Chapter 1
Overview

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REASON FOR ACTION

The Molalla-Pudding Subbasin (Figure 1 - 1) has stream segments listed under section 303(d)[1] of the federal Clean Water Act (CWA) that are exceeding water quality criteria for temperature, bacteria, iron (Fe), manganese (Mn), arsenic (As), nitrate, DDT, chlordane, dieldrin and dissolved oxygen. The Oregon Department of Environmental Quality (DEQ) has developed Total Maximum Daily Loads (TMDLs) for each of these parameters except manganese, arsenic and dissolved oxygen[2]. Wasteload allocations for heat (temperature) and bacteria are developed for individual facilities (point sources) that discharge during the periods in which stream water quality is impaired. DEQ has also developed load allocations for heat (temperature), bacteria, DDT, dieldrin, nitrate, chlordane and iron for nonpoint sources that apply to some or all sectors in the subbasin.

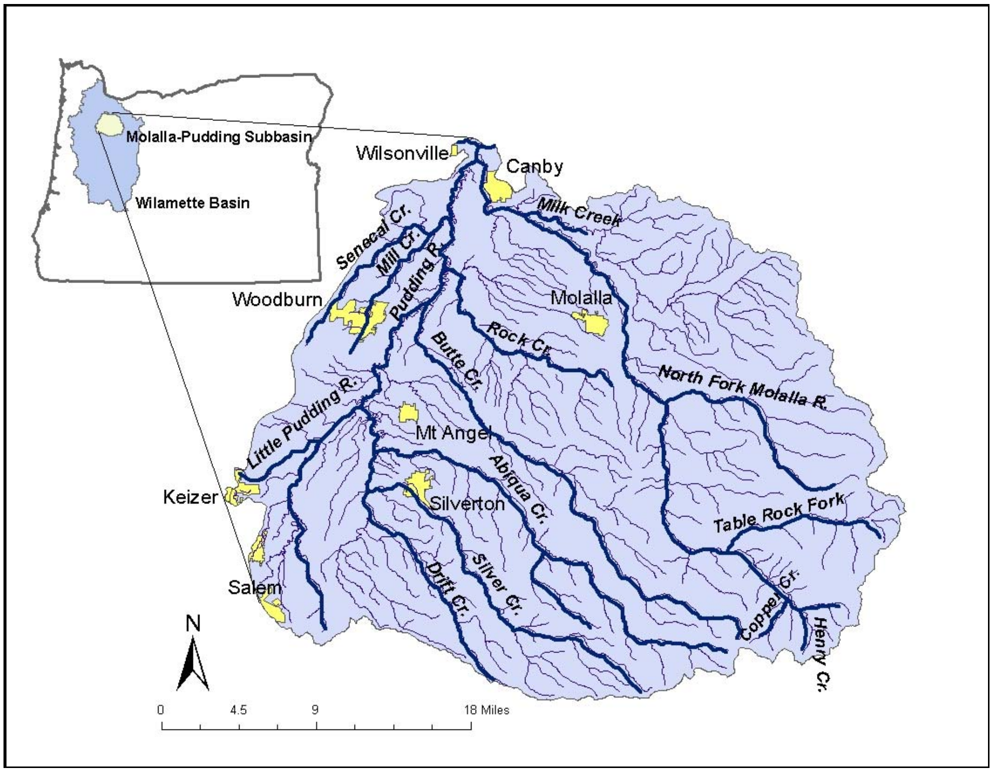

Figure 1 - 1: Location of Molalla-Pudding Subbasin in Willamette Basin.

In 1993, DEQ completed a TMDL to address dissolved oxygen impairment in the Pudding River. DEQ assigned wasteload allocations for biochemical oxygen demand (BOD), ammonia, and total suspended solids to two facilities discharging to the Pudding River. DEQ incorporated the resulting wasteload allocations into the wastewater permits for the City of Woodburn wastewater treatment plant (WWTP) and Agripac (since purchased by JLR, Inc.). The 1993 TMDL was not reviewed or changed as part of this TMDL and the allocations established in that TMDL and incorporated into facility permits remain in effect.

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

[2] Manganese and arsenic were found to be present at natural concentrations, so a TMDL was not developed. The dissolved oxygen listing in W. Fork Little Pudding River occurred after the data collection for the earlier TMDL listings had been completed. Strategies to implement the temperature and bacteria TMDLs will likely benefit dissolved oxygen concentrations in the W. Fork Little Pudding River.

WATER QUALITY 303(D) LISTED WATERBODIES

All 303(d) listings for the Molalla-Pudding Subbasin are presented in Table 1 – 1 and Figure 1 - 2 through Figure 1 - 5. Water quality impairments discovered during data review and analysis (for previously unlisted segments) and addressed with TMDLs are also listed in Table 1 – 1. In addition, DEQ had identified water quality impairments in two streams (Zollner Creek and Little Pudding River) from two currently used pesticides, chlorpyrifos and azinphos-methyl (as discussed in detail in Appendix I). While 303(d) listing may be necessary in the future, DEQ does not recommend the development of TMDLs for these parameters at this time based on a successful on-going Pesticide Stewardship Project (PSP) with OSU Extension Service, the Marion Soil and Water Conservation District, agricultural interests and other stakeholders in the Pudding Watershed. DEQ would like to provide adequate time for education and management practice changes associated with the Pudding River PSP to produce positive results. If this collaborative approach does not result in generally decreasing levels of chlorpyrifos and azinphos-methyl in the next two to three years, DEQ will re-evaluate the need to develop TMDLs.

Table 1 – 1: Name and location of listed Molalla-Pudding Subbasin waterbodies.

Water Body	Listed River Mile	Parameter	Season – Criteria	Assessment Year	Action
Beaver Creek	0 to 6.8	Temperature	Year Around (Non-spawning) – Core cold water habitat: 16.0 ºC.	2004	TMDL Completed
Butte Creek	11.9 to 35.6	Temperature	Year Around (Non-spawning) – Core cold water habitat: 16.0 ºC.	2004	TMDL Completed
Drift Creek	0 to 9.5	Temperature	Year Around (Non-spawning) – Salmon and trout rearing and migration: 18.0 ºC.	2004	TMDL Completed
Little Pudding River	0 to 18.3	DDT	Year Around	Previously Unlisted	TMDL Completed
Molalla River	0 to 25	Fecal Coliform	Fall/Winter/Spring	1998	Delisted 2004, but still showing impairment TMDL Completed
Molalla River	19.7 to 44.7	Temperature	August 15 – June 15 – Salmon and steelhead spawning: 13.0 ºC.	2004	TMDL Completed
Molalla River	18.2 to 48.3	Temperature	Year Around (Non-spawning) – Core cold water habitat: 16.0 ºC.	2004	TMDL Completed
Molalla River	0 to 25	Temperature	Summer	1998	Delisted 2004, but still showing impairment TMDL Completed
Pine Creek	0 to 7.2	Temperature	Year Around (Non-spawning) – Core cold water habitat: 16.0 ºC.	2004	TMDL Completed
Pudding River	0 to 35.4	DDT	Year Around	1998	TMDL Completed
Pudding River	0 to 35.4	Dieldrin	Year Around	Previously Unlisted	TMDL Completed
Pudding River[3]	0 to 35.4	*E. Coli*	Fall/Winter/Spring	2004	TMDL Completed
Pudding River	0 to 35.4	Fecal Coliform	Summer	1998	Delisted 2004, but still showing impairment TMDL Completed
Pudding River	0 to 35.4	Iron	Year Around	2004	TMDL Completed

[3] A 1998 listing for Pudding River (River Mile 0 to 35.4) for fecal coliform in fall/winter/spring is not included in Table 1-1 because the 2004-06 listing for E. coli applies to the same reach and season.

Table 1 -1: Continued

Water Body	Listed River Mile	Parameter	Season – Criteria	Assessment Year	Action
Pudding River	0 to 35.4	Manganese	Year Around	2004	Recommended for Delisting
Pudding River	0 to 61.8	Temperature	Year Around (Non-spawning) Salmon and trout rearing and migration: 18.0 ºC.	2004	TMDL Completed
Silver Creek	0 to 5.9	Fecal Coliform	Summer	1998	TMDL Completed
Silver Creek	0 to 5.9	Temperature	Summer -- Rearing: 17.8 ºC.	1998	TMDL Completed
South Fork Silver Creek	0 to 7	Temperature	Year Around (Non-spawning) - Salmon and trout rearing and migration: 18.0 ºC.	2004	TMDL Completed
Table Rock Fork Molalla River	0 to 8.3	Temperature	August 15 - June 15 -- Salmon and steelhead spawning: 13.0 ºC.	2004	TMDL Completed
Table Rock Fork Molalla River	0 to 12	Temperature	Year Around (Non-spawning) -- Core cold water habitat: 16.0 ºC.	2004	TMDL Completed
Teasel Creek	0 to 6.3	Temperature	Year Around (Non-spawning) -- Salmon and trout rearing and migration: 18.0 ºC.	2004	TMDL Completed
West Fork Little Pudding River	0 to 5.1	Dissolved Oxygen	January 1 - May 15	2004	Not addressed
West Fork Little Pudding River	0 to 5.1	*E. Coli*	Fall/Winter/Spring	2004	TMDL Completed
Zollner Creek	0 to 7.8	Arsenic	Year Around	2004	Recommended for Delisting
Zollner Creek	0 to 7.8	Chlordane	Year Around	2002	TMDL Completed
Zollner Creek	0 to 7.8	Dieldrin	Year Around	2002	TMDL Completed
Zollner Creek	0 to 7.8	DDT	Year Around	Previously Unlisted	TMDL Completed
Zollner Creek	0 to 7.8	Fecal Coliform	Fall/Winter/Spring	1998	TMDL Completed
Zollner Creek	0 to 7.8	Fecal Coliform	Summer	1998	TMDL Completed
Zollner Creek	0 to 7.8	Iron	Year Around	1998	TMDL Completed
Zollner Creek	0 to 7.8	Manganese	Year Around	1998	Recommended for Delisting
Zollner Creek	0 to 7.8	Nitrates	Year Around	2002	TMDL Completed
Zollner Creek	0 to 7.8	Temperature	Summer -- Rearing: 17.8 ºC.	1998	TMDL Completed

