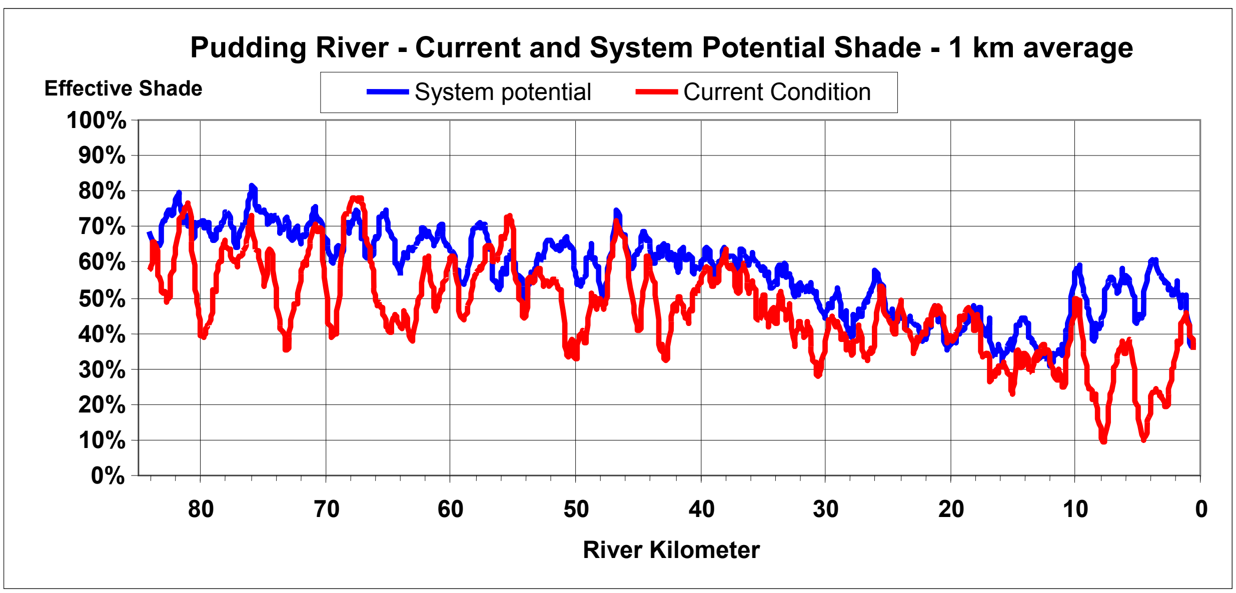


Figure 2 - 30: Pudding River current and system potential effective shade.

Shade curves have been developed for distinct physical units in the Willamette Valley and upland forest areas of the Cascade and Coast Ranges in the Willamette Basin. Shade curve development uses trigonometric equations to estimate the shade underneath tree canopies characteristic of a particular physical unit. The categorization of the physical units is explained in Appendix B, "Potential Near-Stream Land Cover for Willamette Basin." These physical units are termed "geomorphic" units in Appendix B, though their categorization takes into account such factors as geomorphology, geology, vegetation, elevation, and soil type. This section continues to refer to the units as "geomorphic" units or "geomorphic" classifications when referring to the differentiation among geomorphic units, recognizing that factors in addition to geomorphology differentiate the units. 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 relative areas of the geomorphic classifications (Figure 2 - 31) of the Molalla-Pudding Subbasin are presented in Table 2 - 38. Despite the relatively fine scale of the geomorphic classifications, the differences among the various shade curves are subtle.

