Chapter 4
Pesticides TMDL

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INTRODUCTION

The pesticides total maximum daily loads (TMDLs) for the Molalla-Pudding Subbasin have been developed within hydrologic units 1709000902 (Butte Creek/Pudding River), 1709000903 (Rock Creek/Pudding River), 1709000904 (Senecal/Mill Creek) and 6th field hydrologic units associated with the Little Pudding River watershed and tributaries on the west side of the upper Pudding River. The TMDLs address segments of the following streams identified as water quality limited on the 303(d) list: Pudding River and Zollner Creek, as well as previously unlisted impairments on the Pudding River and Little Pudding River. Required TMDL components from OAR 340-042-0040 are listed in Table 4 - 1.

Table 4 - 1: Components of the DDT and Dieldrin TMDLs.

Name and Location of Waterbodies 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 1709000902, 1709000903, 1709000904 and the 6th field HUCs 170900090108, 170900090109 and 170900090110.
Pollutant Identification OAR 340-042-0040(4)(b)	*Pollutants:* dichlorodiphenyltrichloroethane (DDT), dieldrin, and chlordane.
Water Quality Standards and Beneficial Use Identification **OAR 340-042-0040(4)(c)** **OAR 340-041-0033(1)** **OAR 340-041-0033(2)**	(1) Narrative Criteria: Toxic substances may not be introduced above natural background levels in the waters of the State in amounts, concentrations, or combinations that may be harmful, may chemically change to harmful forms in the environment, or may accumulate in sediments or bioaccumulate in aquatic life or wildlife to levels that adversely affect public health, safety or welfare, aquatic life, wildlife or other designated beneficial uses. (2) Numeric Criteria: Levels of toxic substances may not exceed the criteria listed in Table 20 which were based on criteria established by EPA and published in Quality Criteria for Water (1986), unless otherwise noted. Human Health Criteria are 0.000024, 0.000071, and 0.00046 micrograms per liter for DDT, dieldrin, and chlordane, respectively. Aquatic Life Chronic Criteria are 0.001, 0.0019, 0.0043 micrograms per liter for DDT, dieldrin, and chlordane, respectively. The Oregon Environmental Quality Commission approved new toxics criteria in May 2004, including revisions of the DDT, dieldrin, and chlordane criteria in Table 33A , but these values are not yet approved by EPA. For this TMDL, DEQ uses the more conservative of the criteria in Table 20 and Table 33A. Beneficial Uses: Fish and aquatic life: Salmon and trout rearing and migration (aquatic life criteria). Water and fish consumption (human health criteria)
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: The loading capacity was determined through the development of load duration curves that determine the load that will achieve the human health criteria for DDT, dieldrin, and chlordane. Excess Load: The difference between the actual pollutant load and the loading capacity of a waterbody. Excess load was calculated for five flow intervals across all flow conditions. Sources: DDT, dieldrin, and chlordane were used for urban and agricultural insect control until 1972, 1970, and 1988, respectively. All three chemicals persist in the environment because they degrade slowly and are fat soluble, so may bioaccumulate in aquatic organisms. The source of these banned pesticides to streams is primarily sediment transported by erosion and runoff from agricultural land use. Urban stormwater has not been discounted as a source, but the greater percentage of land use in the Molalla Pudding Subbasin is agricultural.

Table 4 – 1 Continued

Wasteload Allocations OAR 340-042-0040(4)(g) **Load Alloacations OAR 340-042-0040(4)(h)** **Surrogate Measures OAR 340-042-0040(5)(b)** ***40 CFR 130.2(i)***	Waste Load Allocations (Point Sources): DEQ allots wasteload allocations for DDT and dieldrin to point sources that cover their current conditions of discharge. The point sources to which wasteload allocations are given are wastewater treatment plants that discharge into the DDT-listed reach of the Pudding River. Load Allocations (Non-Point Sources): Load allocations for DDT and dieldrin are expressed as a percent reduction, partially attained through a TSS target of 15 mg/l in Pudding River and Zollner Creek and 7 mg/L in Little Pudding River. Additional reductions in DDT and dieldrin inputs to surface water will be necessary to achieve load allocations. The chlordane load allocation is expressed as a percent reduction in fish tissue concentrations. Surrogate Measures Total Suspended Solids (TSS) concentrations are used as one surrogate measure of DDT based on the relationship between the two parameters, the relative ease of measuring TSS and the relevance of TSS to applicable measures of performance (e.g. erosion control). The TSS/dieldrin relationship is not as strong as that between TSS and DDT, but based on fewer detections and lower concentrations of dieldrin, as well as an apparent decreasing trend in dieldrin concentrations, DEQ believes that achieving DDT criteria through TSS reduction and other means will also result in the attainment of dieldrin criteria. A percent reduction is also used as a surrogate measure because the allowable DDT and dieldrin load allocations would be less than current analytical methods could detect. A percent reduction in fish tissue concentrations is the surrogate measure for the chlordane load allocation.
Seasonal Variation OAR 340-042-0040(4)(j) ***CWA §303(d)(1)***	Violations of water quality standards occur throughout the year and under both low flow and high flow conditions.
Margins of Safety OAR 340-042-0040(4)(i) ***CWA §303(d)(1)***	*Margins of Safety:* No numeric margin of safety is developed in this TMDL, although conservative assumptions and procedures result in an implicit margin of safety. Modeling and reductions are based on achieving the stringent human health criteria rather than the chronic aquatic life criteria. Also, assigning reductions to the Little Pudding River and Zollner Creek (for DDT) addresses pollutant loads in streams not yet listed for pesticide exceedances.
Reserve Capacity OAR 340-042-0040(4)(k)	DEQ allocates 10% of the loading capacity for DDT, dieldrin, and chlordane to reserve capacity.
Water Quality Management Plan OAR 340-042-0040(4)(l)	The Water Quality Management Plan (WQMP) provides the framework of management strategies to attain and maintain water quality standards. Detailed plans and analyses included in specific DMA implementation plans will supplement the WQMP.

NAME AND LOCATION OF WATERBODIES

Two streams in the Molalla-Pudding Subbasin, Pudding River and Zollner Creek, a tributary to the Pudding River, are included on the 303(d) list of water quality impaired waterbodies due to high levels of pesticides. The Pudding River from mouth to river mile 35.4 is listed due to high levels of DDT. Zollner Creek from mouth to RM 7.8 is listed due to high levels of chlordane and dieldrin. Both streams are water quality limited for these pollutants year-round.

While not currently included on the 303(d) list, recent monitoring by ODEQ shows that Zollner Creek and the Little Pudding River, which is also a tributary to the Pudding River, contain levels of DDT and its metabolites which exceed State of Oregon water quality criteria. Little Pudding River enters the Pudding River at RM 37.5 and Zollner Creek enters at RM 29.6. Loads from these streams appear to be the primary cause of DDT criteria exceedances in the Pudding River. While also not currently included on the 303(d) list, monitoring by USGS shows that Pudding River may contain levels of dieldrin which exceed State of Oregon water quality criteria.

Table 4 - 2 and Table 4 - 3 show 303(d) listed reaches addressed by this TMDL.

Table 4 - 2: Molalla-Pudding Subbasin waterbodies 303(d) listed for pesticides and additional documented impairments.

Waterbody LLID and River Miles	Parameter	Season	Criteria	Beneficial Uses	Assessment Year Action
Pudding River 0 to 35.4	DDT	Year Around	Table 20 Toxic Substances	Anadromous fish passage Drinking water Resident fish and aquatic life	1998 Added to database
Zollner Creek 0 to 7.8	Chlordane	Year Around	Table 20 Toxic Substances	Drinking water Fishing	2002 Added to database
Zollner Creek 0 to 7.8	Dieldrin	Year Around	Table 20 Toxic Substances	Anadromous fish passage Drinking water Resident fish and aquatic life	2002 Status modification - Added to 303(d) list
Pudding River 0 to 35.4	Dieldrin	Year Around	Table 20 Toxic Substances	Anadromous fish passage Drinking water Resident fish and aquatic life	Not previously listed
Zollner Creek 0 to 7.8	DDT	Year Around	Table 20 Toxic Substances	Anadromous fish passage Drinking water Resident fish and aquatic life	Not previously listed
Little Pudding River 0 – 18.3	DDT	Year Around	Table 20 Toxic Substances	Anadromous fish passage Drinking water Resident fish and aquatic life	Not previously listed

Table 4 - 3: Data used as basis for 303(d) listings and additional documented impairments.

Waterbody LLID and River Miles	Parameter	Data Source and Supporting Data
Pudding River 0 to 35.4	DDT	Previous Data: USGS Data: (Site 14202000, at Aurora): 2 of 4 values, at or above detection, with an average of 0.0015 µg/L exceeded DDT standard (0.001 µg/L – fresh water chronic criteria, .024 ng/l water and fish ingestion criterion) between 5/25 – 11/9/94 (USGS, 1995).
Zollner Creek 0 to 7.8	Chlordane	Previous Data: USGS 14201300: 5/5 samples > criterion of 0.46 ng/L.
Zollner Creek 0 to 7.8	Dieldrin	Previous Data: USGS 14201300: 3/5 > criterion of 0.071 ng/L.
Pudding River 0 to 35.4	Dieldrin	USGS Data: (Site 14202000, at Aurora): 2 of 5 values, unfiltered water samples, at or above detection (0.001 µg/L), exceeded 0.071 ng/l water and fish ingestion criterion in 1994.
Zollner Creek 0 to 7.8	DDT	Zollner Creek Near Mt Angel (USGS 14201300, ODEQ 10899) DDT detected in 3 of 10 ODEQ samples collected 2005-2007 . All detections exceed 0.001 µg/L aquatic life chronic criterion and 0.000024 µg/L human health criterion.
Little Pudding River 0 to 18.3	DDT	Little Pudding River at Rambler Road (ODEQ 31875) DDT detected in 9 of 10 ODEQ samples collected 2005-2007. All detections exceed 0.001 µg/L aquatic life chronic criterion and 0.000024 µg/L human health criterion.