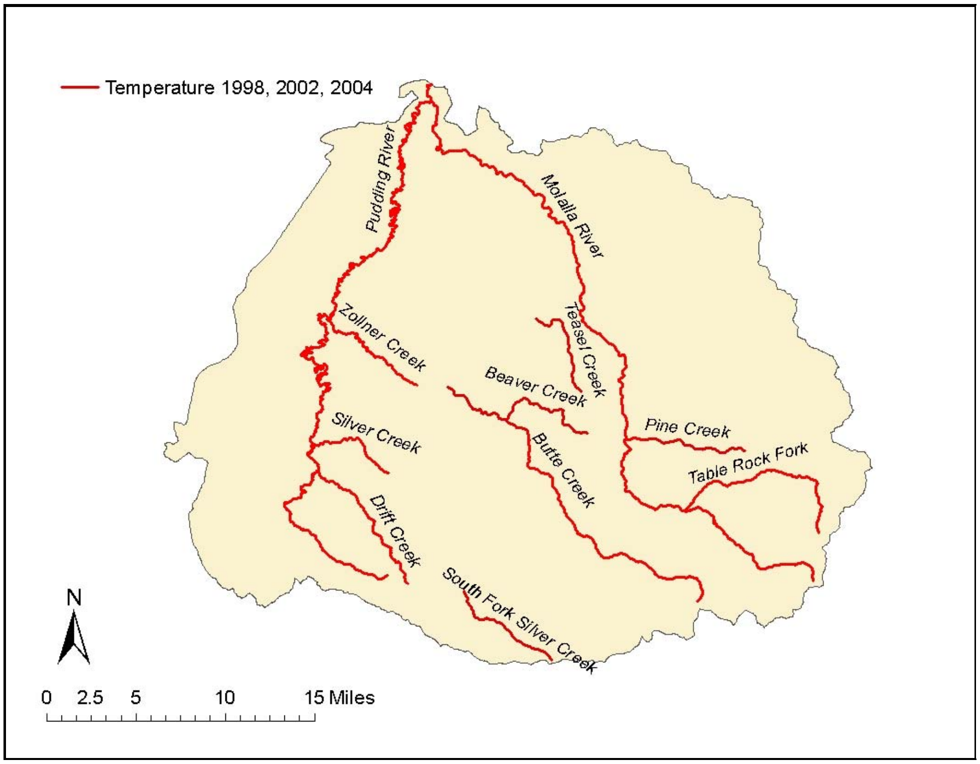

Figure 1 - 2: Streams not meeting temperature criteria in the Molalla-Pudding Subbasin.

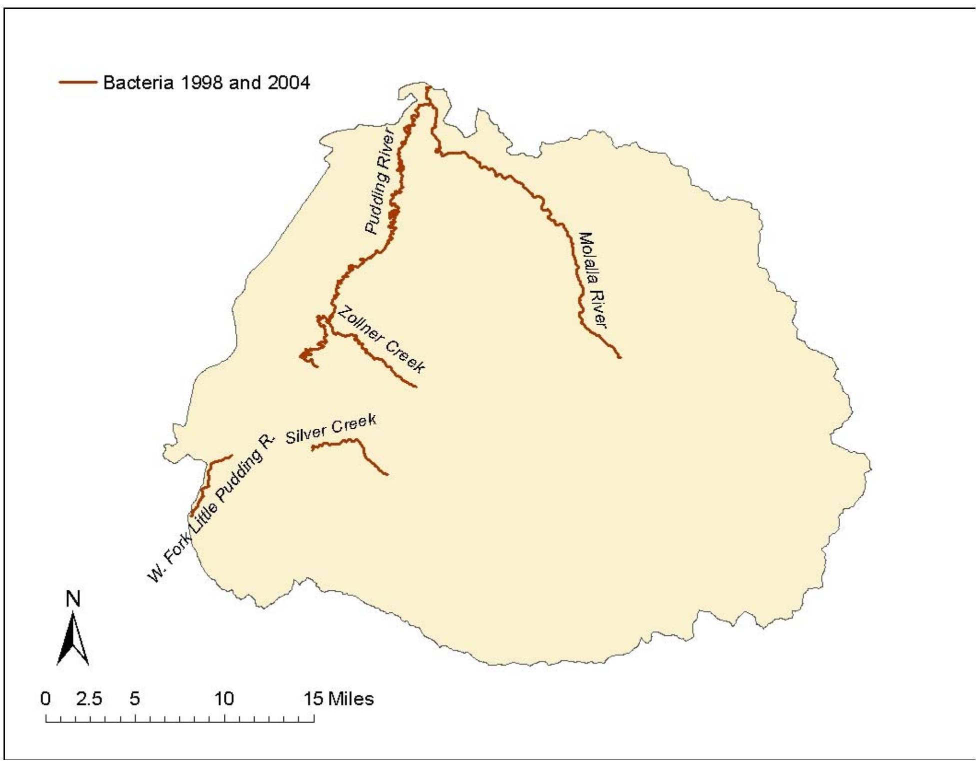

Figure 1 - 3: Streams not meeting bacteria criteria in the Molalla-Pudding Subbasin.

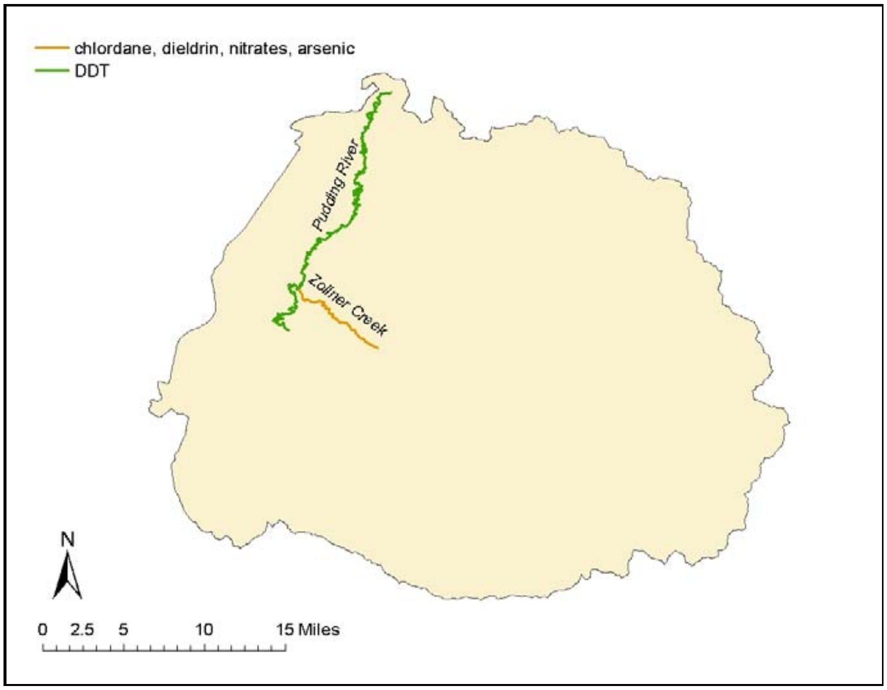

Figure 1 - 4: Streams not meeting various toxics criteria in the Molalla-Pudding Subbasin.

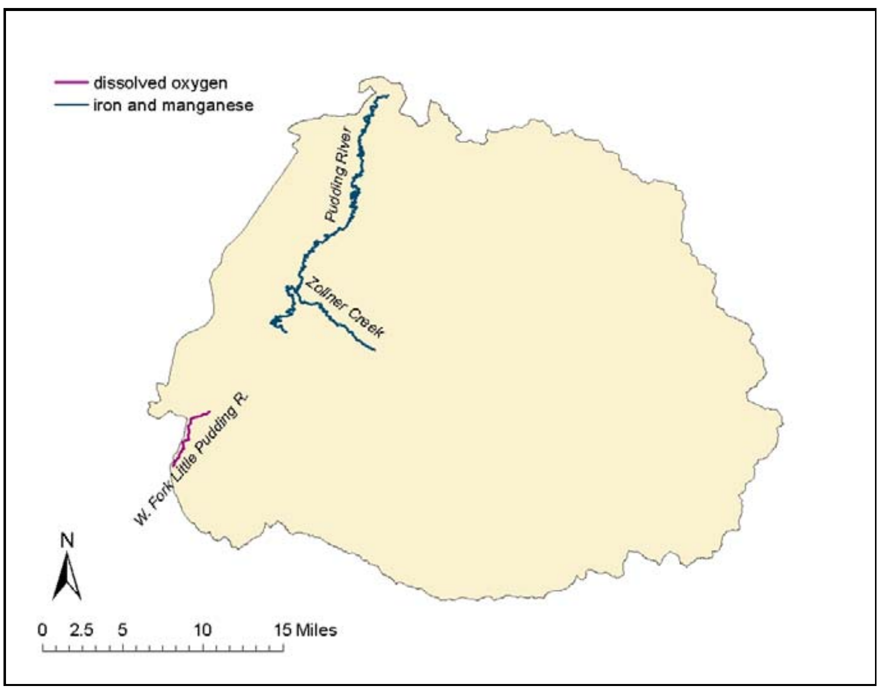

Figure 1 - 5: Streams not meeting metals or dissolved oxygen criteria in the Molalla-Pudding Subbasin.