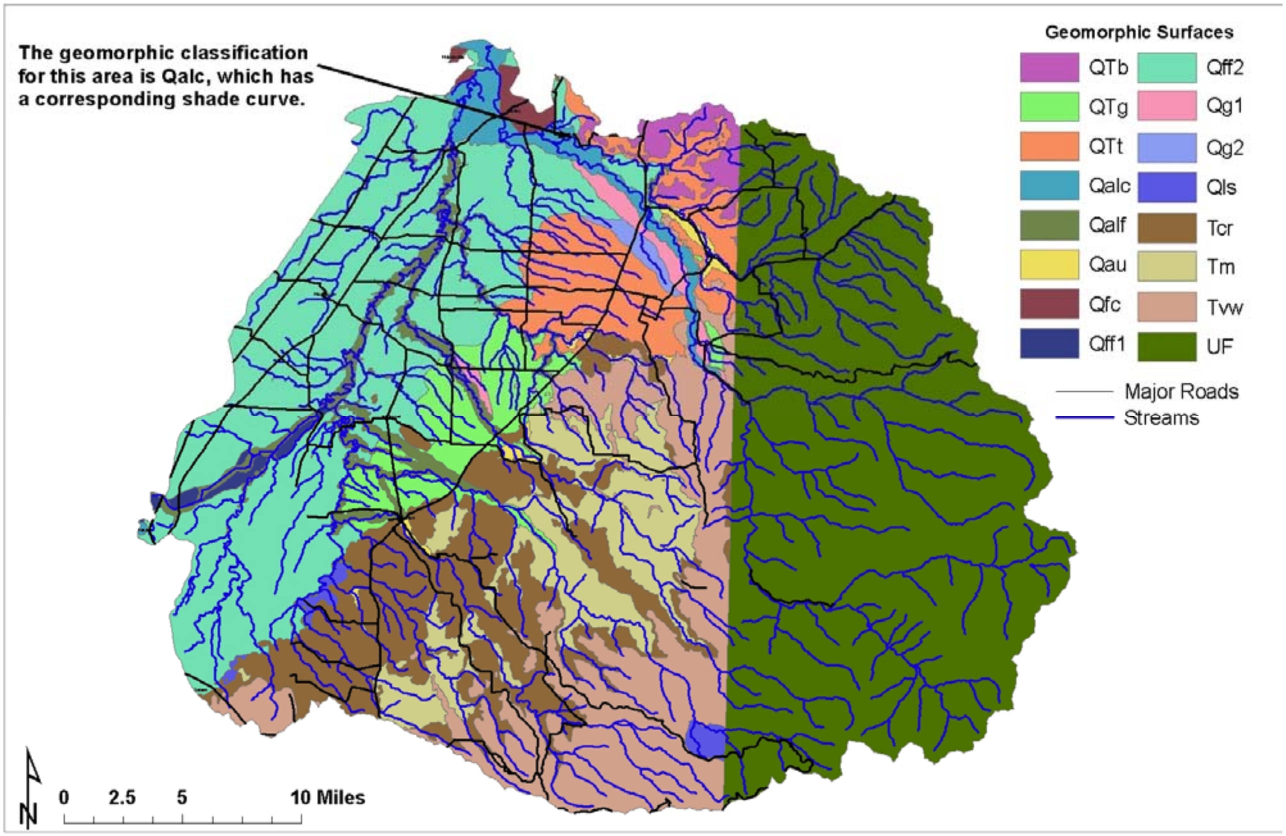


Figure 2 - 31: Geomorphic classifications in the Molalla-Pudding Subbasin that determine the appropriate shade curve for load allocations via effective shade.

Table 2 - 38: Total area of geomorphic classifications in the Molalla-Pudding Subbasin.

Geomorphic Unit	Acres	Square miles	Relative area
Qalc – Quaternary alluvium (silt, sand, gravel) for major Willamette tributaries	10,471	16.4	2%
Qalf - Quaternary alluvium (clay, silt, sand, gravel) for smaller streams	18,872	29.5	3%
Qau – Quaternary alluvium undifferentiated	3,839	6.2	0.7%
Qfc – Coarse Missoula Flood deposits	2,562	4.0	0.4%
Qff1 – Younger and lower fine-grained Missoula Flood deposits	2,130	3.3	0.4%
Qff2 – Main body of fine-grained Missoula Flood deposits	112,518	176	20%
Qg1 – upper Pleistocene sand and gravel, postdates Missoula floods	3,876	6.1	0.7%
Qg2 – Pleistocene sand and gravel that predates Missoula Floods	1,957	3.1	0.3%
Qls – Holocene and Pleistocene landslide deposits and colluvium	2,734	4.3	0.5%
QTb – Pleistocene and Pliocene Boring Lava	5,791	9.0	1%
QTg – Pleistocene and possibly Pliocene terrace gravel	19,663	30.7	3.5%
QTt – possibly Pleistocene and Pliocene Troutdale Formation	28,794	45	5%
Tcr – Miocene Columbia River Basalt	61,031	95.4	11%
Tm – Miocene to lower Eocene marine sedimentary rocks	38,592	60.3	6.9%

Tvw – upper Eocene to Pliocene volcanic and volcaniclastic rocks	65,595	102	11.6%
Upland Forest	183,251	286	33%
Total	**561,676**	**877**	**100%**

How to Use a Shade Curve:

1. Determine the applicable geomorphic or upland forest unit that applies to the stream of interest.
Example: Lower Milk Creek watershed, indicated in Figure 2 - 32, is in the Qalc (Quaternary alluvium) geomorphic unit .

2. Determine the stream aspect from north.
Example: Based on one's location on the stream, facing north in-stream mid-channel, determine the river's aspect. For this example, assume the aspect is 0º or 180º from north (this means the river reach runs south to north).

3. Determine the channel width of the stream reach.
Example: Measure the channel width using a tape measure. For this example, assume the channel width is 25 feet. The channel width in Figure 2 - 32 is the distance from the edge of right bank vegetation to the edge of left bank vegetation.

Figure 2 - 32: Illustrated channel width.
Channel width approximates bankfull width, from the edge of right bank vegetation to left bank vegetation.

4. Using the corresponding Shade Curve, and the appropriate stream aspect line and channel width (x-axis), read the y-axis to determine the percent effective shade and solar radiation loading.   In the example below, Figure 2 - 33, where the blue curve crosses a vertical line from the x-axis at 25 feet (8 m), the corresponding effective shade value (read on the left y-axis) is 80% effective shade. The corresponding solar radiation loading is 0.129 kcal/cm^2/day. System potential vegetation average height is 88.2 feet (26.9 m), and tree canopy density is 71%. If it is difficult to determine the stream's aspect from north, the average stream aspect from north, represented in Figure 2 - 34 by the black line, can be used to determine the solar radiation loading and effective shade.