POLLUTANT IDENTIFICATION

The primary pesticides of concern in the Pudding River Watershed are the listed pesticides: chlordane, dieldrin, and DDT (dichlorodiphenyltrichloroethane), including the DDT metabolites DDE and DDD. Chlordane, dieldrin, and DDT are toxic organochlorine pesticides. Historically, DDT, dieldrin, and chlordane were used extensively as agricultural insecticides and to control insect disease vectors such as mosquitoes. The use of these compounds has been banned in the United States for decades (DDT since 1972, chlordane since 1988, and dieldrin since 1970) but they are long-lived in soils.

Sampling performed by USGS as part of the U.S. Geological Survey National Water-Quality Assessment (NAWQA) Program (Bonn, et al, 1995 and Rinella and Janet, 1998) and the Willamette River Basin Water Quality Study (Anderson, et al, 1996 and Anderson, et al, 1997) suggests that a number pesticides may be present in the Willamette Basin in concentrations which may exceed either State of Oregon water quality criteria or other national or international criteria [1]. In addition to the listed pesticides (DDT and its metabolites DDE and DDD, chlordane, dieldrin), additional pesticides identified in the Willamette Basin include, atrazine, chlorpyrifos, diazinon, lindane (γ-HCH), and malathion. In particular, chlorpyrifos was identified as exceeding water quality criteria in the Molalla-Pudding subbasin. DEQ has not developed TMDLs for these additional pesticides, but does discuss and analyze the presence of these current use pesticides in the Molalla-Pudding Subbasin in Appendix I of this document.

A review of USGS and ODEQ monitoring data did not reveal any detected water column concentrations of chlordane. Therefore, the basis for the Zollner Creek 303(d) listing for chlordane is unclear. While no chlordane was detected in the water column, chlordane was detected in fish tissue samples collected in 1992 and 1997 in concentrations which exceed potential Oregon Department of Human Services (DHS) action levels. Fish tissue samples may also include fish tissue samples, such as from Sculpin, and shellfish tissue samples, such as from Asiatic clams. Therefore, even though no chlordane was detected in the water column, a TMDL has been developed to address this listing.

[1] Other pesticide criteria have been established by such bodies as National Academy of Sciences and National Academy or Engineering (NAS/NAE), the Canadian Council of Resources and Environmental Ministers (CCRM), or the U.S. Environmental Protection Agency (USEPA).

DDT

DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane)[2] does not occur naturally in the environment. DDT is a pesticide that was once widely used to control insects on agricultural crops and insects that carry diseases like malaria and typhus, but is now used in only a few countries to control malaria. Technical grade DDT may also contain DDE (1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene) and DDD (1,1-dichloro-2,2-bis(p-chlorophenyl)ethane) as contaminants. DDD, now banned, was also used to kill pests, but to a far lesser extent than DDT. Both DDE and DDD are breakdown products of DDT[3].

CHLORDANE

Chlordane is a man-made chemical that was used as a pesticide in the United States from 1948 to 1988 (ATSDR, 1994)[4]. It is a broad spectrum insecticide that has been used extensively for termite control, as an insecticide for homes and gardens, and as a control for soil insects during the production of crops such as corn. Chlordane is readily soluble in natural fats and fat soluble substances[5]. It is estimated that prior to 1983, 3.6 million pounds were used annually in the U.S. Technical grade chlordane is a mixture of at least 50 compounds; the major constituents are cis- and trans-chlordane, heptachlor, cis- and trans-nonachlor, and alpha-, beta- and gamma-chlordane. In the aquatic environment, chlordane is very persistent in the adsorbed state. Based on the high bioconcentration factor (BCF) values ranging between 7,240 and 20,000 chlordane is expected to have a high potential for bioconcentration. Trans-nonachlor is the most bioaccumulative of the chlordanes exceeding human health guidelines in fish tissue.[6]

DIELDRIN

Aldrin and dieldrin[7] are the common names of two structurally similar compounds that were once used as insecticides. They are chemicals that are made in the laboratory and do not occur naturally in the environment. Technical-grade aldrin contains not less than 85.5% aldrin. The trade names used for aldrin include Aldrec, Aldrex, Drinox, Octalene, Seedrin, and Compound 118. Technical-grade dieldrin contains not less than 85% dieldrin. The trade names used for dieldrin include Alvit, Dieldrix, Octalox, Quintox, and Red Shield[8].

Dieldrin is a long-lived oxidation breakdown product of aldrin. Aldrin quickly breaks down into dieldrin in the body or in the environment, typically within a matter of days. Thus, the environmental concentrations of dieldrin are a cumulative result of the historic use of both aldrin and dieldrin. Dieldrin is extremely persistent in the environment, and by means of bioaccumulation it is concentrated many times as it moves up the food chain. Its persistence is due to its extremely low volatility and low solubility in water resulting in a high affinity for fat (USEPA 1993, Meyer 1990).[9]

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[2] DDT Synonyms:
A synonym for p,p'-DDT is 4,4'-DDT and a synonym for o,p'-DDT is 2,4'-DDT.
A synonym for p,p'-DDE is 4,4'-DDE and a synonym for o,p'-DDE is 2,4'-DDE.
A synonym for p,p'-DDD is 4,4'-DDD and a synonym for o,p'-DDD is 2,4'-DDD.
(U.S. EPA Substance Registry System
http://iaspub.epa.gov/srs/srs_proc_qry.name_query)

[3] (http://www.atsdr.cdc.gov/toxprofiles/phs35.html#bookmark01
Public Health Statement for DDT, DDE, and DDD, U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, September 2002).

[4] http://www.atsdr.cdc.gov/toxprofiles/phs31.html

[5] Ambient Water Quality Criteria for Chlordane, EPA 440/5-80-027, U.S. EPA, Washington DC October 1980.

[6] In the Lake Michigan Mass Balance, trans-nonachlor will serve as a model for the cyclodiene pesticides."
Lake Michigan Mass Balance Study, USEPA
http://www.epa.gov/glnpo/lmmb/substs.html#Trans-nonachlor

[7] The scientific name for aldrin is 1,2,3,4,10,10-hexachloro-1,4,4α,5,8,8α-hexahydro-1,4-endo,exo-5,8-dimethanonaphthalene. The abbreviation for the scientific name of aldrin is HHDN. The scientific name for dieldrin is 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4α,5,6,7,8,8α-octahydro-1,4-endo,exo-5,8-dimethanonaphthalene. The abbreviation for the scientific name for dieldrin is HEOD.

[8] U.S. Department of Heath and Human Services, Agency for Toxic Substances & Disease Registry (ATSDR).
(http://www.atsdr.cdc.gov/toxprofiles/phs1.html#bookmark01

[9] *Ambient Water Quality Criteria for Aldrin/Dieldrin, EPA 440/5-80-019, U.S. EPA, Washington DC October 1980*

Aldrin and dieldrin have been two of the most widely used domestic pesticides. The primary use of the chemicals in the past was for control of corn pests, although they were also used to controls the pests of other crops. The U.S. Department of Agriculture canceled all uses of aldrin and dieldrin in 1970. In 1972, however, EPA approved aldrin and dieldrin for killing termites and use continued until 1987. In 1987, the manufacturer voluntarily canceled the registration for use in controlling termites[10].

WATER QUALITY STANDARDS AND BENEFICIAL USES

The beneficial uses affected by the presence of pesticides are anadromous fish passage, drinking water, fishing (Human Health – Water and Fish Ingestion), and resident fish and aquatic life. The most sensitive beneficial use is Human Health – Water and Fish Ingestion. This TMDL evaluates the 303(d) listed parameters, in order to determine if water column, fish or shellfish tissue, or sediment concentrations are high enough to potentially adversely impact aquatic life or human health.

WATER COLUMN CRITERIA

State of Oregon water quality criteria are shown in Table 4 - 4. The State of Oregon adopted toxics water quality criteria from EPA guidance (EPA, 1986) to protect the most sensitive beneficial uses of Oregon waterbodies. Those criteria are summarized in Table 20 of OAR 340-041-0033. The Oregon Environmental Quality Commission approved new toxics criteria in May 2004, including revisions of the DDT, dieldrin, and chlordane criteria in Table 33A, but EPA has not yet approved those criteria because of on-going litigation regarding fish consumption rate. Until the 2004 proposed criteria are approved, DEQ continues to use the criteria in Table 20 for federal Clean Water Act purposes, including TMDLs. In this TMDL, if the Table 33A criterion is more conservative than the Table 20 criterion (e.g. dieldrin), DEQ has used the Table 33A criterion as the applicable criterion. Chronic and acute aquatic life criteria are intended to protect aquatic life. Human health criteria are intended to minimize adverse human health effects from ingestion of water and organisms residing in the waterbody.

Table 4 - 4: Water Quality Criteria

	Freshwater				Human Health For Consumption of:				Drinking Water MCLs
Compound	Acute µg/L		Chronic µg/L		Water + Organism[B] µg/L		Organism only[B] µg/L		µg/L
Chlordane	2.4	Table 20	0.0043	Table 20	0.00046	Table 20	0.00048	Table 20	2
Dieldrin	2.5	Table 20	0.0019	Table 20	0.000071	Table 20	0.000076	Table 20	
Chlordane	2.4	Table 33A	0.0043	Table 33A	0.00080	Table 33A	0.00081	Table 33A	
DDT	1.1	Table 20	0.001	Table 20	0.000024	Table 20	0.000024	Table 20	
DDD 4,4'-					0.00031	Table 33A	0.00031	Table 33A	
DDE 4,4'-					0.00022	Table 33A	0.00022	Table 33A	
Dieldrin	0.24	Table 33A			0.000052	Table 33A	0.000054	Table 33A	

MCL - Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards. Table 20 and 33A are contained in OAR 340-41-0033

[10] http://www.atsdr.cdc.gov/toxprofiles/phs1.html#bookmark01 and U.S. Department of Heath and Human Services, Agency for Toxic Substances & Disease Registry ATSDR

FISH TISSUE CONCENTRATIONS OF CONCERN

Action levels for poisonous or deleterious substances are established by the Food and Drug Administration (FDA) to control levels of contaminants in human food and animal feed. Action levels and tolerances represent limits at or above which FDA will take legal action to remove products from the market. Where no established action level or tolerance exists, FDA may take legal action against the product at the minimal detectable level of the contaminant. FDA action levels for fish (edible portion) are shown in Table 4 - 5[11].