WATER QUALITY PARAMETERS ADDRESSED

The following Molalla-Pudding Subbasin 303(d) parameters are addressed in this TMDL:

- Temperature
- Bacteria
- Toxics (As, Mn, Fe, dieldrin, chlordane, DDT, nitrate)

Changes to the temperature and bacteria criteria occurred between the earliest subbasin listings (1998) and the most recent listings (2004/2006). One change was the replacement of fecal coliform by *E. coli* as the indicator for bacteria criteria compliance in 1996. The 1998 listings were based on data collected before 1996 and, hence, the fecal coliform criteria. The temperature criteria were revised as part of the rewrite of the Water Quality Standards (OAR 340-041) in 2004. Two effects from the temperature criteria rewrite, evident in the listings, is a small difference in the numeric criteria (e.g. 17.8 ºC vs. 18 ºC) and different seasonal use designations. The toxics listings include the three legacy pesticides (listed above), metals (iron, manganese, and arsenic), and nitrate. While DEQ prepared a TMDL for iron, DDT, dieldrin and chlordane, DEQ did not develop TMDLs for manganese or arsenic, but has analyzed the data to explain likely sources; DEQ concluded that observed manganese and arsenic concentrations reflect natural background conditions.

WATER QUALITY PARAMETERS NOT ADDRESSED

The dissolved oxygen listing in the West Fork Little Pudding River, listed in the 2004/2006 Integrated Report (May 2006), is not addressed. The timing of this listing did not allow for incorporation of a dissolved oxygen TMDL in the current work scope, including assessing intergravel dissolved oxygen that would allow more complete interpretation of the dissolved oxygen criteria. Until TMDLs for dissolved oxygen are developed, riparian protection and restoration measures developed to address stream temperature concerns in the basin will benefit dissolved oxygen levels. Furthermore, water quality restoration efforts to address bacteria listings may also benefit other parameters such as dissolved oxygen.

WHO HELPED US

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

- Marion Soil and Water Conservation District
- U.S. Bureau of Land Management (BLM)
- U.S. Geological Survey, Oregon District (USGS)
- Oregon Water Resources Department (WRD)
- Oregon Department Forestry (ODF)

DEQ assembled a TMDL review committee that consisted of representatives from:

- Clackamas County
- Marion County
- Marion Soil and Water Conservation District
- Molalla River Watch
- Pudding River Watershed Council
- Canby Utilities
- NPDES permit holders
- Agricultural landowners and operators
- Watershed residents
- City of Woodburn
- City of Silverton
- City of Canby

Through the committee, DEQ informed interested parties in the subbasin as data analysis proceeded and as allocations were developed. The committee provided useful feedback throughout TMDL development.

SUBBASIN OVERVIEW

The Molalla-Pudding subbasin (Hydrologic Unit Code 17090009) is located in the north-eastern portion of the middle Willamette Basin. The Molalla River flows into the Willamette River between river miles 35 and 36. The Molalla River (including the Pudding River watershed) drains approximately 878 square miles (2,274 square kilometers; 561,920 acres) of which the Pudding River drains approximately 530 square miles (1,373 square kilometers; 339,200 acres)[4]. The Pudding River flows into the Molalla River at approximately 0.7 miles upstream of the Molalla River's confluence with the Willamette River. The topography, surficial geology, stream channel characteristics, and land use are distinct between the Molalla River and Pudding River portions of the subbasin.

The Molalla-Pudding subbasin is located within Clackamas and Marion Counties, and includes the cities of Woodburn, Mt. Angel, Silverton, Canby, Molalla, Hubbard, Gervais, Aurora, Brooks, Barlow, Colton and Scotts Mills and portions of Salem, Keizer, Donald, and Wilsonville. Most land in the Molalla-Pudding Subbasin is privately owned (Figure 1 - 6). The U.S. Bureau of Land Management (BLM) administers the largest portion of public land in the subbasin, including Oregon and California Railroad lands (O & C Lands). [5] The U.S. Forest Service manages comparatively little land in the far eastern and southeastern portions of the subbasin. The largest portion of state-managed land is Silver Falls State Park, located in the south central portion of the subbasin.

[4] State Water Resources Board, Stream Mile Survey Willamette Basin, 1967.

[5] Management of BLM O & C Lands established by O & C Lands Act of 1937, explained at the following location: http://www.blm.gov/or/plans/wopr/oclands.php

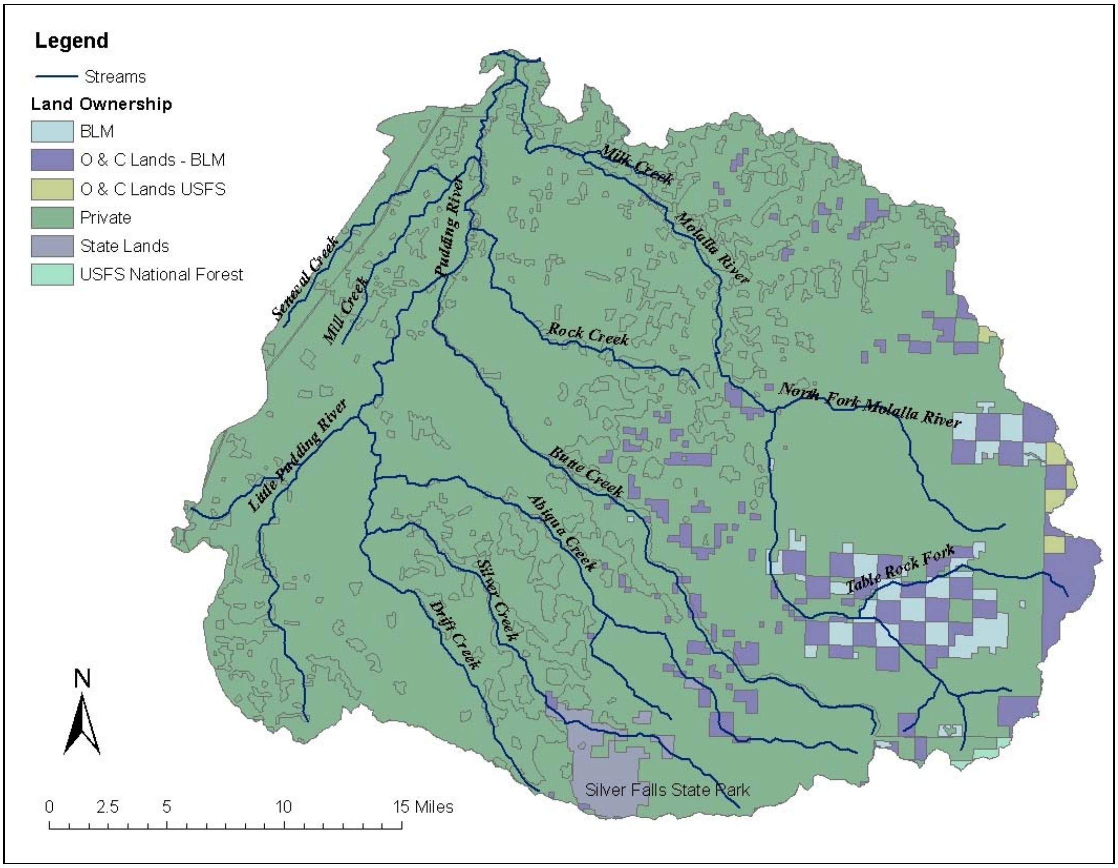

Figure 1 - 6: Land ownership in the Molalla-Pudding Subbasin.

Agriculture and forestry land uses predominate in the subbasin (Figure 1 - 7). Agricultural land use is most common in the lower elevation and western portions of the subbasin. Forestry land use occurs mainly in the eastern portion of the subbasin. Urban land use is concentrated around the cities of Woodburn, Silverton, Mt. Angel, Canby and Molalla. Urban land use associated with the larger cities of Salem and Keizer occurs in the southwestern corner of the subbasin.

In general, agricultural watersheds with the highest crop diversity are those located in the northern part of the basin. In the northern part of the basin row crops, berries, orchards, nurseries, and vineyards are common, whereas in the southern part of the basin grass seed and other seed crops predominate (Anderson, et al, 1997; Anderson, et al, 1996). The differences are primarily a result of difference in soil types (Anderson, et al, 1997).