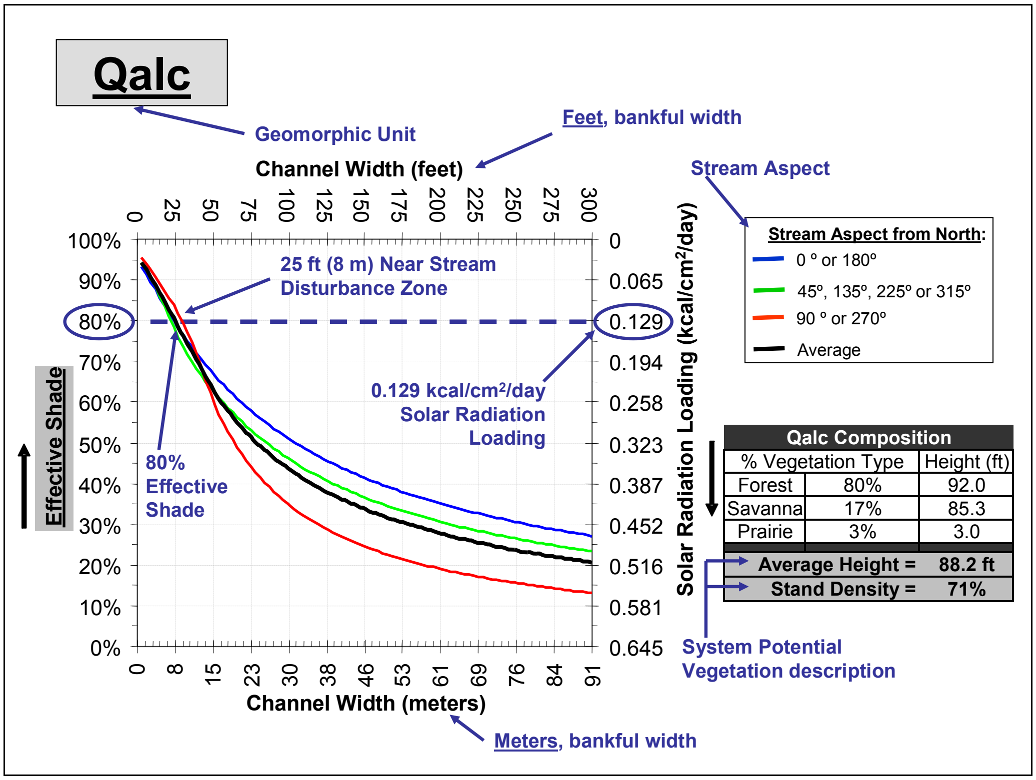


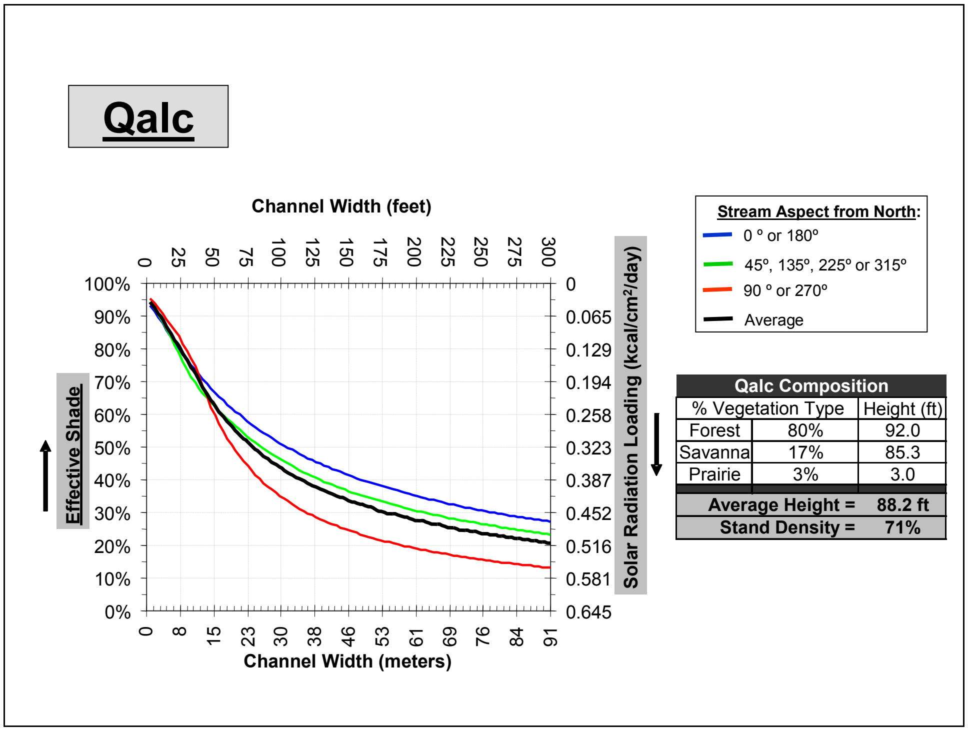
Figure 2 - 33: Example shade curve.