Table 4 - 5. FDA Action levels for fish (edible portion)

Pesticide	FDA Action Level
CHLORDANE	0.3 ppm (300 µg/kg)
DDT, DDE, & TDE	5 ppm (5000 µg/kg)
ALDRIN & DIELDRIN	0.3 ppm (300 µg/kg)

Fish Advisories for the State of Oregon are issued by the Oregon Department of Human Services (DHS) Environmental Toxicology Program. To date, DHS has not issued any fish advisories for chlordane, DDT or dieldrin and, therefore, has not established official Oregon action levels for these compounds. When determining advisory thresholds, DHS typically begins with USEPA fish screening levels (Table 4 - 6) and adjusts them using an assumed consumption rate of 20 g/day, rather than 6.5 g/day. Application of this methodology results in the assumed action levels shown in Table 4 - 6 (Kauffman, K.W., 2007).

Table 4 - 6: DHS Assumed action levels for fish

Pesticide	USEPA fish tissue screening value (carcinogenicity)	DHS assumed action level (adjusted to assumed 20 g/d consumption rate)
Chlordane (total)	80 µg/kg (0.08 ppm)	27 µg/kg
DDT (total isomers)	300 µg/kg (0.3 ppm)	100 µg/kg
Dieldrin	7 µg/kg (0.007 ppm)	2.3 µg/kg

SEDIMENT CONCENTRATIONS OF CONCERN

Oregon DEQ has not promulgated criteria for streambed sediment. In order to determine if sediment concentrations of chlordane, dieldrin, and DDT and other pesticides exceed levels of potential concern, concentrations may be compared to sediment quality guidelines recommended by other organizations to support and maintain designated uses of the aquatic environment (Tanner, 2002). Guidelines for comparison to observed concentrations are from the Puget Sound Dredged Disposal Analysis Program (PSDDA, 2000) and the Canadian Council of Ministers of the Environment (CCME, 2001) (Table 4 - 7).

The PSDDA is a joint program of the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers, with the responsibility of regulating dredged material management activities in the State of Washington under the Clean Water Act. Two PSDDA guidelines are listed, the screening level and the maximum level. The screening level identifies the concentration below which the disposal of dredged material is expected to have no unacceptable adverse effects (Tanner, 2002).

Canadian governmental agencies have based sediment guidelines on the simultaneous effects of several contaminants on benthic organisms. Probable effect levels (PEL) are interim guidelines developed by the Canadian Council of Ministers of the Environment. They indicate the concentrations above which adverse biological effects are expected to occur frequently (Tanner, 2002).

[11] U. S. Food and Drug Administration, Industry Activities Staff Booklet, August 2000
http://www.cfsan.fda.gov/~lrd/fdaact.html#ddt

Table 4 - 7: Guidelines for organic chemicals in streambed sediments (Tanner, 2002)

Organic chemical	PSDDA Screening Level Guideline (µg/kg)	Canadian Interim Guideline Probable Effects level (µg/kg)
Total chlordane (*cis*-chlordane + *trans*-chlordane + *cis*-nonachlor + *trans*-nonachlor + oxychlordane)	-	8.87
Dieldrin	10	6.67
Total DDD (2,4'-DDD + 4,4'-DDD)	-	8.51
Total DDE (2,4'-DDE + 4,4'-DDE)	-	6.75
Total DDT (4,4'-DDD + 4,4'-DDE + 4,4'-DDT)	6.9	-
Lindane (γ-HCH)	10	1.38

SOURCES OR SOURCE CATEGORIES

A review of existing data and previous studies indicates that the main source areas for the pesticides of concern are areas of agricultural land use associated with sediment entering streams. USGS found in the Willamette River Basin Water Quality Study that water column concentrations of several pesticides, particularly DDT, correlated with suspended solids concentrations (Anderson, et al, 1996 and Anderson, et al, 1997). The USGS also found that pesticides correlate highly with the percent of watershed in agricultural land use. Since much of the sediment which enters streams comes from sediment washed off fields during storm events, pesticides associated with sediment may be controlled by reducing surface erosion.

DEQ's data review and modeling (explained in detail in Appendix J) indicate that the major sources of DDT to the Pudding River are Zollner Creek and Little Pudding River. The data review that led to conclusions about source areas makes up this section.

Frequent monitoring of water column pesticides concentrations was performed by USGS at three locations in the Pudding River watershed: Little Abiqua Creek Near Scotts Mills (1992 - 2004), Pudding River At Aurora (1992 - 1997), and Zollner Creek Near Mt Angel (1992 - 2006) (Figure 4 - 1 and Table 4 - 8). Occasionally monitoring was also done by USGS at other sites. DEQ performed frequent monitoring of water column pesticides at 10 sites from 2005 to 2007, shown in Table 4 - 9.

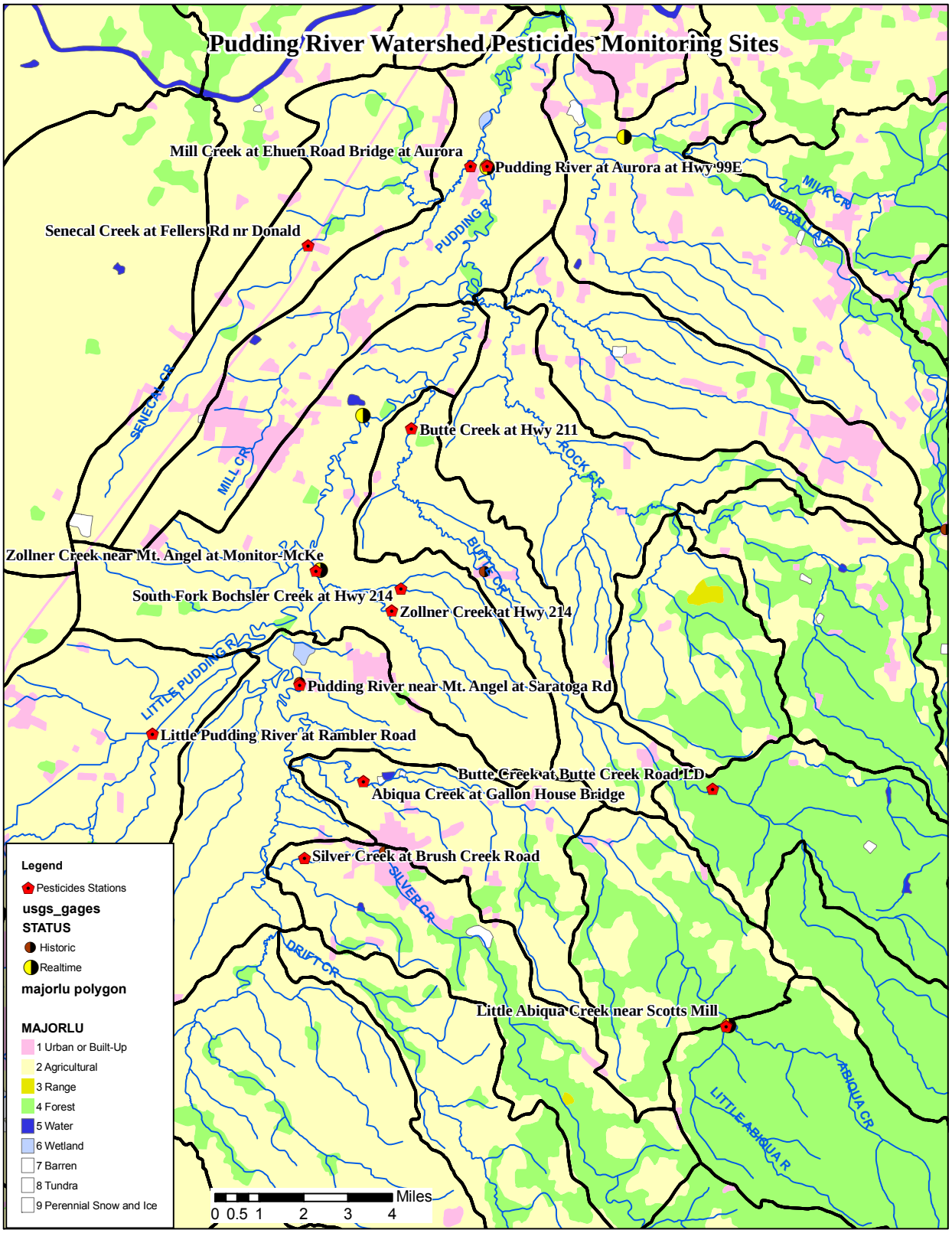

Figure 4 - 1: USGS and ODEQ Pesticides Monitoring Stations

Table 4 - 8: Active and historic USGS discharge gages and water quality monitoring sites

USGS Gage Number	NAME	RM	Drainage Area (sq.mi.)	Periods	LAT	LONG	STATUS	ELEV (ft)
14202000	Pudding River at Aurora (Hwy 99E, u/s from Mill Cr)	8.1	479	1928-64, 93-97, 02-present	45.2333	-122.7489	Realtime	72
14201340	Pudding River near Woodburn	23.4	314	1997-present	45.1514	-122.8031	Realtime	130
14201300	Zollner Creek near Mt. Angel	0.4	15.0	1993-present	45.1006	-122.8206	Realtime	240
14200000	Molalla River near Canby	6.0	323	1928-59, 63-78, 00-present	45.2444	-122.6861	Realtime	94
14200300	Silver Creek near Silverton	3.0	47.9	1963-79	45.0094	-122.7875	Historic	218
14200400	Little Abiqua at Scotts Mills	0.1	9.8	1993-2004	44.9558	-122.6272		800
14201000	Pudding River near Mt. Angel (Saratoga Rd)	40.7	204	1939-66	45.0361	-122.8292	Historic	120
14201500	Butte Cr at Monitor	5.9	58.7	1936-85	45.1017	-122.7450	Historic	155