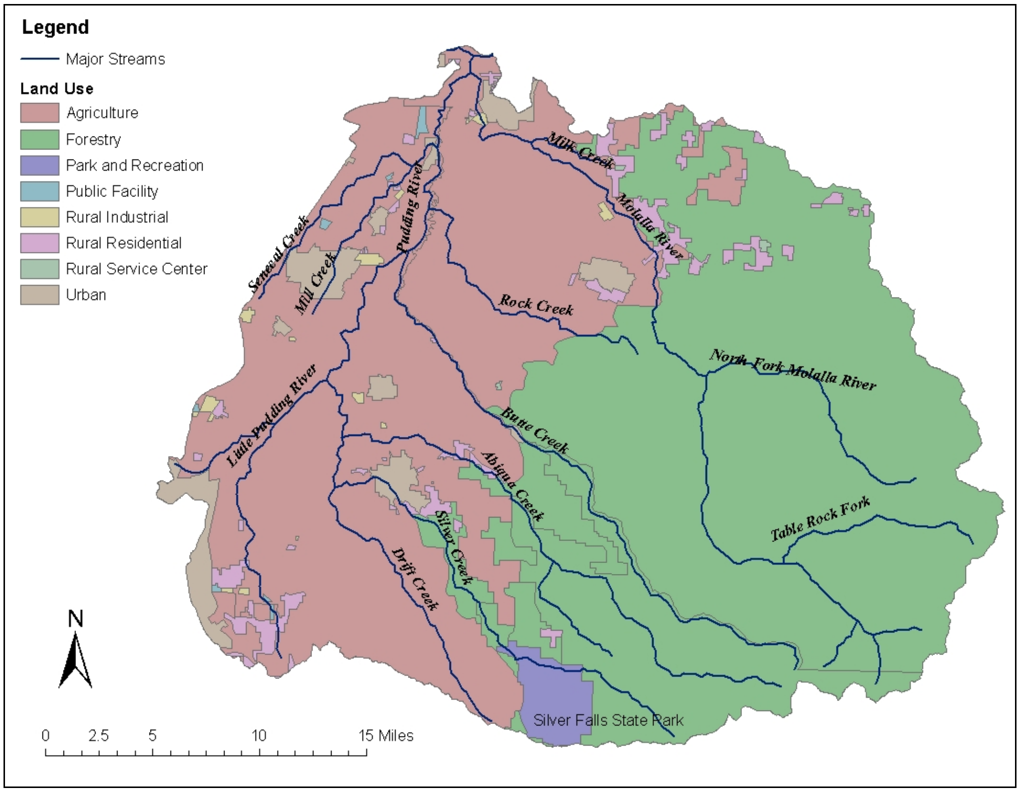

Figure 1 - 7: General land use in the Molalla-Pudding Subbasin.

CLIMATE

Precipitation ranges from approximately 40 inches (102 cm) per year in the lower elevations to approximately 80 inches (205 cm) per year in the Cascade foothills, in the eastern portion of the subbasin. Most precipitation (80%) falls between October and March. Mean annual precipitation is approximately 51 inches (130 cm), most of which falls as rain below 500 feet (152 m) in elevation. The portion of annual precipitation that falls as snow increases about 10% for each 1000 feet (305 m) in elevation (Woodward, 1998). Mean annual maximum air temperatures range from 60 ºF (15.5 ºC) at lower elevations to 47 ºF (8.3 ºC) at higher elevations, and annual average minimum temperatures ranging from 31 – 40 ºF (-0.5 - 4.4 ºC). Summer temperatures at low elevations tend to range from 60 to 90 ºF (15.5 – 32.2 ºC) and winter temperatures from 30 to 50 ºF (-1.1 – 10 ºC).

GEOLOGY AND GEOGRAPHY

The lower elevations of the Molalla-Pudding subbasin constitute a valley plain; intermediate between the valley plain and the Cascade foothills is a transitional slope. The transitional slope consists of coalesced alluvial fans in the south to ridges and rolling upland in the north. The Cascade foothills slope westward and have deeply incised canyons; the topography becomes more rugged toward the northern part of the subbasin (Hampton, 1972).

Surficial geology in the mainstem Pudding and lower Molalla River watersheds is comprised of alluvial deposits, both valley alluvium and Willamette Silt. Relatively young volcanics (late Pliocene to Pleistocene, roughly younger than 2 million years before present (mybp), fine- to coarse-grained Pliocene sedimentary rocks (roughly 2 – 5 mybp), and middle to late Miocene (roughly 15 mybp) volcanic flows and mudflows of the Sardine Formation are exposed in the northeastern portion of the subbasin, including the Milk Creek watershed. At elevations greater than approximately 350 feet above sea level (due east of the town of Molalla), the Molalla and

North Fork Molalla Rivers' erosion has exposed the Sardine Formation volcanics and volcanic mudflows, and the Little Butte Volcanics tuffs, basalts, andesites, and volcanic breccias. Columbia River Basalts are exposed along the mainstem Molalla River approximately a mile upstream from the confluence with Trout Creek. Oligocene (30 – 35 mybp) marine rocks underlie the Pudding River portion of the subbasin. Tributaries entering the Pudding River from the southeast (e.g. Abiqua, Butte, Silver Creeks) flow through these exposed marine rocks as well as Columbia River Basalts and volcanic flows and breccias of the Little Butte Volcanic Series.

The oldest rocks in the Molalla-Pudding subbasin belong to the Little Butte Volcanic Series, basalt and pyroclastic debris extruded in the Cascade foothills in Oligocene time (30 – 35 million years before present, mybp).   These igneous rocks interfinger with Oligocene to early Miocene marine rocks. Columbia River Basalts inundated the area in the middle Miocene (12 to 15 mybp). Tectonic activity and associated accelerated erosion led to deposition of sedimentary formations such as the Troutdale Formation. Volcanic activity continued through the middle Pliocene (~3.4 mybp) resulting in the Sardine Formation, and resumed in late Pliocene and early Pleistocene as the Boring Lava. Erosion and alluvial deposition associated with glacial activity occurred in the Pleistocene. In the late Pleistocene (after 0.66 mybp), coarse alluvial materials were covered with Willamette Silt. A northwest trending fault traverses a portion of the western subbasin near the town of Mt. Angel and was most recently active in 1993 (Thomas, *et al*., 1996).

The volcanic rocks and sedimentary rocks derived from volcanic materials in the Molalla-Pudding Subbasin contain relatively high percentages of iron (Fe) and the trace elements manganese (Mn) and arsenic (As) compared to non-volcanic rocks. Hinkle and Polette (1999) describe how silicic volcanic rocks are commonly associated with high concentrations of As (a component of volcanic glass) and that As may be adsorbed or coprecipitated with iron oxides and absorbed to clay mineral surfaces. The background concentrations of Fe, Mn, and As are discussed further in Chapter 6.

Hydrogeologic units occurring in the Molalla-Pudding subbasin include the Willamette Silt, Willamette Aquifer, Willamette Confining Unit, and the Columbia River Basalt Aquifer (Woodward, 1998). Three alluvial fans occur in the subbasin, the Molalla fan and the Canby fan, that are part of the Willamette Aquifer, as well as a portion of the Salem fan in the southwestern portion of the subbasin. The Salem fan is offset by the Mt. Angel fault, being thicker on the down-dropped, southern side of the fault. The Molalla fan is four to six miles wide and up to 120 feet thick; the Canby fan is smaller, only approximately two miles wide, and up to 100 feet thick. The Willamette Silt unit extends into the eastern portion of the Molalla-Pudding subbasin, underlying approximately the lower two-thirds of the Pudding River, but not extending as far east as the mainstem Molalla River. The Molalla and Canby fans are responsible for the flow pattern of the Molalla River, forced east by the Molalla fan and west by the Canby fan (Woodward, 1998).

HYDROLOGY

The currently and historically active gauges in the Molalla-Pudding subbasin and their dates of operation are listed in Table 1 - 2.

Table 1 - 2: Currently maintained and historic gauges in the Molalla-Pudding Subbasin.

USGS Gage Number	Gage Location	Begin Date	End Date
14200000	Molalla River near Canby, OR	8/1/1928	current
14198500	Molalla River above Pine Creek, near Wilhoit, OR	10/1/1935	9/30/1993
14199000	Molalla River near Molalla, OR (inactive 10/1/1905 – 9/30/1946)	10/1/1905	9/30/1951
14198400	Bull Creek near Wilhoit, OR	3/31/1993	current
14199704	Nate Creek tributary near Colton, OR	6/7/2002	current
14200300	Silver Creek at Silverton, OR (resumed by City of Silverton in approximately 2002)	10/1/1963	9/30/1979
14200400	Little Abiqua Creek near Scotts Mills, OR	7/1/1993	9/30/2004
14201500	Butte Creek at Monitor, OR (inactive 10/1/1936-9/30/1940 and 10/1/1952-10/1/1966)	1/1/1936	9/30/1985
14201300	Zollner Creek near Mt. Angel, OR	7/1/1993	current
14201000	Pudding River near Mt. Angel, OR	10/1/1939	3/31/1966
14201340	Pudding River near Woodburn, OR	10/1/1997	current
14202000	Pudding River at Aurora, OR	10/1/1928	current

The Molalla River and Abiqua Creek have higher ratios of baseflow to drainage area relative to other streams in the subbasin, indicating that they drain moderately permeable basalt flows and pyroclastic debris of the Sardine Formation (Hampton, 1972). The Pudding River, as well as Butte and Silver Creeks, drain less permeable basalt of the Columbia River Group, basalt and pyroclastic debris of the Little Butte Volcanic Series, and marine sandstone and siltstone. Baseflow is generally attributable to groundwater, which may influence both surface water temperature and metals concentrations (Fe, Mn, and As), and is discussed in that context in Chapters 2 and 6.