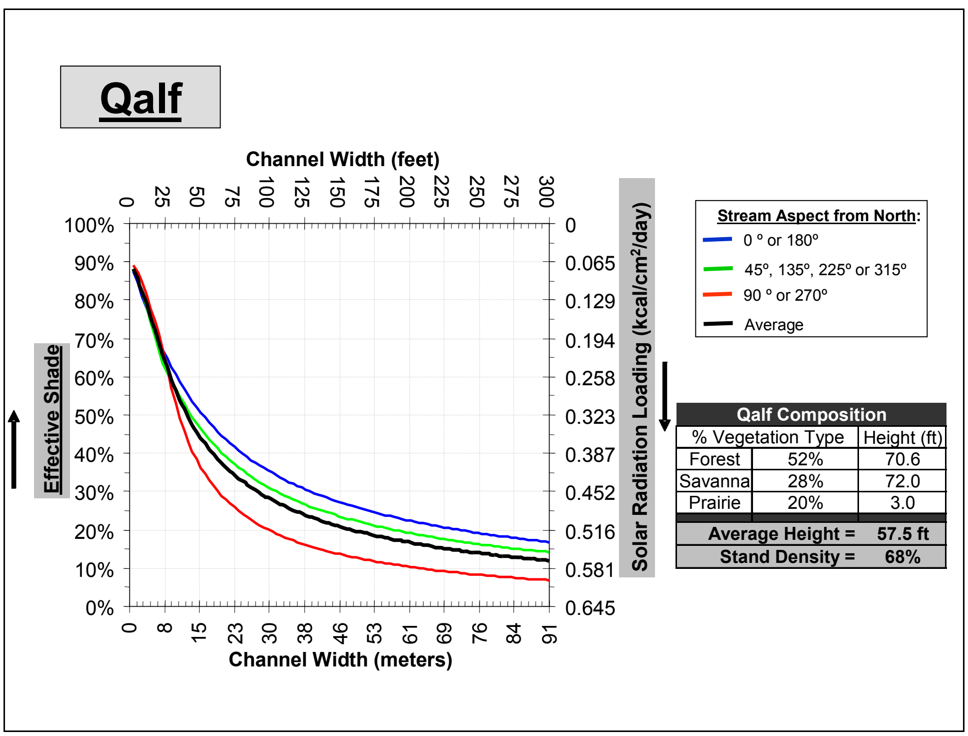
> *Conclusion*: A land owner or manager living adjacent to lower Milk Creek, measures the channel width of a stream reach as 25 feet (8 m), with a stream aspect from north of 0º or 180º. The land owner identifies their location and the corresponding geomorphic unit as Qalc in this example. The land owner 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 that attains system potential vegetation.

The shade curve method provides no information on existing shade conditions or the expected system potential stream temperature. It does provide estimates of how much shading needs to increase to eliminate temperature increases from anthropogenic non point sources. The shade curves presented in Figure 2 - 34 apply to all water bodies in the Molalla-Pudding Subbasin based on the geomorphic and upland forest unit of the reach.

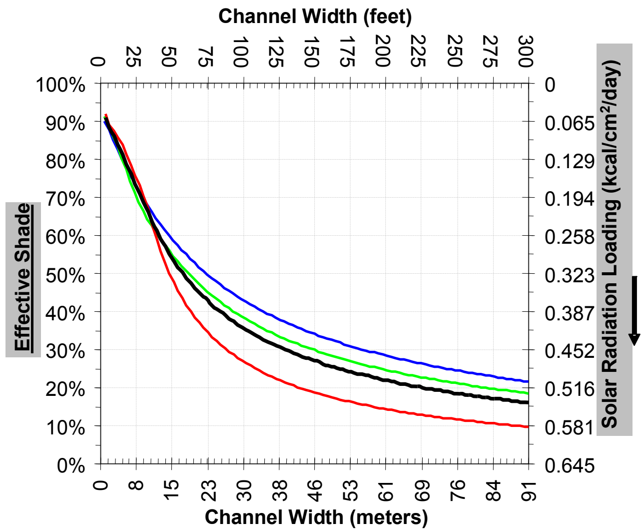
The geomorphic unit Qg2, pre-Missoula Flood Quaternary Sand/Gravel, covers only a small percentage of the Molalla-Pudding Subbasin area (0.3%). DEQ has not developed a shade curve for this unit because the historical hydrologic conditions that limited tall vegetation on this surface no longer persist. For the small percentage of area covered by this surface, effective shade may be allocated based on an adjacent geomorphic code.

Figure 2 - 34: Shade Curves for Molalla-Pudding Subbasin Geomorphic Classifications.