Table 4 - 9: ODEQ water quality monitoring sites

Station Name and DEQ Lab Analytical Storage and Retrieval (LASAR) number	% Urban	% Ag	% Forest	River Mile	Drainage Area u/s from station
				mi	(mi^2)
Pudding River at Aurora (Hwy 99E) (USGS Gage 14202000, 10917)	5	58	36	8.1	479.0
Pudding River near Mt. Angel (Saratoga Rd) (old USGS Gage 14201000, 31877)	3	47	50	40.7	204.0
Abiqua Creek at Gallon House Bridge (31872)	2	29	68	1.9	76.0
Butte Creek at Hwy 211 (10896)	1	24	75	1.3	67.8
Silver Creek at Brush Creek Road (10646)	6	17	77	1.3	54.4
Little Pudding River at Rambler Road (31875)	22	74	3	2.9	52.9
Zollner Creek Near Mt Angel (Monitor-McKee Rd) (Gage 14201300, 10899)	1	99	0	0.4	15.0
Zollner Creek at Hwy 214 (11515)	1	98	1	1.0	6.9
South Fork Bochsler Creek at Hwy 214 (11514, tributary to Zollner Cr)	1	98	1	0.6	2.6
Senecal Creek at Fellers Rd (trib to Mill Cr to Pudding R)	8	89	3	3.1	9.7
Little Abiqua Creek near Scotts Mill (Gage 14200400)	0	4	96	0.4	9.8
Butte Creek at Butte Creek Road LD (31874)	0	4	96	15.8	49.2

USGS and ODEQ measured water column concentrations of these parameters were compared to criteria to determine if concentrations could potentially adversely affect aquatic life or human health (Table 4 - 10). Parameters in concentrations in excess of applicable criteria are shown as "> Std." Parameters detected but not in concentrations in excess of applicable criteria as shown as ">DL." Parameters all or virtually all below detection are shown as "OK." GS and Q in table indicate whether the dataset is via USGS (GS) or ODEQ (Q). t-DDT shown in Table 4 - 10 is the Total DDT concentration and includes DDT and its metabolites (t-DDT = 4-4'-DDT + 4-4'-DDE + 4-4'-DDD).

Table 4 - 10 shows the percent of land above each station on an areal basis that is classified as urban, agriculture, or forest. Rinella and Janet, 1998, classified streams with land use greater than 90% forested as "forested"; and streams with land use greater than 50% agricultural and less than 25% urban as "agricultural." In accordance with this, the Zollner Creek (including Bochsler Creek) and Little Pudding River sites are agriculture sites, whereas Little Abiqua Creek and Butte Creek at Butte Creek Road LD sites are forestry sites. The remaining sites are integrator sites: those sites which include a mixture of land uses.

Table 4 - 10: Comparisons of observed concentrations to water quality criteria or other levels of concern. Parameters in concentrations in excess of applicable criteria are shown as "> Std." Parameters all or virtually all below detection are shown as "OK." GS and Q in table indicate whether the dataset is via USGS (GS) or ODEQ (Q). Note 1: One estimated concentration for 4,4'-DDT of 0.002 µg/L exceeded criteria. Note 2: One of 12 samples exceeded DL with a concentration of 0.002 µg/L (> ODEQ criteria of 0.001 µg/L).

Station Name and Lab Analytical Storage and Retrieval (LASAR) number	**% Urban**	**% Ag**	**% Forest**	**t-DDT**	**Chlordane**	**Dieldrin**
Integrator Sites (mix of agriculture, forestry and urban land uses):						
Pudding River at Aurora (Hwy 99E) (Gage 14202000, LASAR 10917)	5	58	36	**>Std (GS) OK (Q)[1]**	**OK (GS) OK (Q)**	**>Std (GS) OK (Q)**
Pudding River near Mt. Angel (Saratoga Rd) (old Gage 14201000, LASAR 31877)	3	47	50	**OK (Q)**	**OK (Q)**	**OK (Q)**
Abiqua Creek at Gallon House Bridge (31872)	2	29	68			
Butte Creek at Hwy 211 (near mouth) (10896)	1	24	75	**>Std (Q)**		**OK (Q)**
Silver Creek at Brush Creek Road (10646)	6	17	77	**OK (Q)**		
Agriculture Sites:						
Little Pudding River at Rambler Road (RM 2.9) (31875)	22	**74**	3	**>Std (Q)**	**OK (Q)**	**OK (Q)**
Zollner Creek Near Mt Angel (Monitor-McKee Rd) (Gage 14201300, 10899)	1	**99**	0	**>Std (GS) >Std (Q)**	**OK (GS)**	**>Std (GS) >Std (Q)**
Zollner Creek at Hwy 214 (11515)	1	**98**	1			
South Fork Bochsler Creek at Hwy 214 (11514, tributary to Zollner Cr)	1	**98**	1			
Senecal Creek at Fellers Rd (trib to Mill Cr to Pudding R)	8	**89**	3			**OK (GS)**
Forestry Sites:						
Little Abiqua Creek near Scotts Mill (Gage 14200400)	0	4	**96**	**OK (GS)**	**OK (GS)**	**OK (GS)**
Butte Creek at Butte Creek Road LD (31874)	0	4	**96**	**>Std (Q)[2]**	**OK (Q)**	**OK (Q)**

In forested sites, there was only one detection of a pesticide of concern: a single DDT detection out of 11 for the upper Butte Creek site (Butte Creek Road LD). This represents a detection frequency of less than 10%. For integrator sites with less than 50% agriculture, there was also only one detection of a pesticide of concern, a single DDT detection out of 5 near the mouth of Butte Creek (at Hwy 211). This represents a 20% frequency of detection.

Zollner Creek and its tributary Bochsler Creek are the only streams with land use > 90% agriculture. Chlordane was not detected, but state criteria for DDT and dieldrin were exceeded. The Little Pudding River also has a high percentage of agriculture, as well as a relatively high percentage urban. While the only pesticide of concern in excess of criteria at this site was DDT, the concentrations of DDT at this site were the highest observed in the subbasin.

Integrator sites showed pesticide concentrations that appear to relate more to whether the site is impacted by Zollner Creek and Little Pudding River than the percent agriculture. DDT and dieldrin which have been detected in Zollner Creek or the Little Pudding River, have also been detected downstream at the Pudding River at Aurora (RM 8.1) site. However, upstream at the Pudding River near Mt. Angel site, no pesticides of concern were detected, even though this site has a percent agriculture that is similar to the Aurora site (47% vs. 58%). Pesticides of concern were also not detected at the other integrator sites, other than for a single DDT detection at the lower the Butte Creek site.

The following section presents observed concentrations of the 303(d) listed pesticides: DDT, chlordane, and dieldrin.

DDT

DDT was one of the most frequently detected organochlorine compounds in samples collected from 39 Willamette Basin sites during Phase I and Phase II of the Willamette River Basin Water Quality Study (WRBWQS) (Anderson, et at, 1996). However, DDT was not detected during other studies by USGS, mainly because, while a lot of measurements were made of 4,4'-DDE concentrations, far fewer were made for total DDT (t-DDT = DDT + DDE + DDD). This is because 4,4'-DDE was the only DDT metabolite measured routinely by USGS as part of the Phase III of the WRBWQS (USGS Schedule 2010 methodology)(Anderson, et al, 1997). Prior to 2001 the method detection limit (MDL) for these analyzes was a relatively high 0.006 µg/L, which is quite a bit higher than the 0.001 µg/L DEQ chronic criteria for t-DDT. For samples analyzed 2001 and later, the MDL was generally 0.003 µg/L. Other than for a few estimated values, 4,4'-DDE was detected in none of the Molalla-Pudding Subbasin samples.

For a limited number of USGS Pudding River and Zollner Creek samples, analyses were performed for 4,4'-DDT and its metabolites 4,4'-DDE and 4,4'-DDD. These analyses had minimum reporting levels (MRLs) of 0.001 µg/L, which allow for comparison to the 0.001 µg/L DEQ criterion. Recent samples collected by ODEQ were also analyzed for 4,4'-DDT, 4,4'-DDE and 4,4'-DDD with MRLs of 0.001 µg/L. Concentrations in excess of ODEQ criteria were observed in Pudding River, Little Pudding River, Zollner Creek, and Butte Creek, but not in the heavily forested Little Abiqua Creek, Silver Creek, or upper Butte Creek. Note, however, that while the MRL for each metabolite is 0.001 µg/L, the detection level for t-DDT is the sum of these MRLs, or 0.003 µg/L, so simply because the three metabolites are below detection does not necessarily mean that the criteria has been met.

DDT and its metabolites were the most commonly detected organic compounds in fish tissues from the Willamette Basin (Anderson, et al, 1997). However, the only DDT metabolite analyzed for by USGS during Phase III of the Willamette River Basin Water Quality Study, 4,4'-DDE, was detected in none of the water column samples collected in the Willamette Basin (Anderson, et at, 1997). But this may be because the detection level for 4,4'-DDE was relatively high and no analyses were performed for other DDT metabolites or for DDT itself.