The Molalla River transmits about 80% of its annual discharge in the November through April wet season (Woodward, 1998). The upper Molalla River has an average annual flow of 197 cfs. Average January flow in the lower Molalla River is 2,392 cfs and average summer flow ranges from 100 to 200 cfs (Cole, *et al.*, 2004). Hampton, 1972, calculated the 10^{th} percentile of 7-day-averaged stream flow (7Q10 flow) in the Molalla River at Canby to be 44 cfs. With the benefit of a larger data set (1928 – 1993), DEQ calculated the 7Q10 flow at this location to be 28 cfs, probably reflecting increasing consumptive uses of surface water. Snowpack storage does not account for a significant contribution to Molalla River flow, but rather there is a strong correlation between precipitation and discharge (BLM, 1999).

The Pudding River transmits about 90% of its annual discharge in the November through April wet season (Woodward, 1998). Based on the historical flow record of a gauge near Mt. Angel, the upper Pudding River average flow in January is approximately 1,565 cfs and in August, approximately 31 cfs. Lower Pudding River stream discharge, historically measured at the town of Aurora, is approximately 46 cfs in August and 2,927 cfs in December (Runyon, *et al.*, 2006). DEQ calculated the 7Q10 flow for the Pudding River at Aurora as 24.8 cubic feet per second (cfs), based on all available stream discharge data (1928 – 1964, 1993 – 1997, 2002 – 2007). The current 7Q10 low flow rate for the Pudding River is probably less than that – DEQ's review of stream discharge measurements indicated that flow rates have decreased over time, possibly due to increased diversions for irrigation.

WATER USE

Figure 1 - 8 illustrates the quantity and location of water withdrawals in the Molalla-Pudding Subbasin. A large percentage of the water withdrawn from the natural flow in the Molalla-Pudding Subbasin is used for irrigation. Municipal use accounts for about 7% of water withdrawals and power development another 5%. Other uses each account for less than 3% of total water withdraw (Figure 1 - 9).

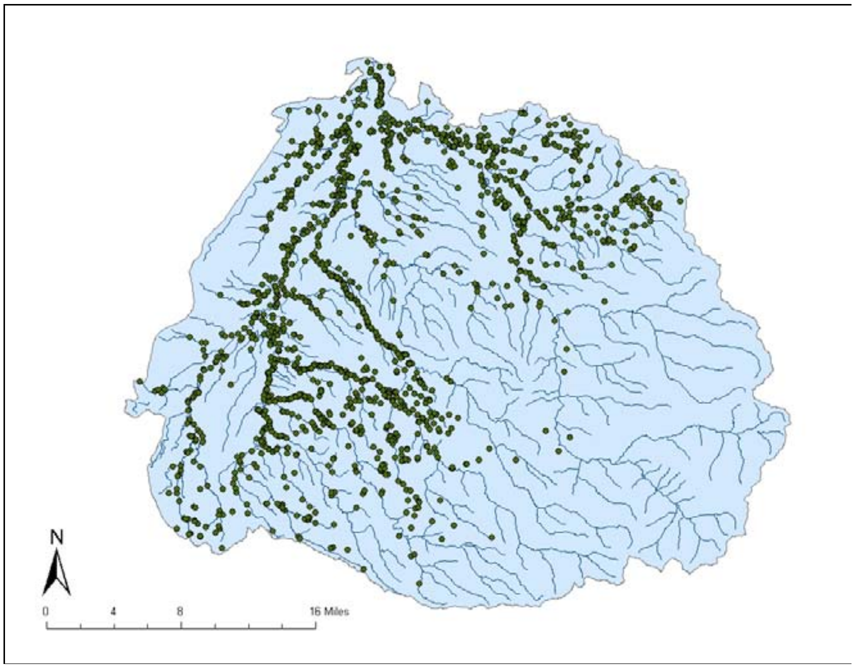

Figure 1

Figure 1 - 8: Surface water withdrawals in the Molalla-Pudding Subbasin.

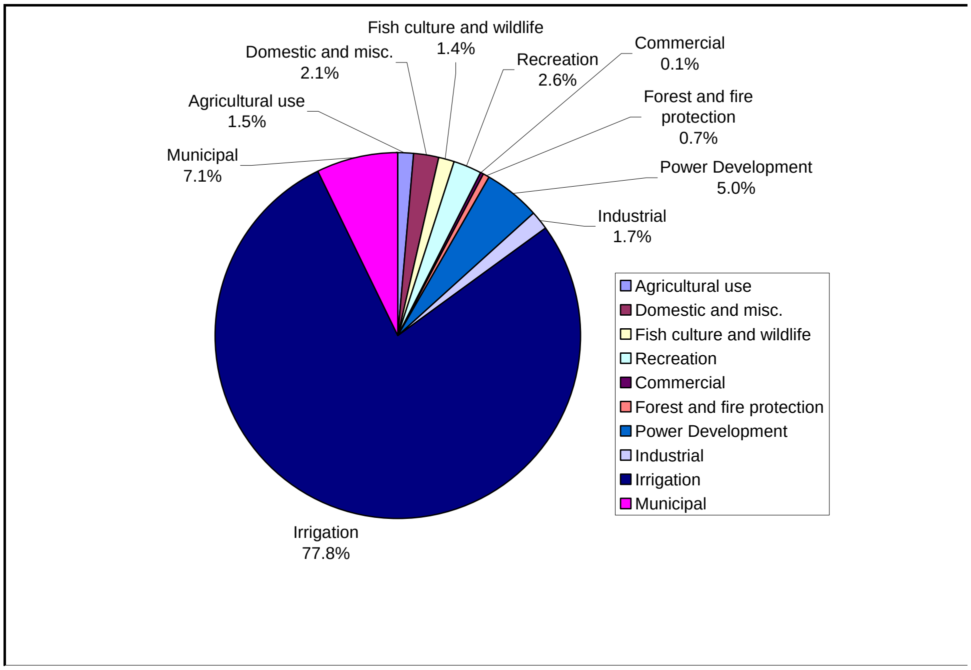

Figure 2

Figure 1 - 9: Percentage distribution of water withdrawals on June 1, not including withdrawals from reservoirs, in the Molalla-Pudding Subbasin.

Several streams do have instream flow requirements for supporting aquatic life, minimizing pollution, and providing anadromous and resident fish habitat (Table 1- 3). The instream rights tend to be among the most junior water rights.

Table 1 - 3:   Instream requirements in the Molalla-Pudding subbasin for supporting aquatic life, minimizing pollution, and providing anadromous and resident fish habitat.

Stream	Rate (cfs)	Begin Date	End Date
Abiqua Cr. at mouth	75	1-Jan	31-May
	60	1-Jun	15-Jun
	40	16-Jun	30-Jun
	25	1-Jul	15-Jul
	20	16-Jul	31-Jul
	15	1-Aug	30-Sep
	40	1-Oct	15-Oct
	60	16-Oct	31-Oct
	75	1-Nov	31-Dec
Silver Creek from Silverton to mouth	60	1-Jan	31-May
	50	1-Jun	15-Jun
	35	16-Jun	30-Jun
	23	1-Jul	15-Oct
	60	16-Oct	31-Dec
Milk Creek at mouth	85	1-Jan	31-May
	60	1-Jun	15-Jun
	45	16-Jun	30-Jun
	40	1-Jul	15-Jul
	30	16-Jul	31-Jul
	20	1-Aug	15-Oct
	40	16-Oct	31-Oct
	85	1-Nov	31-Dec
Molalla River from Milk Cr. to mouth	500	1-Jan	30-Jun
	200	1-Jul	31-Jul
	100	1-Aug	30-Aug
	150	1-Sep	30-Sep
	450	1-Oct	31-Oct
	500	1-Nov	31-Dec
Molalla River near Wilhoit gauge	35	1-Jan	31-Dec
Butte Cr. from Scotts Mills to mouth	75	1-Jan	15-Jun
	50	16-Jun	30-Jun
	25	1-Jul	15-Jul
	25	16-Jul	31-Jul
	12	1-Aug	30-Aug
	20	1-Sep	30-Sep
	75	1-Oct	15-Oct
	75	16-Oct	31-Dec
Pudding River at Aurora	80	1-Jan	31-May
	60	1-Jun	30-Jun
	50	1-Jul	15-Jul
	40	16-Jul	30-Sep
	60	1-Oct	31-Oct
	80	1-Nov	31-Dec
Pudding R. near Mt. Angel	10	1-Jan	15-Jan

There are three groundwater limited areas in the Pudding portion of the subbasin: a 16 square mile area around Mt. Angel, a 22 square mile area south and west of Molalla, and a 22 square mile area near the south border of the subbasin. An analysis of water levels presented in the watershed assessment indicates that water levels have decreased in wells between 1.5 and 5.2

feet per year in the basalt aquifer, and 0.6 to 2.2 feet in the sedimentary aquifer (3 out of 18 wells) over the years 1996 – 2002. Water levels have also dropped 3.3 to 8.2 feet per year in wells in the Mt. Angel area (early 1970s to 1992) and 1.7 feet average in wells in the Gladtidings area (mid 1970s through 1990) (Runyon, *et al*., 2006).