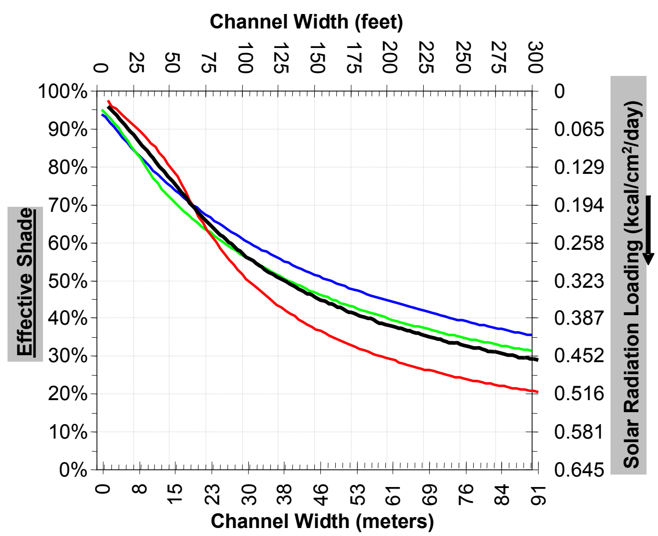


Qau



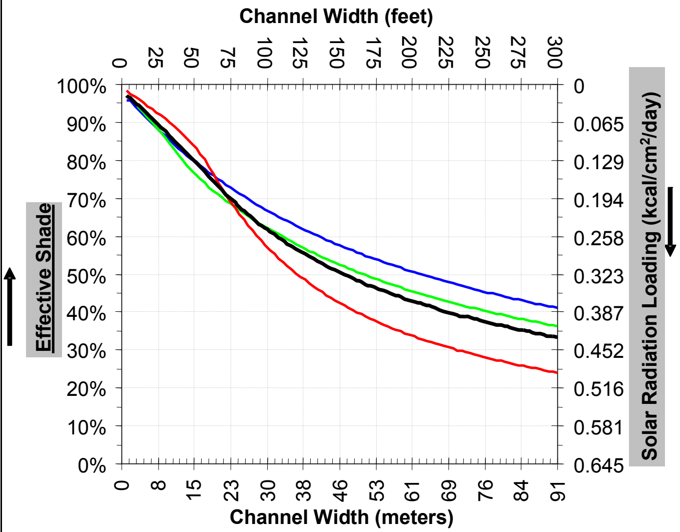
Qau Composition		
% Vegetation Type		Height (ft)
Forest	60%	93.9
Savanna	23%	75.5
Prairie	17%	3.0
Average Height =		**74.2 ft**
Stand Density =		**69%**

Qfc



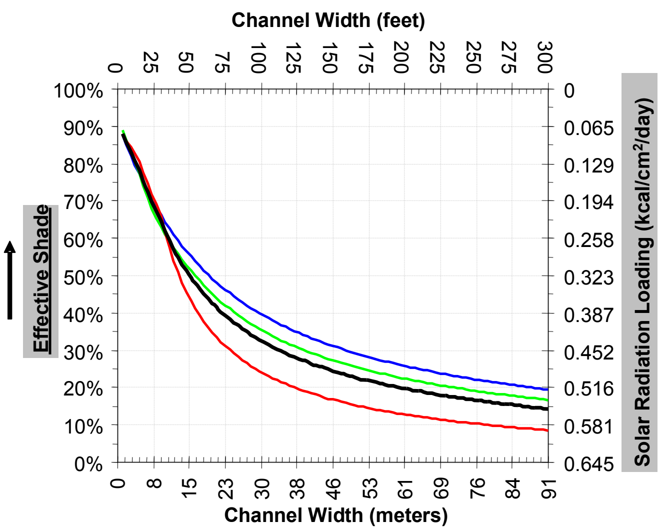
Qfc Composition		
% Vegetation Type		Height (ft)
Forest	56%	100.4
Savanna	44%	153.5
Prairie	0%	0.0
Average Height =		**123.8 ft**
Stand Density =		**64%**

Qff1



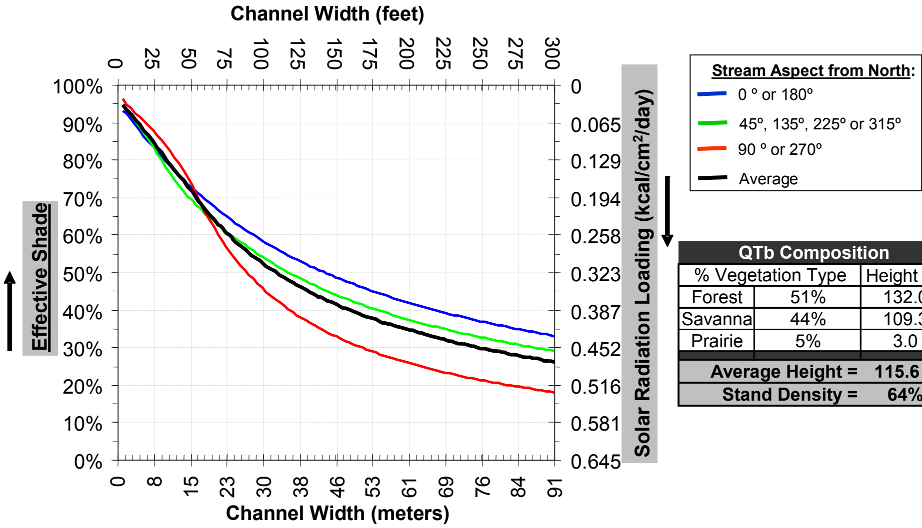
Qff1 Composition		
% Vegetation Type		Height (ft)
Forest	81%	145.8
Savanna	19%	80.7
Prairie	0%	0.0
Average Height =		133.5 ft
Stand Density =		70%