The USGS found during Willamette River Basin Water Quality Study (WRBWQS) that in-stream DDT concentrations in the Willamette Basin correlate with suspended solids concentrations (Anderson, et al, 1996). DDT and its metabolites preferentially associate with the suspended phase because they are

hydrophobic, with organic carbon-water partitioning coefficients (K_{oc}) of 770,000 for DDD, 4,400,000, for DDE and 243,000 for DDT (Anderson, et al, 1996). The fraction of DDT in the suspended phase is controlled by the K_{oc} values, the concentration of suspended organic carbon, and the degree to which equilibrium is achieved. Theoretical computations performed by USGS predicted that 55 to 81 percent of the mass of DDT and metabolites should have been associated with the suspended phase if the systems were at equilibrium. In all cases measured by USGS, observed amounts in the suspended phase were only slightly greater than predicted.

DDT - Water Column Data

Integrator Sites

Pudding River integrator sites include Pudding River at Aurora (RM 8.1) and Pudding River at Mt. Angel (RM 40.7). Tributary integrator sites include sites on Abiqua, Butte, and Silver Creeks.

The Pudding River at Aurora station (USGS gage No. 14202000 and DEQ LASAR No. 10917) is the most important integrator site since it is the most downstream integrator site in the watershed and integrates all loads except for those from Mill Creek and its tributary Senecal Creek. It is the integrator site with the highest percent land use as agriculture (58%) and it is the only integrator site located downstream from the confluences of Zollner Creek and Little Pudding River, which are streams dominated by agriculture and which at times contain significant concentrations of pesticides. It is the only integrator site where pesticides were detected frequently. The only other integrator site where a pesticide was detected was the lower Butte Creek site, for which DDT was detected in one sample.

At the Pudding River at Aurora integrator site, DDT was detected occasionally in samples collected by both USGS and ODEQ. Observed total DDT (t-DDT) concentrations are shown in Figure 4 - 2, with measurements from 1993 and 1994 by USGS and 2005 through 2007 by ODEQ. As shown, DDT was detected in 2 of 6 USGS and 1 of 11 DEQ samples, with the single DEQ detection an estimate only.

For Figure 4 - 2, t-DDT concentrations were calculated by setting DDT, DDE, and DDD non-detects to zero. These constitute “best case” concentrations, since the MRLs for DDT, DDE, and DDD are all 0.001 µg/L. Therefore, actual t-DDT concentrations could be greater than the values shown.

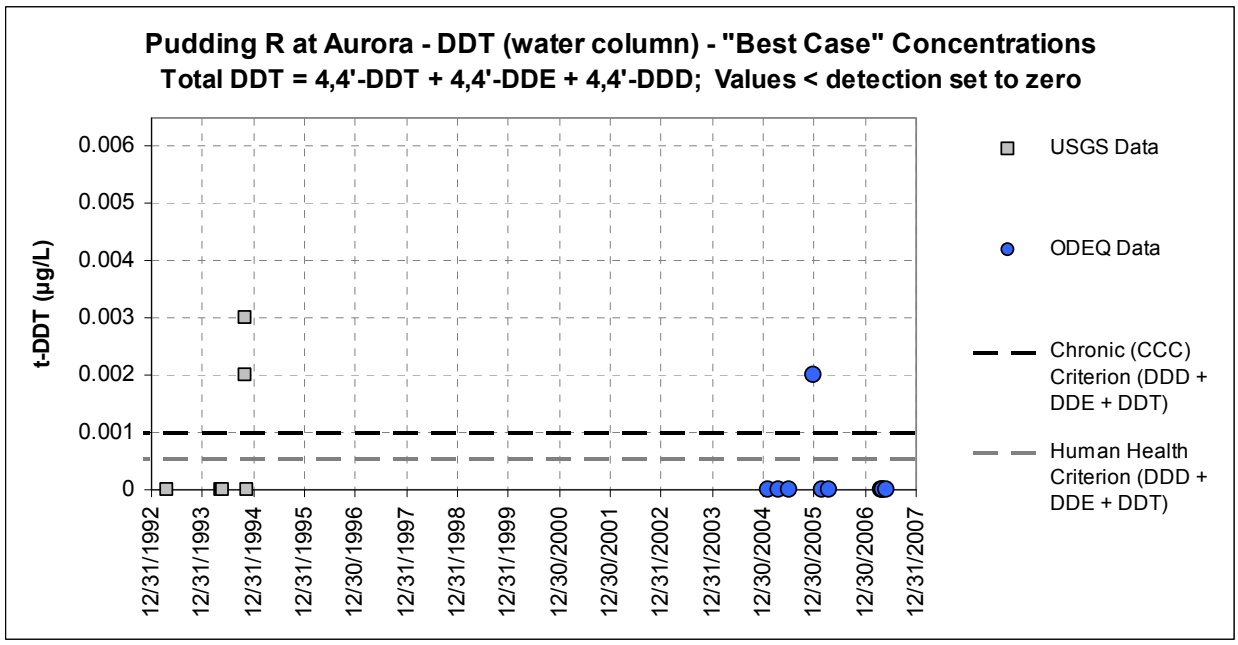

Figure 4 - 2: Pudding River at Aurora (RM 8.1) - "Best Case" t-DDT concentrations

Alternatively, to determine “worst case” concentrations, values less than detection could be set to MRLs, as shown in Figure 4 - 3. Since 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT each have detection levels of 0.001 µg/L, the detection level for t-DDT is 0.003 µg/L. Since this detection level is greater than the chronic criterion of 0.001µg/L, concentrations greater than the criteria may not always be detected. This is also true for human health criteria. Separate human health criteria apply for DDD, DDE, and DDT. These individual criteria sum to 0.000554 µg/L (0.554 ng/L). Therefore, concentrations in excess of human health criteria may frequently not be detected.

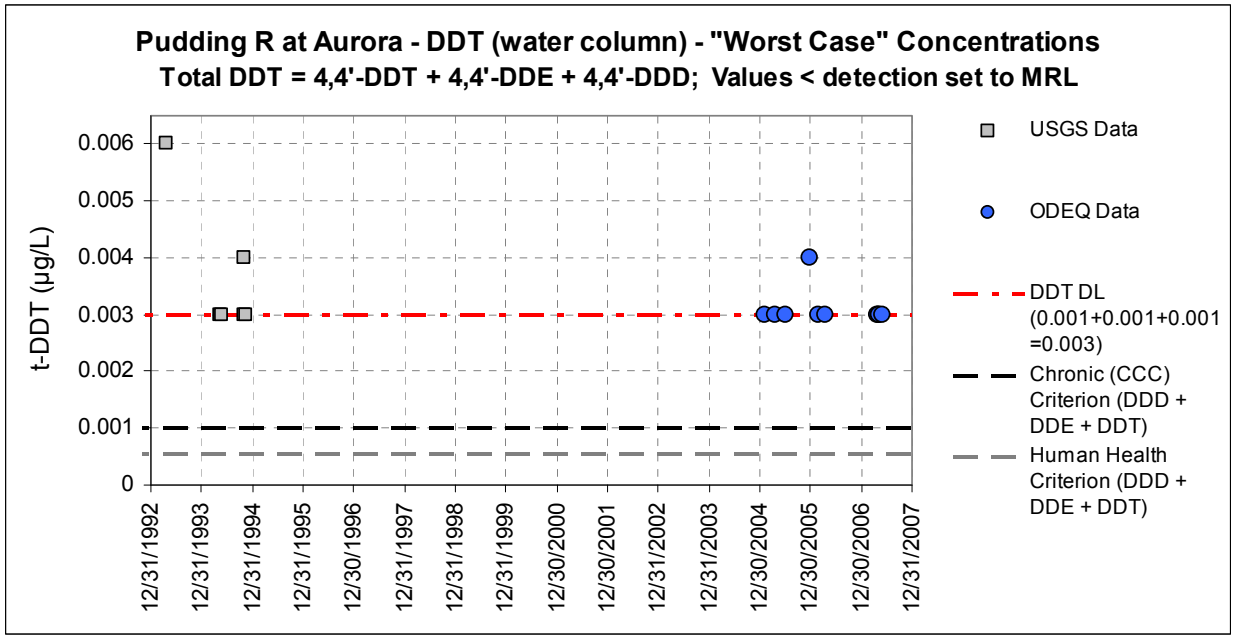

Figure 4 - 3: Pudding River at Aurora (RM 8.1) - "Worst Case" t-DDT concentrations

Figure 4 - 4 shows the range of likely t-DDT concentrations for each sample, with a mid point plotted half way between the maximum and minimum values. As shown, all samples could have contained concentrations greater than applicable chronic toxicity and human health based criteria. However, t-DDT was only shown to be present in excess of criteria in 3 of the samples, and for one of the samples, the 12/21/2005 DEQ measurement, the concentration was only an estimate.

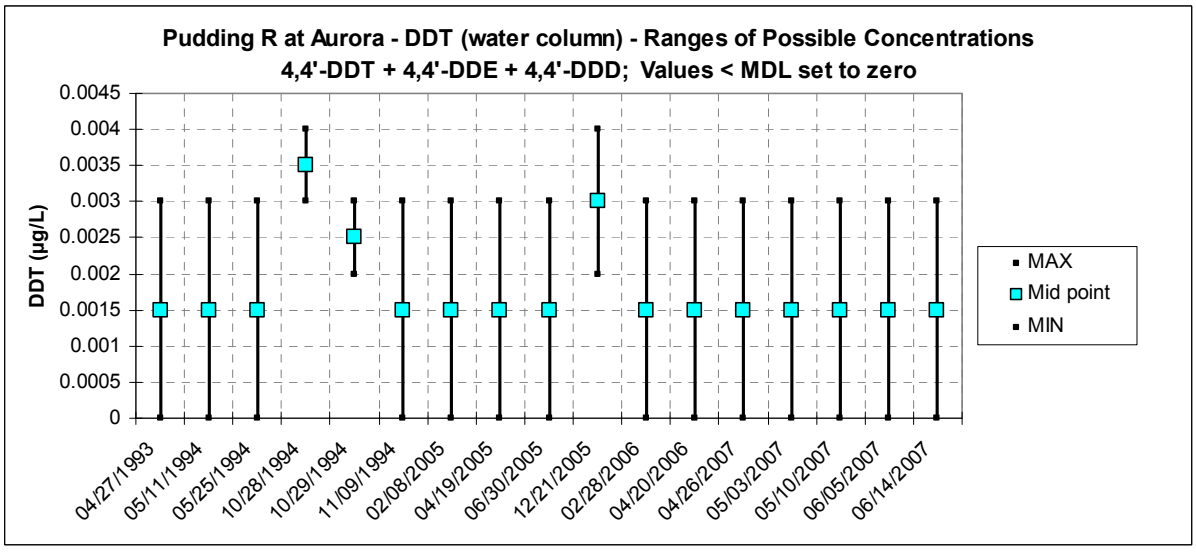

Figure 4 - 4: Pudding River at Aurora (RM 8.1) – Ranges of possible t-DDT concentrations

The only other integrator site where DDT was detected is Butte Creek at Hwy 211 (RM 1.3), where DDT was detected in 1 of 4 samples (Figure 4 - 5). For the single detection the 4,4'-DDT concentration was 0.002 µg/L (both DDE and DDD were below detection). The Butte Creek watershed is 75% forest and 24% agriculture. No other pesticides of concern were detected at this site. As discussed below, DDT was also detected at the upper Butte Creek site, which is a site where forestry comprises 96% of the drainage area land use.