FISH USE

Historically (before human construction at Willamette Falls), only winter steelhead and spring Chinook, and possibly Pacific lamprey, were able to ascend Willamette Falls and spawn and rear in the Molalla River (BLM, 1999). Winter steelhead occupied many third and fourth order streams and the larger Molalla tributaries and currently rear and migrate in the lower Molalla River and lower Milk Creek, and spawn in the upper portions of those streams (Oregon Dept. Fish and wildlife 1:24K fish distribution maps[6]). Spring Chinook currently rear and migrate in the lower Molalla River and spawn in the upper Molalla River, North Fork and Table Rock Fork. The upper limit for fish migration in the Molalla River is Henry Creek Falls at river mile 43.5. (BLM, 1999). Summer steelhead, fall Chinook, and Coho were introduced to the watershed (Cole, 2004). Summer steelhead migrate in the lower Molalla River mainstem and spawn in the upper mainstem and North Fork Molalla River. Fall Chinook spawn in the lower Molalla River and rear and migrate in lower Milk Creek. Coho rear and migrate in the lower Molalla River downstream of Milk Creek and spawn in Milk Creek.

Historical and current fish use in the Pudding River watershed is less documented because of the large percentage of private land (Runyon, *et al.*, 2006). Currently the lower Pudding River mainstem, as well as lower Butte, Rock, Silver and Abiqua Creeks support rearing and migrating winter steelhead. This species spawns in upper Butte, Abiqua, and Silver Creeks. Spring Chinook rear and migrate in the Pudding River downstream of Abiqua Creek and spawn in upper Abiqua and Butte Creeks. Coho rear and migrate in the Pudding River as far upstream as Drift Creek and spawn in the upper Pudding River and Drift, Silver, Abiqua, and Butte Creeks. Fall Chinook seem to rear in the Pudding River only near the confluence with the Molalla River (Oregon Dept. Fish and wildlife 1:24K fish distribution maps).

WATERSHED DESCRIPTIONS

The fifth field hydrologic units that comprise the Molalla-Pudding Subbasin are illustrated in Figure 1 - 10. This section describes the larger tributary watersheds for which assessments have been done and characteristics of the mainstem Molalla and Pudding Rivers. Individual descriptions of smaller tributaries are not available but landscape and vegetation characteristics would be similar to the nearest large tributary or mainstem stream. There are six distinct ecoregions in the Molalla-Pudding Subbasin (Figure 1 - 11) that combine with landscape and channel characteristics to define each of the watersheds. Watersheds described in this section include:

Molalla River tributaries

- Milk Creek (102 square miles)[7]
- North Fork Molalla (69 square miles)[8]
- Table Rock Fork (36 square miles)[7]

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[6] http://nrimp.dfw.state.or.us/nrimp/default.aspx?pn=fishdistmaps

[7] Area estimate from State Water Resources Board, Stream Mile Survey Willamette Basin, 1967.

[8] Area calculated in ArcGIS 9.2 from 6th field hydrologic unit code layer derived from U.S. Bureau of Land Management in Portland, Oregon; Hydrologic unit boundaries digitized from 1:24,000 scale maps.

Pudding River tributaries

- Mill Creek (53 square miles)[7]
- Rock Creek (86 square miles)[7]
- Butte Creek (70 square miles)[6]
- Little Pudding River (63 square miles)[6]
- Abiqua Creek (78 square miles)[6]
- Silver Creek (54 square miles)[6]
- Drift Creek (25 square miles)[7]

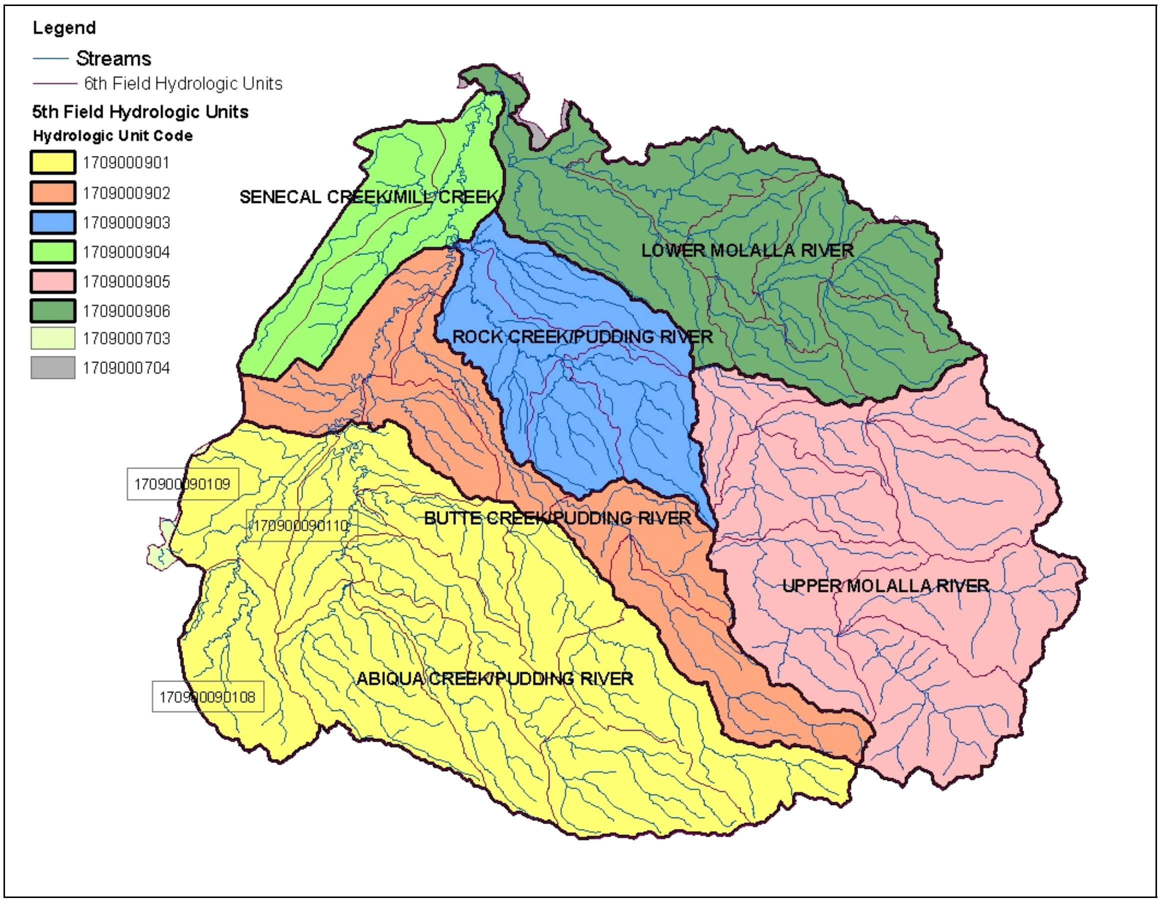

Figure 1 - 10: Fifth field hydrologic units in the Molalla-Pudding Subbasin.
Delineations derived from U.S. Bureau of Land Management in Portland, Oregon; Hydrologic unit boundaries digitized from 1:24,000 scale maps.

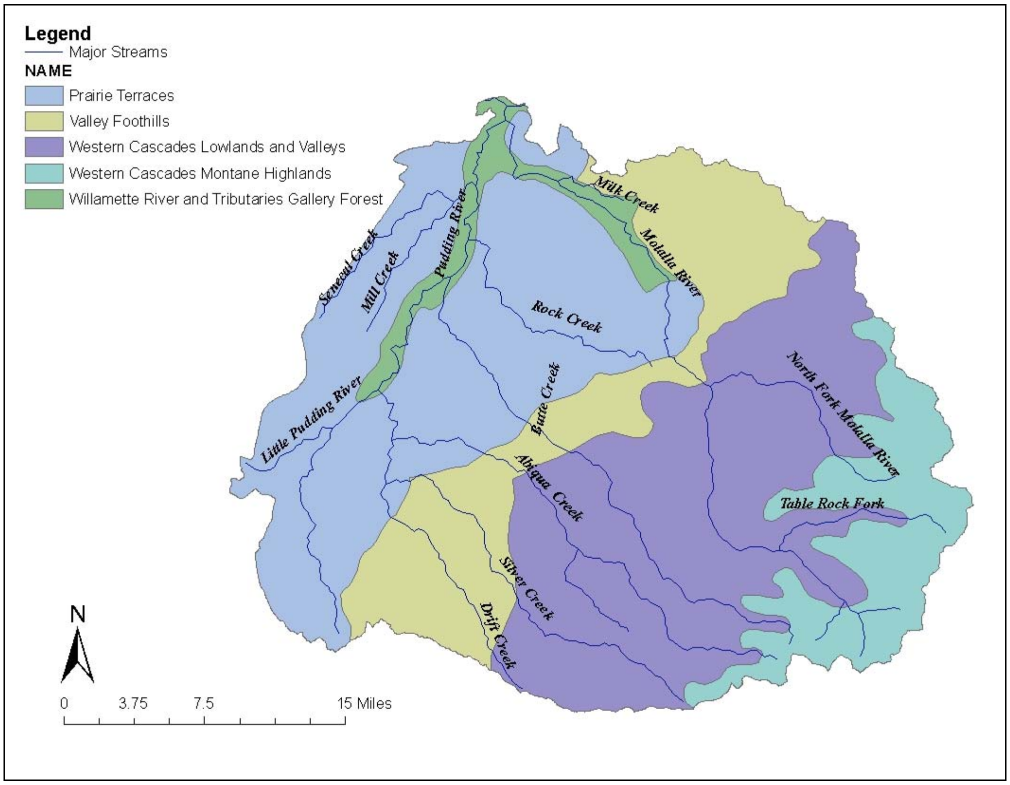

Figure 1 - 11: Ecoregions within the Molalla-Pudding Subbasin.
Data source is Oregon Natural Heritage Program; boundaries digitized from 1:250,000 scale maps.