Qff2



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%

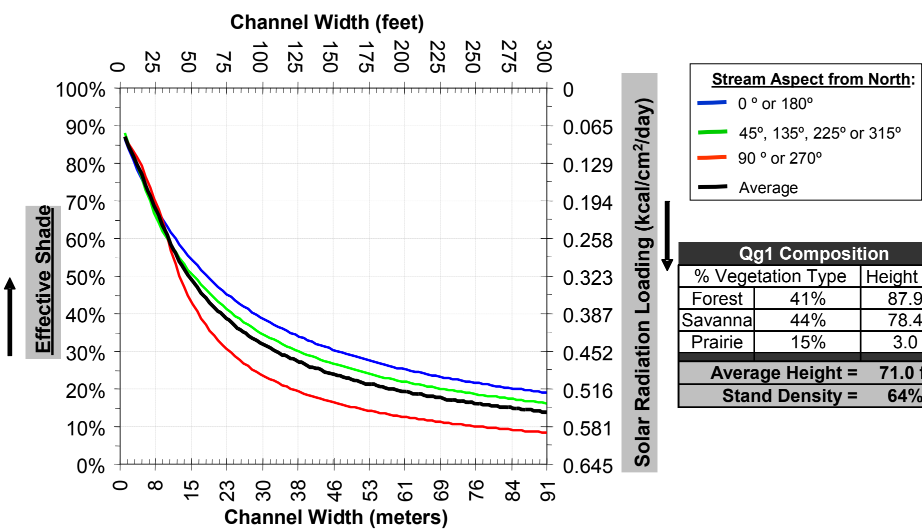
QTb



QTb Composition	
% Vegetation Type		Height (ft)

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

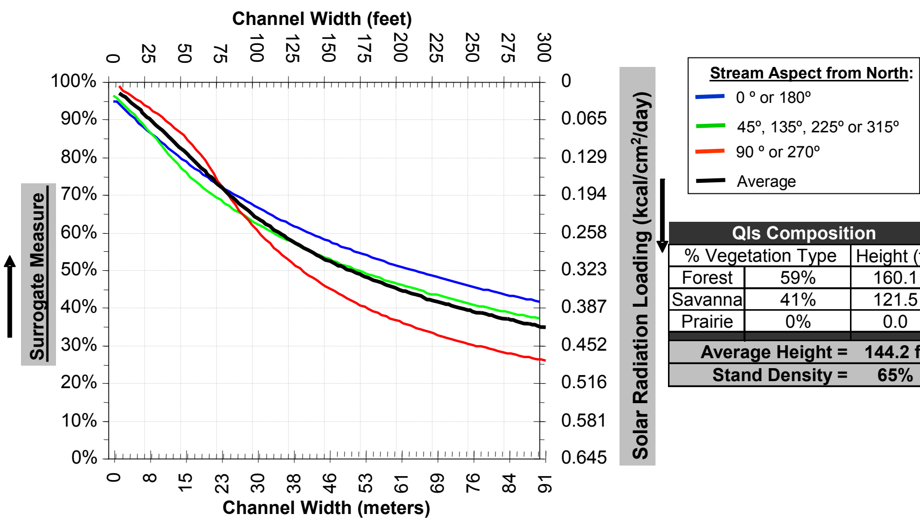
Qg1



Qg1 Composition

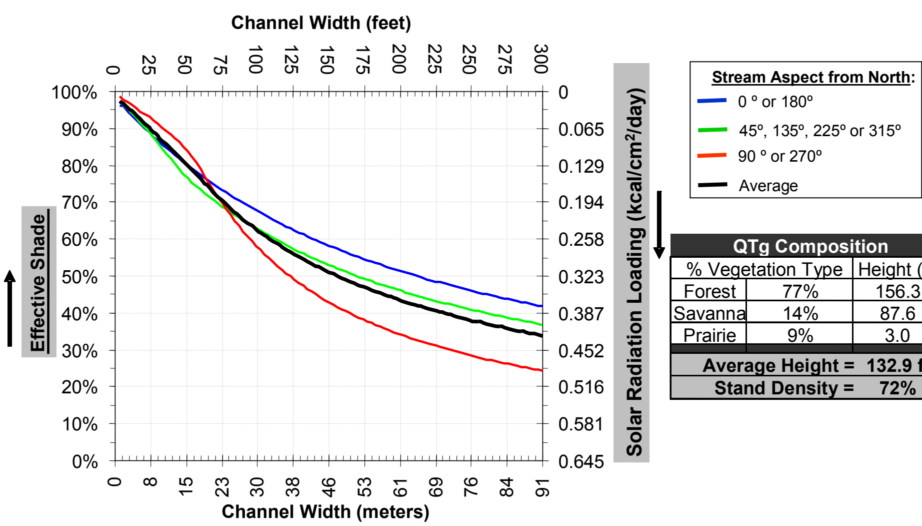
% Vegetation Type		Height (ft)
Forest	41%	87.9
Savanna	44%	78.4
Prairie	15%	3.0
Average Height =		**71.0 ft**
Stand Density =		**64%**