For Figure 4 - 5, the concentrations of metabolites that were not detected were set to zero. Therefore, the total DDT concentrations shown represent "best case" concentrations. As discussed above, actual concentrations could be greater than these.

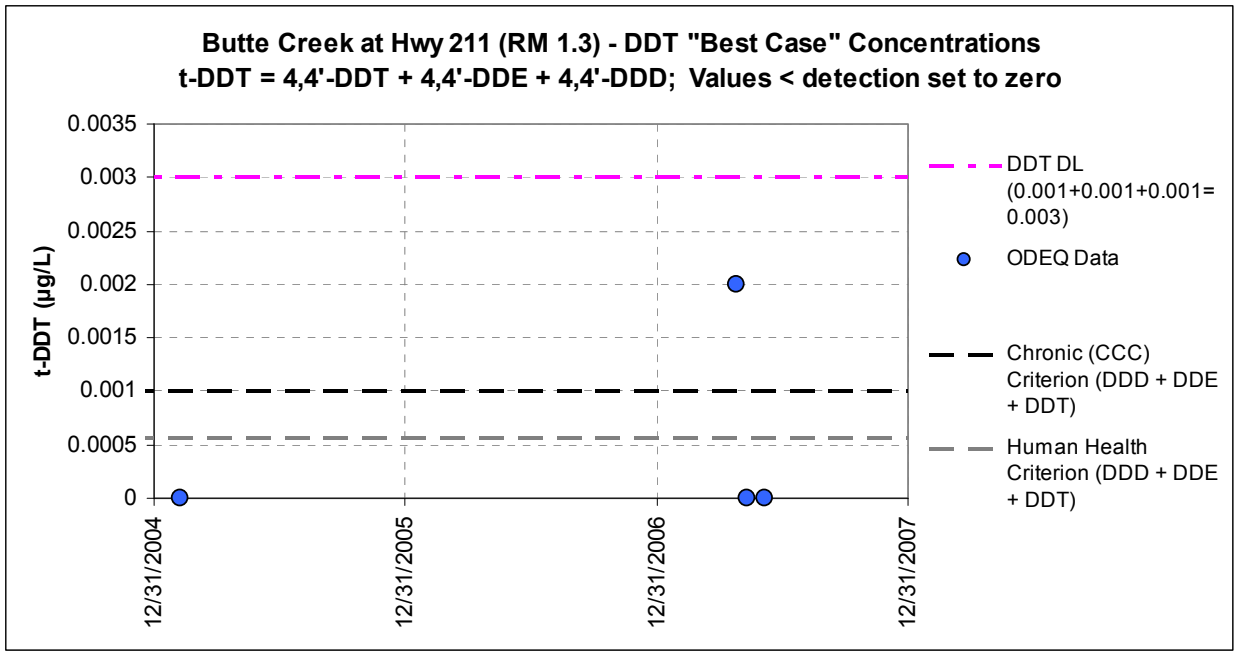

Figure 4 - 5: Butte Creek at Hwy 211 (RM 1.3) - "Best Case" t-DDT concentrations

DDT - Agriculture Sites

DDT was detected frequently in the two agricultural watersheds, Zollner Creek and Little Pudding River (in addition to being detected at the Pudding River at Aurora integrator site located downstream from Zollner Creek and Little Pudding River). Total DDT concentrations for Zollner Creek Near Mt. Angel and Little Pudding River at Rambler are shown in Figure 4 - 6 and Figure 4 - 7. These are the only agriculture sites where DDT, DDE, and DDD were measured with low MRLs of 0.001 µg/L. For the Zollner Creek near Mt. Angel site, DDT was detected in 1 of 6 USGS and 3 of 10 ODEQ samples. For the Little Pudding River at Rambler Road site, DDT was detected in 9 of 10 ODEQ samples (USGS did not monitor this site).

For the plots, concentrations for metabolites that were not detected were set to zero. Therefore, the total DDT concentrations shown represent "best case" concentrations.

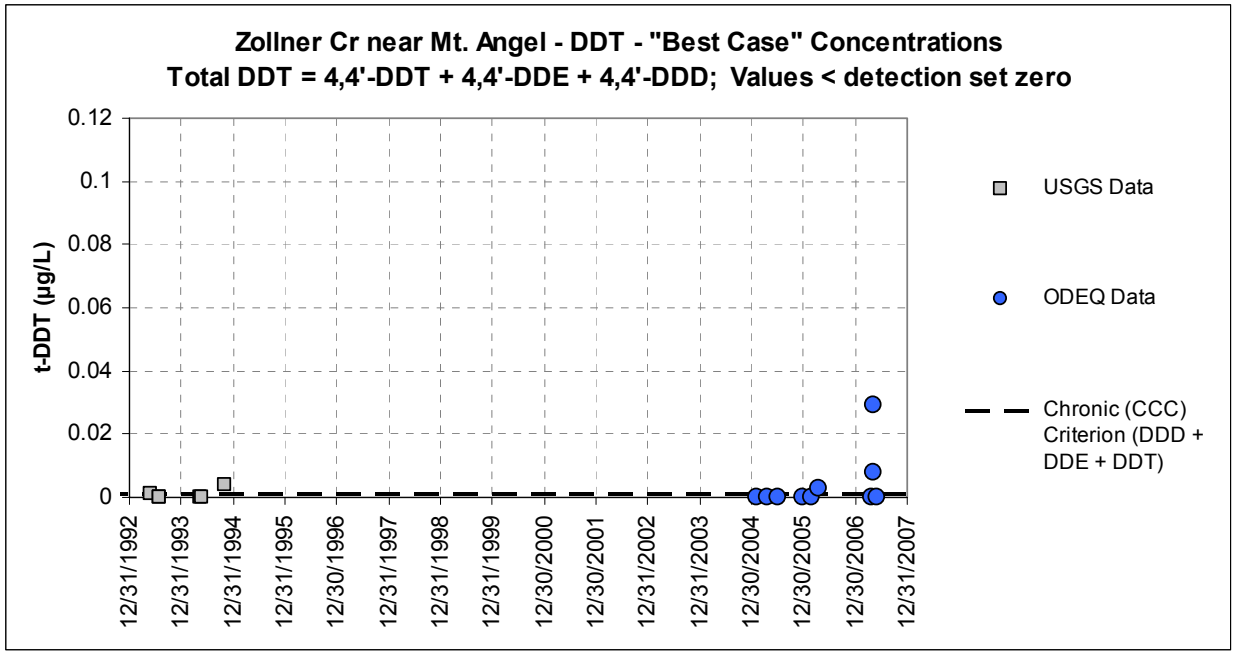

Figure 4 - 6: Zollner Creek Near Mt. Angel- "Best Case" t-DDT concentrations

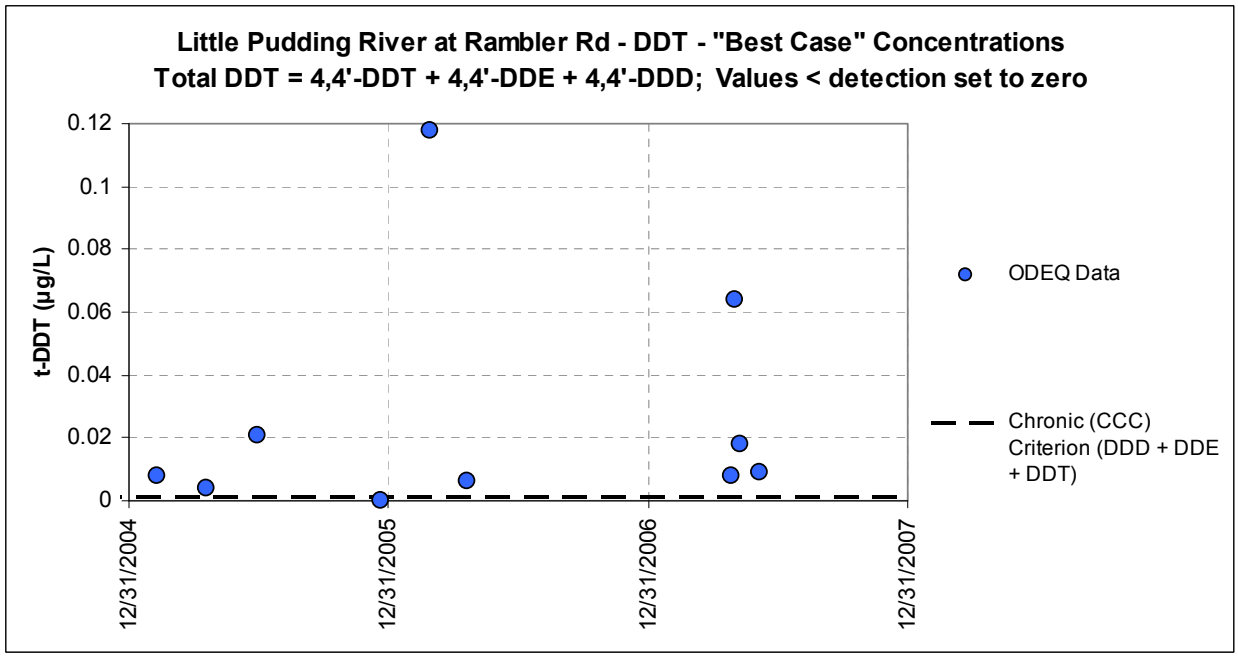

Figure 4 - 7: Little Pudding River at Rambler - "Best Case" t-DDT concentrations

Potential “worst” case (maximum) concentrations are presented in Figure 4 - 8 and Figure 4 - 9 (logarithmic scale). In the worst case scenario, values less than the detection level were set equal to the detection level. As shown, due to detection level limitations, all samples could potentially have contained concentrations greater than applicable chronic toxicity and human health based criteria. However, only Little Pudding River samples were found to contain concentrations that virtually always exceed criteria (Figure 4 - 9).