Molalla Watersheds

The lower Molalla River watershed is generally described as that portion downstream of the confluence with North Fork Molalla River, approximately river mile 25[9]. The elevation at the Molalla River's confluence with the Willamette River is 56 ft. above sea level and the highest elevation in the lower Molalla watershed is 1,930 ft. Milk Creek is the largest tributary to the lower Molalla River and enters the Molalla River at approximately river mile 8. Over 80% of the land use in the lower Molalla is agricultural and approximately 12% is rural residential. The remainder is urban (City of Canby) and forestry, forestry land use occurring predominantly in the Cedar Creek drainage. Approximately 55 square miles (142 square km) drain directly to the lower Molalla River, not including the Milk Creek drainage. The lower Molalla River stream channel ranges from a small to large floodplain channel. The ecoregion along lower Molalla River riparian areas and floodplain is Willamette River and Tributaries Gallery Forest. Though there is a high proportion of invasive species, native vegetation includes black cottonwood, Oregon ash, Western Hawthorne, big leaf maple, willow, dogwood, hazelnut, and snowberry. Outside of riparian and flood plain areas, the lower Molalla River ecoregion is Prairie Terraces with a small percentage of the Valley Foothills and Western Cascade Lowland and Valleys ecoregion just downstream of the North Fork Molalla River confluence. The Molalla River is a source of drinking water for the cities of Molalla and Canby. Jackson Creek (a tributary to Milk Creek) is a source of drinking water for Colton.

The upper portion of the Molalla River watershed, generally defined by the Salem District of the U.S. Bureau of Land Management (BLM,1999) as upstream of Cedar Creek (which is two miles

[9] The description and characteristics of the Molalla River watershed are taken from Cole, M., Blaha, R., and Killian, M. 2004, Lower Molalla River and Milk Creek Watershed Assessment, ABR, Inc. – Environmental Research & Services, Forest Grove, OR.

downstream of the North Fork Molalla confluence) comprises 202 square miles (523 square km). At Cedar Creek, the elevation of the Molalla River is 460 feet above sea level; the highest point in the watershed is 4,800 feet above sea level (BLM, 1999). The BLM manages approximately 67 square miles (173 square km) in the upper Molalla watershed; The U.S. Forest service manages an additional 3.9 square miles (10 square km). Less than 3% of the upper watershed is state forest and approximately 58% is private (BLM, 1999). Major tributaries to the upper Molalla River are the North Fork Molalla (57 square miles; 147 square km) and Table Rock Fork (35 square miles; 91 square km). The river mainstem has a moderate grade and varies in width, though narrow, bouldery gorges and wider, riffled areas. The upper 28 miles averages a gradient of 1.2% which decreases downstream to an average of 0.25% (BLM, 1999).

Dickey Prairie area, which marks the lower end of the upper Molalla, supports a limited woodland of white oak, Douglas fir, big leaf maple, Oregon ash and red alder (BLM, 1999). Up to an elevation of 3000 feet above sea level dominant trees are western hemlock, Douglas fir and western red cedar. At higher elevations, noble fir, silver fir, Douglas-fir and western hemlock dominate. Current vegetation patterns reflect the logging history of the watershed. Logging occurred in the North Fork Molalla and Molalla watershed on private lands since 1930. Public land logging occurred more in patches of clear cuts. With the exception of the Table Rock Wilderness area, most of the watershed has been logged and tree stands are young (BLM, 1999). While 52% of the vegetation in the upper Molalla watershed is more than 80 years old, less than 10% of riparian vegetation in Gawley and Pine Creeks is at least 80 years old. In the lower elevation subwatersheds, less than 3% of vegetation is more than 80 years old. About 4% of the upper watershed is old growth, generally above 3,500 ft (BLM, 1999).

Road density, steep gradients, unstable soils and high precipitation lead to erosion and runoff that impair water quality and affect streamflow, primarily, though not exclusively, downstream of Table Rock Fork (BLM, 1999). Lower elevation subwatersheds are in poor to fair condition from a high level of recreational use, lack of stream shading, road density, and harvesting (BLM, 1999).

Currently, BLM and the U. S. Forest Service maintain approximately 30 square miles (78 square km) of the federal lands in the upper Molalla River watershed as riparian reserves. Riparian reserves are buffers along standing and flowing water, intermittent stream channels, ephemeral ponds, and wetlands. Riparian reserve width is generally one or two site potential tree heights, which range from 180 – 200 ft. In the riparian reserves, about half the tree stands are older than 80 years and approximately a third are younger than 40 years (BLM, 1999). BLM maintains 46 square miles (119 square km) in the upper watershed as late-successional reserves, managed for habitat development and preservation. A remaining 26 square miles (67 square km) are Matrix lands, managed for harvest (BLM, 1999).

Milk Creek Watershed

Milk Creek joins the Molalla River at approximately river mile 8. The largest tributaries to Milk Creek are Canyon and Woodcock Creeks. Stream flow measured by the Oregon Water Resources Department on August 21, 2001, at the mouth of Milk Creek was 16.8 cfs. Elevation in the Milk Creek watershed ranges from approximately 120 to over 4,200 feet. Land use in the lower portion of this watershed is predominantly rural residential and agricultural, whereas rural residential and forestry predominate in the upper Milk, Canyon and Woodcock Creek watersheds. With a few exceptions for BLM holdings (5.6 square miles/14.5 square km) most area in this watershed is privately owned.

Cole, et al. (2004) describe several hydrologic and ecological characteristics of the Milk Creek watershed. Streams in the lower and middle watershed have low to moderate gradients and comprise floodplain type channels as well as confined type channels. Upper watershed streams, as well as Canyon and Woodcock Creeks, have moderate gradients and are often confined in steep-sided canyons. A smaller percentage of upper watershed streams are floodplain type channels. Floodplain type channels are more sensitive to disturbance and, hence, more responsive to restoration (WPN, 1999). Most of the Milk Creek watershed is in the Valley Foothills ecoregion with the upper watershed in the Western Cascade Lowlands and Valleys ecoregion. Natural upland vegetation in the Valley Foothills ecoregion consists of Douglas fir, Oregon white oak, and western red cedar, though current vegetation also includes pastureland, vineyards and orchards. Western hemlock, red alder, vine maple comprise the Western Cascade Lowlands ecoregion, as well as Douglas fir and western red cedar (Cole, *et al*., 2004).

North Fork Molalla Watershed

BLM manages approximately 10 square miles (27 square km) of the North Fork Molalla watershed. BLM characterizes (BLM, 1999) most of the subwatersheds in the North Fork Molalla watershed as poor to fair condition and reports road effects on stream flow. Emerald, Cougar and Goat Creek watersheds are characterized as in the poorest condition. The North Fork Molalla, itself, is if fair condition but extensive vegetation openings and lack of shading exist. In the federal riparian reserves, more than half of the tress are between 80 and 199 years old, and 8% are old growth. Percentages of mature and old growth trees are less is state forest riparian reserves. DEQ measured flow in the North Fork on July 22, 2005, as approximately 45 cubic feet per second (cfs).

Table Rock Fork Watershed

The Table Rock Fork watershed comprises 35 square miles (91 square km), nine square miles (23 square km) of which are in a wilderness area (BLM, 1994). Land use is predominantly forestry and approximately 60% of the land in this watershed is managed by BLM. Even though most BLM land is managed as late successional reserve or wilderness area, there are high storm stream turbidities and mass movements from unstable soils and slopes greater than 60% (BLM, 1994). The average annual flow in the Table Rock Fork is 201 cfs. More than half of the watershed's trees are more than 80 years old (BLM, 1999).

Pudding River Watersheds

Elevation in the Pudding River watershed ranges from 66 ft. above sea level at the confluence with the Molalla River to 4,280 ft. in the Butte Creek watershed[10]. The Pudding River is mainly a moderately confined to confined, low gradient channel. The lower Pudding River watershed (approximately defined as that portion downstream of the confluence with the Little Pudding River) consists of 21.2 acres of wetlands per square mile, and the upper portion, 9.6 acres per square mile. Riparian vegetation along the mainstem Pudding River is about 65% hardwood, 15% each field/grass and brush, and less than 5% coniferous.

Pudding River substrate, as well as that of its western tributaries, is typically composed of silt and sand. Tributaries in the southeastern portion of the watershed differ from the Pudding River mainstem. The tributaries, such as Silver, Rock, Abiqua and Butte Creeks originate as higher gradient streams flowing along weakened areas in basalt bedrock. The tributaries transition to the flatter valley of the mainstem Pudding River through constricted bedrock canyons and waterfalls. These constrictions and associated higher velocities allow these tributaries to transport relatively large amounts of gravel. Both Abiqua Creek and Silver Creek supply drinking water for the City of Silverton.

[10] The description and characteristics of the Pudding River watershed are taken from Runyon, *et al.*, 2006, Pudding River Watershed Assessment.