Qls



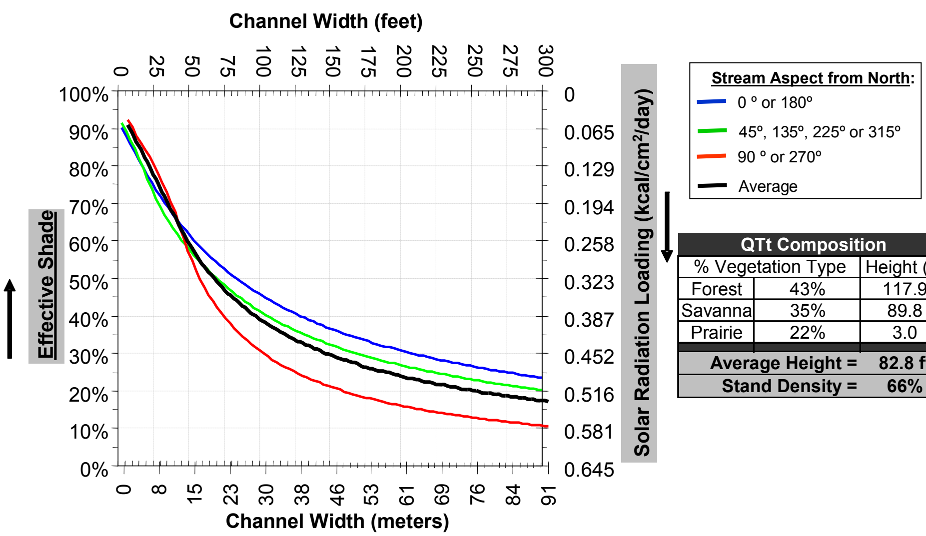
Qls Composition		
% Vegetation Type		Height (ft)
Forest	59%	160.1
Savanna	41%	121.5
Prairie	0%	0.0
Average Height =		144.2 ft
Stand Density =		65%

QTg



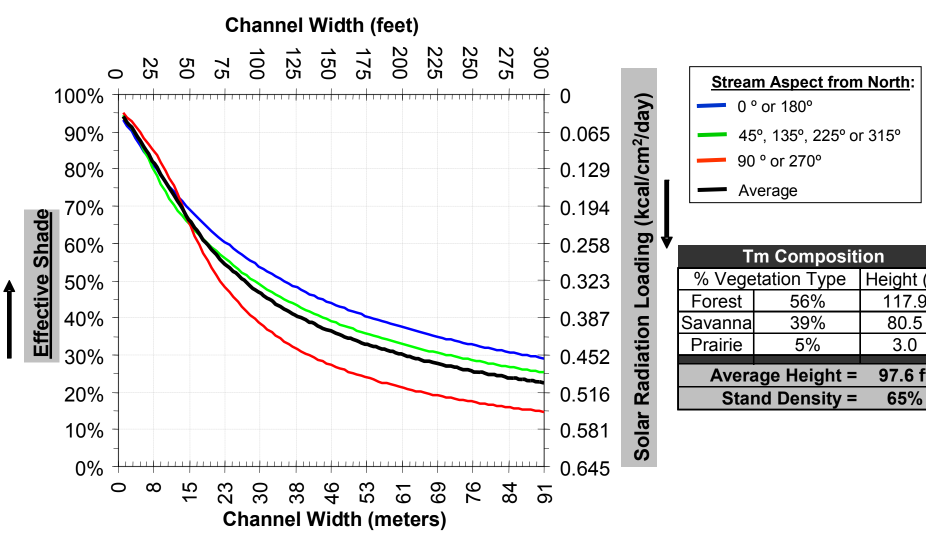
QTg Composition		
% Vegetation Type		Height (ft)
Forest	77%	156.3
Savanna	14%	87.6
Prairie	9%	3.0
Average Height =		132.9 ft
Stand Density =		72%

QTt



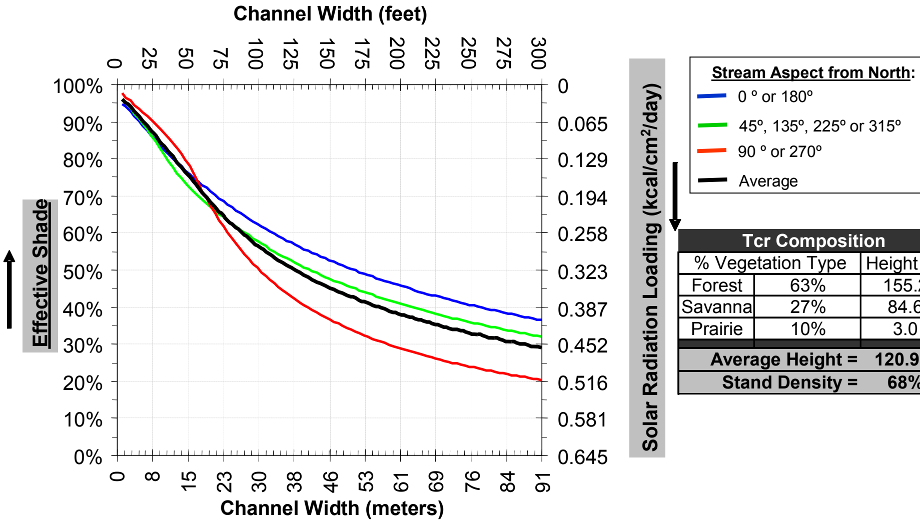
QTt Composition		
% Vegetation Type		Height (ft)
Forest	43%	117.9
Savanna	35%	89.8
Prairie	22%	3.0
Average Height =		**82.8 ft**
Stand Density =		**66%**