A significant difference between the Little Pudding River and Zollner Creek watersheds is that, while agriculture is a significant land use in both watersheds, urban is a significant land use for the Little Pudding (22%) and not for Zollner. Much of this urban area is within the limits of the cities of Salem and Keizer. Loads from urban stormwater could be a source of some of the observed DDT.

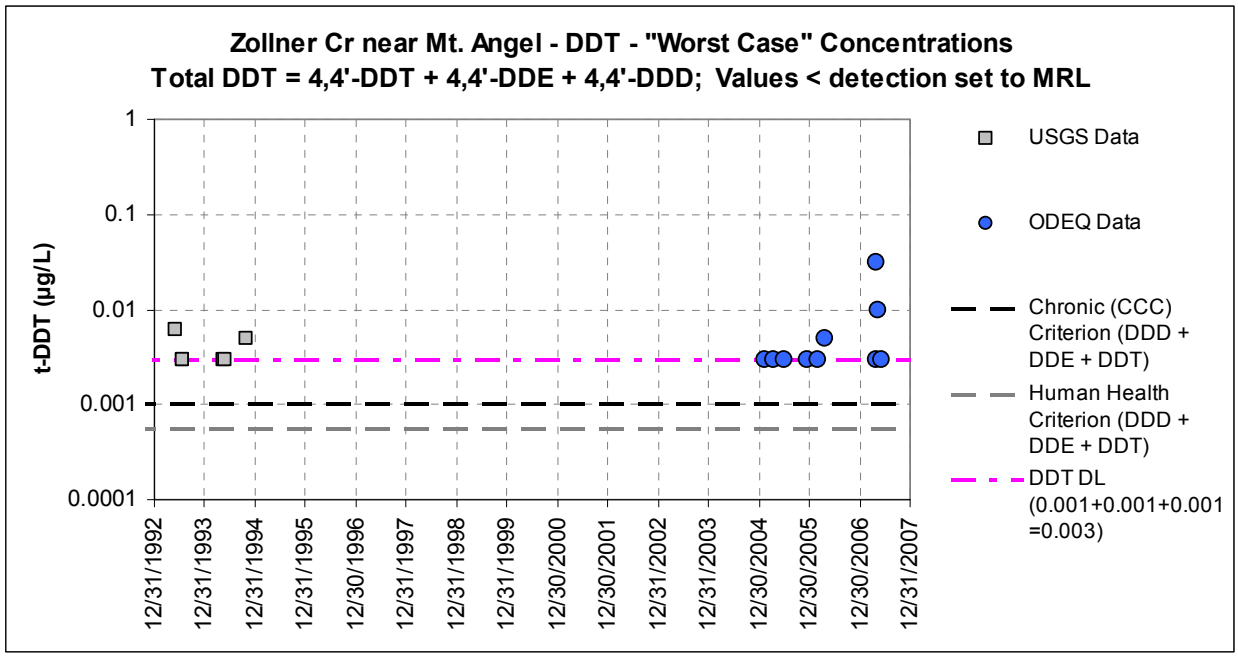

Figure 4 - 8: Zollner Creek Near Mt. Angel- "Worst Case" t-DDT concentrations

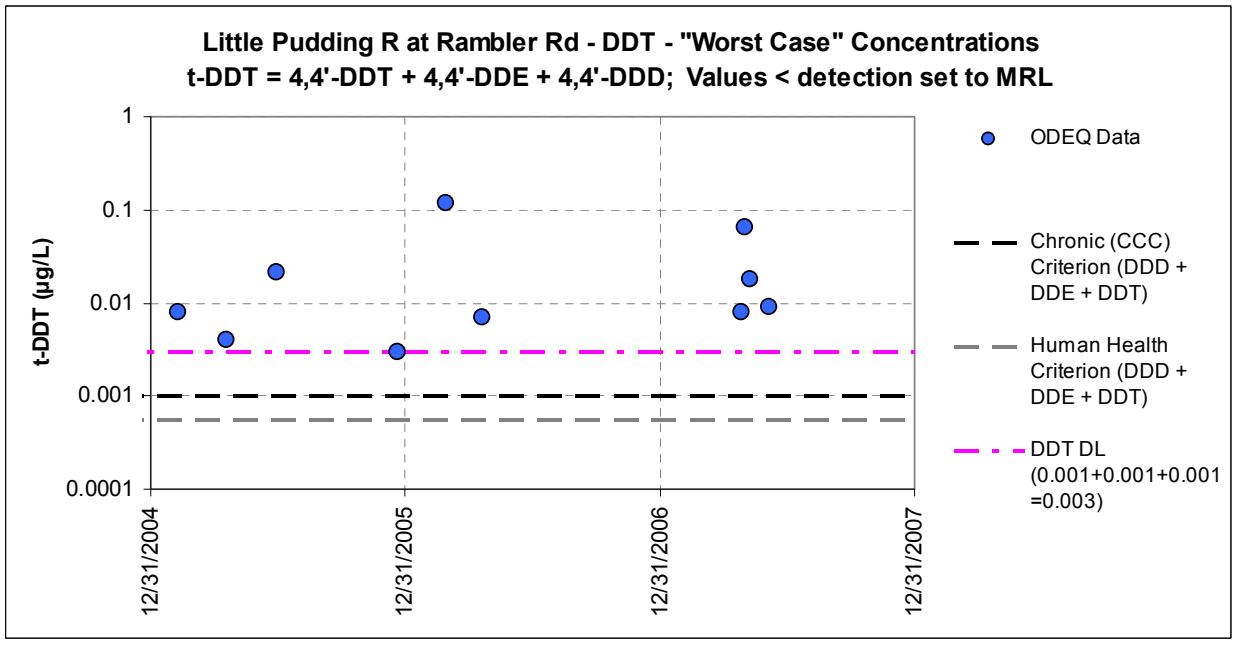

Figure 4 - 9: Little Pudding River at Rambler - "Worst Case" t-DDT concentrations

DDT - Forestry Sites

The only pesticide of concern detected at a forestry site was a single DDT detection out of 11 ODEQ samples collected from 2005 through 2007 at Butte Creek at Butte Creek Road LD. This sample, collected in May of 2007, contained 0.002 µg/L 4,4'-DDT (both DDE and DDD were below detection) (Figure 4 - 10). There were no detections of chlordane or dieldrin at this or the other forestry site (Little Abiqua Creek near Scotts Mill, USGS gage No. 14200400).

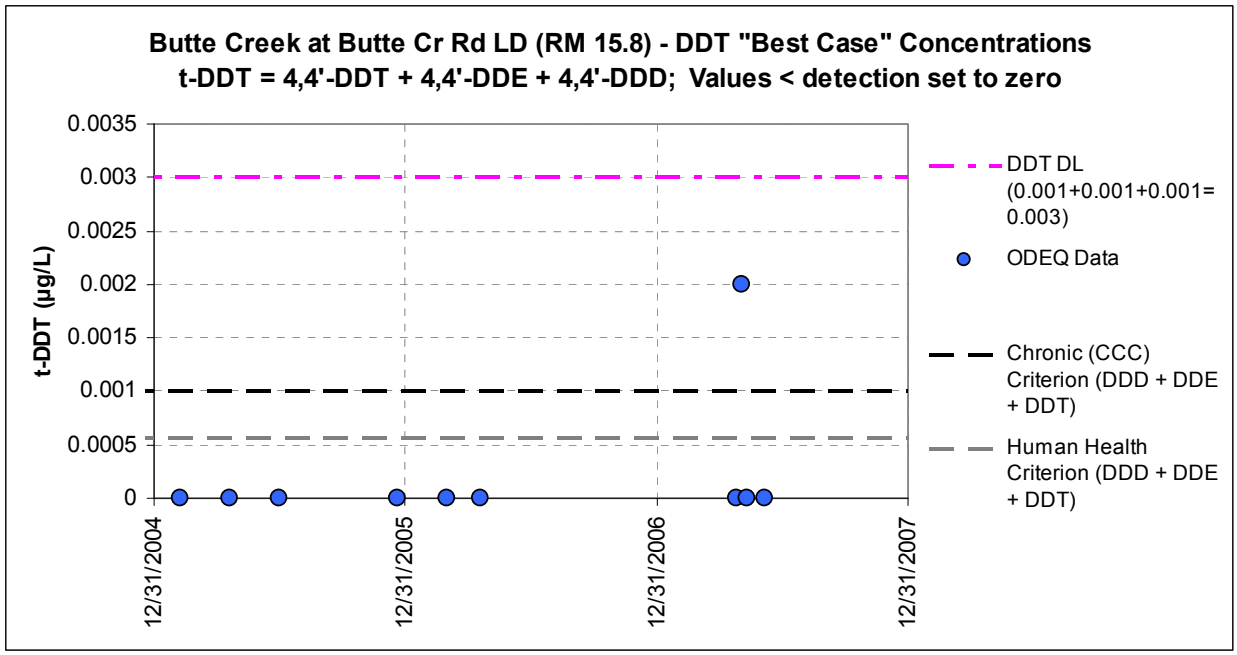

Figure 4 - 10: Butte Creek at Butte Creek Road LD (RM 15.8) - "Best Case" t-DDT concentrations

DDT - Fish Tissue Concentrations

Fish tissue DDT and DDT metabolite concentrations were measured by USGS in Pudding River, Zollner Creek, and Little Abiqua Creek in 1992, 1993, and 1997 (Figure 4 - 11). The following measured parameters were summed to calculate total DDT (t-DDT) : 4,4'-DDT, 2,4'-DDT, 4,4'-DDE, 2,4'-DDE, 4,4'-DDD, and 2,4'-DDD. Resultant t-DDT concentrations are presented in Table 4 - 11.