More than 90% of lands in the Pudding River watershed are privately owned, with dominant land uses being agriculture and forestry. State forests are located in the Abiqua and Butte watersheds and the 170 acre Molalla State Park is located along the lower Pudding River. BLM manages only 2% of the land, primarily in the Abiqua, Rock, and Butte Creek watersheds.

The characteristics of the Pudding River watersheds described in this section have been derived from two primary sources: The Pudding River Watershed Assessment (Runyon, *et al.*, 2006) and the Willamette River Basin Water Quality Study, Phase II, Non-Point Source Pollution in the Pudding River Sub-basin of the Willamette River (E&S Environmental Chemistry and Tetra Tech, 1995). River miles were approximated with DEQ's internal web-based Interactive Mapping Application.

Mill Creek Watershed

Mill Creek begins within the City of Woodburn and enters the Pudding River at the City of Aurora. Land use in the Mill Creek watershed is mostly agricultural with some urban and rural residential (around the cities of Woodburn, Hubbard, and Aurora). Two wastewater treatment plants discharge to Mill Creek, from the cities of Hubbard and Aurora. Senecal Creek is a tributary to Mill Creek, and flows adjacent to two DEQ environmental clean-up sites: the currently operating North Marion County disposal facility as well as the Marion County landfill, which closed in 1973[11]. According to the 2005 Pudding River Watershed Assessment (Runyon, *et al.*, 2006), the Mill Creek channel is low gradient with a confined to moderately confined flood plain and none of the riparian vegetation is dominated by conifers. About 60% of riparian vegetation is hardwood and 15% to 20% of the riparian vegetation is in field or grass and bushes. Small streams in this watershed have treeless riparian areas for about 2/3 of their length. Approximately 12 acres per square mile of the Mill Creek watershed is occupied by wetlands (Runyon, *et al.*, 2006). The August 1, 2007, flow DEQ measured in Mill Creek in 2007 was 2.7 cfs.

Rock Creek Watershed

Rock Creek enters the Pudding River at approximately river mile 14. The land use in this watershed is 16% forest, 82% agriculture (mostly row crops and Christmas trees/orchard/nursery) and 2% urban (E&S Environmental Chemistry and Tetra Tech, 1995). The BLM manages approximately 1,400 acres (2.3 square miles; 6 square km) in the Rock Creek watershed. The Pudding River Watershed Assessment identifies six dams in the watershed as potential barriers to fish migration. Channel type is usually low gradient with a confined to moderately confined flood plain, but may also be a moderate gradient channel with a confined flood plain (Runyon, *et al.*, 2006). About 65% of riparian vegetation is hardwoods, 20% is in fields and grass, and slightly more than 10% consists of low brush (Runyon, *et al.*, 2006). DEQ measured the August 1, 2007, flow as less than one (<1) cfs.

Butte Creek Watershed

Butte Creek watershed enters the Pudding River at river mile 18. Land use in the Butte Creek watershed is 69% forest and 31% agriculture, mostly in orchard/Christmas tress/nursery and row crops (Tetra Tech, 1992). BLM manages about 3,800 acres (5.9 square miles; 15 square km) in the watershed. The Scotts Mills Falls dam is located in the town of Scotts Mills, constructed on top of the existing waterfall. The City of Scotts Mills has water rights for 1 cfs for municipal use[12] from Butte Creek, but this appears not to supply drinking water to the City, now provided by groundwater (Oregon Dept. of Human Services, Health Division, Drinking Water Program)[13]. Several miles of Butte Creek are steep with a narrow and confined valley and moderately steep with a confined floodplain. Remaining miles are low gradient with moderately to confined flood

[11] http://deq12.deq.state.or.us/fp20/StartPage.aspx

[12] According to the Oregon Water Resources Department (http://apps2.wrd.state.or.us/apps/wr/wrinfo/Default.aspx) the permit #S23023 allows 1 cfs, but the associated certificate 24146 limits use to 0.25 cfs.

[13] http://www.oregon.gov/DHS/ph/dwp/

plain. Calculations from gauge data collected on Butte Creek over several years indicate an average August flow of 13.5 cfs and 473 cfs in January. Riparian vegetation consists of 70% hardwood, less than 10% conifer, 15% field and grass, and 10% brush. Approximately seven acres per square mile of the watershed is wetland (Runyon, *et al.*, 2006).

Little Pudding River Watershed

The Little Pudding River enters the Pudding River at approximately river mile 34. Land use in this watershed is 88% agriculture, mostly in row crops, and 11% urban (E&S Environmental Chemistry and Tetra Tech, 1995). Lake Labish, a low area prone to winter flooding, comprises approximately five square miles of the fertile agricultural land of the Little Pudding watershed. Lake Labish is the remnant of a Pleistocene bog and an ancient channel of the Willamette River (Runyon, *et al.*, 2006). Approximately 5.3 acres per square mile of the watershed remains as wetland. The Little Pudding watershed encompasses a portion of the City of Salem and accepts approximately 15% of that city's stormwater[14]. The Little Pudding River channel types are predominantly low gradient with moderately confined to confined flood plains. Riparian vegetation along the Little Pudding River consists of 65% hardwood and 25% fields and grass, with the remainder low brush (Runyon, *et al.*, 2006). Flow management in the Little Pudding watershed makes direct streamflow measurement difficult. Marion County has modeled Little Pudding River watershed hydraulics and collected water level data on either side of the water control structure at Howell Prairie Road (managed by the Lake Labish Water District) (Bob Pancratz, Marion County Public Works, personal communication, July 2007).

Abiqua Creek Watershed

Abiqua Creek enters the Pudding River at approximately river mile 43. Land use is 67% forest and 32% agriculture, mostly hay/grain, grass/pasture and row crops. Only 1% of the land is in urban use. (E&S Environmental Chemistry and Tetra Tech, 1995). BLM manages approximately 1,800 acres (2.8 square miles; 7.2 square km) in the Abiqua Creek watershed. This watershed supplies drinking water for the City of Silverton. Silverton maintains a water supply dam upstream of Powers Creek and has rights to withdraw 10 cfs from Abiqua Creek. The Pudding River Watershed Assessment identifies five additional dams that may be barriers to fish migration. Several miles of stream channel are very steep to moderately steep with a narrow and confined valley. Several more miles of stream channel are low to moderate gradients with a flood plain confined by hills or terraces (Runyon, *et al*., 2006).

Little Abiqua Creek, a tributary to Abiqua Creek free of dams and diversions, was gauged for approximately ten years. Average February flow in Little Abiqua Creek was 76 cfs and average September flow was approximately 36 cfs. Approximately 65% of riparian vegetation along Abiqua Creek is hardwood, 20% conifer, and 10% each fields and grass and brush. Approximately 13.5 acres per square mile of watershed is wetland (Runyon, et al., 2006).

Silver Creek Watershed

Silver Creek joins the Pudding River at approximately river mile 46. Land use within the watershed is primarily forestry upstream of the City of Silverton, and agriculture downstream of Silverton. Forestry land use accounts for approximately 79% of the land area and agriculture, primarily hay/grain/grass/pasture and row crops, approximately 19% (E&S Environmental Chemistry and TetraTech, 1995). Urban land use accounts for less than 5% of the watershed (Runyon, *et al*., 2006). Two large parks are located in the watershed: the Oregon Garden, in Silverton, and Silver Falls State Park, which covers 8,585 acres in the upper watershed.

The City of Silverton constructed a reservoir on Silver Creek in the late 1960s and currently has rights to withdraw 5 cfs from Silver Creek for water supply. Treated wastewater from the City of

[14] This estimate is based on the percentage of the City of Salem area that is within the Little Pudding River watershed (Stephen Downs, P.E., City of Salem Public Works Dept, personal communication, November 2008).

Silverton Wastewater Treatment Plant discharges to Silver Creek. The City of Silverton diverts some of its treated wastewater to the wetlands of the Oregon Garden for final treatment. The wastewater travels through 25 wetland cells before being discharged into Brush Creek, a tributary that joins Silver Creek at approximately river mile 0.8, at a rate of approximately 300 gallons per minute in the summer. Most summer flow in Brush Creek comes from overflow from the Oregon Garden (Runyon, *et al.*, 2006).

The Silver Creek channel is mainly characterized by either low gradient with a confined flood plain or steep with a narrow and confined valley. January average discharge is approximately 575 cfs and August average flow approximately 20 cfs. Approximately 47% of the riparian area is dominated by conifers (Runyon, *et al.*, 2006), and hardwoods comprise about 45%. The remainder of riparian vegetation is brush or field/grass. Approximately 11.5 acres per square mile of the Silver Creek watershed are comprised of wetlands. (Runyon, *et al.*, 2006).

Drift Creek Watershed

Drift Creek enters the Pudding River relatively high in the Pudding River watershed, at approximately river mile 48. Drift Creek's channel type is low gradient with a confined to moderately confined flood plain (Runyon, *et al.*, 2006). Land use in the Drift Creek watershed is 33% forest and 66% agriculture, mostly in hay, grain, grass/pasture and row crop cultivation (E&S Environmental Chemistry and Tetra Tech, 1995). Riparian vegetation consists of about 60% hardwood, and between 10 and 15% in conifer, field/grass, and brush. Within the Drift Creek watershed, approximately seven acres per square mile are occupied by wetlands (Runyon, *et al.*, 2006).

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