Tm



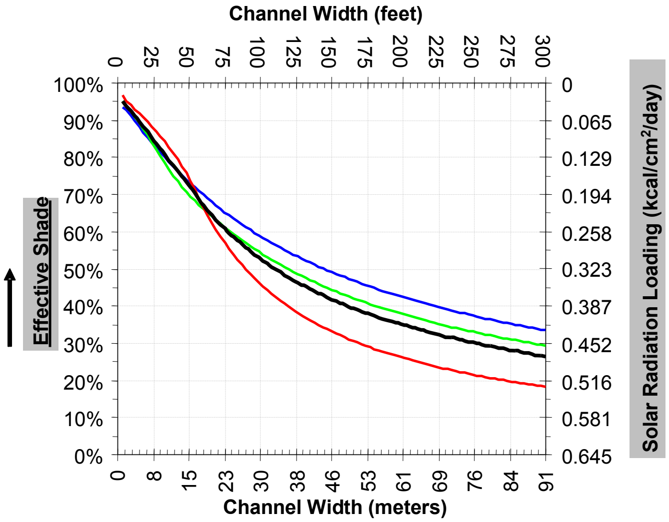
Tm Composition		
% Vegetation Type		Height (ft)
Forest	56%	117.9
Savanna	39%	80.5
Prairie	5%	3.0
Average Height =		**97.6 ft**
Stand Density =		**65%**

Tcr



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%**

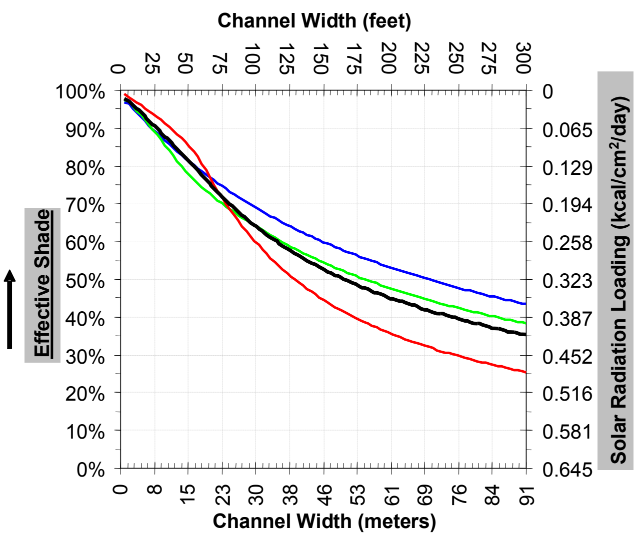
Tvw



Stream Aspect from North:
- 0 ° or 180°
- 45°, 135°, 225° or 315°
- 90 ° or 270°
- Average

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



Stream Aspect from North:
- 0 ° or 180°
- 45°, 135°, 225° or 315°
- 90 ° or 270°
- Average

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

A margin of safety (MOA) 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 2 - 39 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 2 - 39: 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.

DEQ incorporated an implicit margin of safety into the temperature assessment methodology by the following methods:

- Wasteload allocations were based on critical conditions that are unlikely to occur simultaneously. For example, the maximum effluent flows and maximum effluent temperatures that were used to calculate point source heat loads are unlikely to occur simultaneously.
- Receiving stream values were based on attainment of applicable temperature criteria during low flow periods defined as the low flow of a ten year cycle.

- DEQ derived NTP from the 90th percentile or median of current 7-day average daily maximum temperatures, rather than the maximum current 7-day average daily maximum temperatures.

DEQ did not calculate a numeric margin of safety for nonpoint source loads. 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

Reserve capacity has been allocated throughout much of the Willamette Basin. Explicit allocations have generally only been made in conjunction with point source wasteload allocations. Where there are multiple point sources in a waterbody, point sources in combination have been allocated a heat load equivalent to a 0.2˚C stream temperature increase (a portion of the Human Use Allowance). A heat load equivalent to a 0.05˚C stream temperature increase 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 of the human use allowance is apportioned for a heat load set aside as reserve capacity. Reserve capacity will be available for use by point sources or nonpoint sources by application to DEQ. In total, the heat load allocations may not cause a temperature increase in a water quality limited waterbody by more than 0.3°C (0.54°F).

In those situations where the point source is allocated a heat load causing less than 0.2˚C stream temperature increase or if there are no point sources, the remaining portion of the Human Use Allowance will be set aside as an equivalent Reserve Capacity heat load. The nonpoint source apportioning of the human use allowance will remain at 0.05˚C unless special circumstances exist that require a larger or smaller apportionment. This allows for a maximum reserve capacity of 0.25 ˚C. More information regarding the use of reserve capacity may be found in the Water Quality Management Plan, Temperature TMDL Implementation.

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