Figure 4 - 11: Sculpin and Asiatic clam - Typical species used to measure aquatic organism tissue concentrations

The detection level for each of the parameters was 5 µg/kg (wet weight), so the detection level for t-DDT is the summation of the detection levels for the six components, or 30 µg/kg. Therefore, if neither DDT nor its metabolites was detected, then the t-DDT concentration ranged between zero and 30 µg/kg.

DDT was detected in all samples from the agriculture site, Zollner Creek, and in both samples from the Pudding River at Aurora integrator site (Table 4 - 11). In only one sample, the 1997 sample from Zollner Creek, was the DHS assumed action level for t-DDT of 100 µg/kg exceeded. This was due mostly to an unusually high measured concentration of 4,4'-DDE concentration of 550 µg/kg.

DDT was not detected in fish tissue from the forestry site, Little Abiqua Creek. Therefore, the fish tissue concentrations for samples from this stream ranged from somewhere between zero and 30 µg/kg (Table 4 - 11).

Table 4 - 11: Fish t-DDT concentrations

				Total DDT Concentration wet weight, µg/kg	
Site No	**Site**	**Date**	**Body Part**	**Min**	**Max**
14200400	Little Abiqua Creek Near Scotts Mills	9/15/1993	Organism, whole	0	30
14200400	Little Abiqua Creek Near Scotts Mills	9/15/1993	Organism, whole	0	30
14200400	Little Abiqua Creek Near Scotts Mills	8/15/1997	Organism, whole	0	30
14201300	Zollner Creek Near Mt Angel	9/7/1992	Organism, whole	69	84
14201300	Zollner Creek Near Mt Angel	9/7/1992	Edible portion	9	34
14201300	Zollner Creek Near Mt Angel	9/7/1993	Organism, whole	72	87
14201300	Zollner Creek Near Mt Angel	8/12/1997	Organism, whole	659	664
14202000	Pudding River At Aurora	9/8/1992	Edible portion	56	71
14202000	Pudding River At Aurora	9/21/1993	Edible portion	71	86

CHLORDANE

Chlordane - Water column concentrations

Neither USGS nor ODEQ detected chlordane in water column samples collected in the Pudding River watershed. However, due to difficulties associated with analyzing for chlordane, only a limited number of chlordane results were reported. USGS reported results for only 6 Pudding River and 6 Zollner Creek samples, with results reported for chlordane (technical) and heptachlor. Neither chlordane nor heptachlor was detected in the samples.

ODEQ reported chlordane results as part of its 2005 through 2007 studies for six samples from each of the following sites: Butte Creek at Butte Creek Road (RM 15.8), Little Pudding River at Rambler Road (RM 2.9), Pudding River at Aurora (RM 8.1), Pudding River Near Mt. Angel (RM 40.7), and Zollner Creek Near Mt. Angel (RM 0.4). Chlordane was detected in none of these thirty samples.

The lack of chlordane detections in the USGS and ODEQ samples is inconsistent with the basis for the listing which cites five out of five samples collected from the Zollner Creek near Mt. Angel site that violate the human health criterion of 0.46 ng/L. It is likely that the 2002 listing was an error, perhaps included based on fish tissue chlordane detections (described in the following section of this chapter). DEQ's records indicate that the USGS chlordane analytical results from the Zollner Creek site were reviewed again in 2004 with the status designated "unknown." The Zollner Creek chlordane listing was probably not proposed for removal in 2004 because the detection limit of the analysis (0.1 µg/L) exceeded both the chronic aquatic life (0.0043 µg/L) and the human health criteria (0.46 ng/L = 0.00046 µg/L), so attainment of water quality standards could not be confirmed.

Even very low concentrations could pose an unacceptable risk for bioaccumulation. Due to the limited amount of samples analyzed for chlordane and the high detection levels relative to chronic aquatic life toxicity and human health based criteria, DEQ also evaluated fish tissue concentrations.

Chlordane - Fish tissue concentrations

Fish tissue chlordane component concentrations were measured by USGS in the Pudding River, Zollner Creek, and Little Abiqua Creek in 1992, 1993, and 1997. Components measured were Oxychlordane, trans-Nonachlor, cis-Nonachlor, Heptachlor, trans-Chlordane, and cis-Chlordane. Summations of measured component concentrations are presented in Table 4 - 12.

Table 4 - 12: Fish Chlordane concentrations

Site No	Site	Date	Body Part	Chlordane Concentration wet weight, µg/kg	
				Min	Max
14200400	Little Abiqua Creek Near Scotts Mills	9/15/1993	Organism, whole	0	30
14200400	Little Abiqua Creek Near Scotts Mills	9/15/1993	Organism, whole	0	30
14200400	Little Abiqua Creek Near Scotts Mills	8/15/1997	Organism, whole	0	30
14201300	Zollner Creek Near Mt Angel	9/7/1992	Organism, whole	30	45
14201300	Zollner Creek Near Mt Angel	9/7/1992	Edible portion	0	30
14201300	Zollner Creek Near Mt Angel	9/7/1993	Organism, whole	23	38
14201300	Zollner Creek Near Mt Angel	8/12/1997	Organism, whole	35	50
14202000	Pudding River At Aurora	9/8/1992	Edible portion	0	30
14202000	Pudding River At Aurora	9/21/1993	Edible portion	0	30

The detection level for each of the components was 5 µg/kg (wet weight), so the detection level for chlordane is the summation of the detection levels for each of the six components, or 30 µg/kg. For a majority of the measurements, none of the components were detected. Chlordane was not detected in fish tissue from Little Abiqua Creek or the Pudding River, so the fish tissue concentrations for samples from these streams ranged between zero and 30 µg/kg.

Chlordane was detected in 3 out of 4 fish tissue samples in Zollner Creek. In at least two of these samples, chlordane concentrations exceeded the DHS assumed action level for chlordane of 27 µg/kg. Though DEQ did not confirm water column chlordane detections, DEQ based its response to the chlordane listing on these fish tissue detections. DEQ has made the conservative assumption that chlordane presence in fish tissue exceeding DHS action levels indicates a potential chlordane concentration in surface water exceeding the human health criteria.

Chlordane sorbs to sediment, but to a significantly lesser degree than DDT and dieldrin, which is reflected in lower observed organic carbon-water partitioning coefficients, K_{oc}. The K_{oc} for chlordane is 15,500 to 24,000 L/kg[12] . This indicates that at equilibrium from 8 to 12% of chlordane would be sorbed to sediment vs. from 58% to 96% for DDT and its metabolites and 52% for dieldrin.

DIELDRIN

Zollner Creek is included on the 303(d) List due to observed dieldrin detections. Dieldrin was one of the most frequently detected organochlorine compounds in samples collected from 39 Willamette Basin sites during Phase I and Phase II of the Willamette River Basin Water Quality Study (WRBWQS) (Anderson, et at, 1996). However, dieldrin was not detected by USGS during the Phase III of the WRBWQS (Anderson, et at, 1997).

[12] U.S. EPA fact sheet at: http://www.epa.gov/ogwdw/dwh/t-soc/chlordan.html

Dieldrin - Water column concentrations

Like DDT, dieldrin sorbs to sediment. However, dieldrin sorbs to sediment to a lesser degree than DDT which is reflected in lower observed organic carbon-water partitioning coefficients, K_{oc}. The USGS found that empirical data from the Willamette River Basin was consistent with a K_{oc} of 1,700 mL/g reported by USEPA (Anderson, et al, 1996; Anderson, et al, 1997). This is much lower than the K_{oc} values for DDT and its metabolites (770,000 mL/g for DDD, 4,400,000 mL/g, for DDE and 243,000 mL/g for DDT). Based on this 1,700 mL/g value, dieldrin would be almost completely associated with the dissolved phase, whereas most of DDT would be sorbed to sediment (from 58% to 96% of total DDT would be sorbed to sediment, based on a suspended organic concentration of 5.7 mg/L). However, more recently EPA determined that a more appropriate estimate of K_{oc} for dieldrin is 190,546 mL/g. Based on this updated K_{oc}, 52% of dieldrin would be sorbed to sediment (U.S. EPA, 2003).

Dieldrin Integrator Sites

The State of Oregon has established aquatic life chronic and human health based criteria for dieldrin. None of the samples collected in the Pudding River by either USGS or ODEQ exceeded the aquatic life chronic criterion (Figure 4 - 12). Dieldrin was detected in none of the 10 samples collected recently by ODEQ for which dieldrin concentrations were reported and in none of 34 samples collected by USGS that were filtered prior to analysis. However, dieldrin was detected in 2 of 5 unfiltered USGS samples. Detected concentrations equaled the typical MRL for the method of 0.001 µg/L. While these concentrations are less than the 0.0019 µg/L chronic criterion, they significantly exceed the 0.052 ng/L (0.000052 µg/L) human health based criterion.

The two detected dieldrin concentrations indicate that the Pudding River is impaired for dieldrin. Although this impairment was not included on the 303(d) list, DEQ has determined the load capacity and developed a load allocation for dieldrin in the Pudding River.

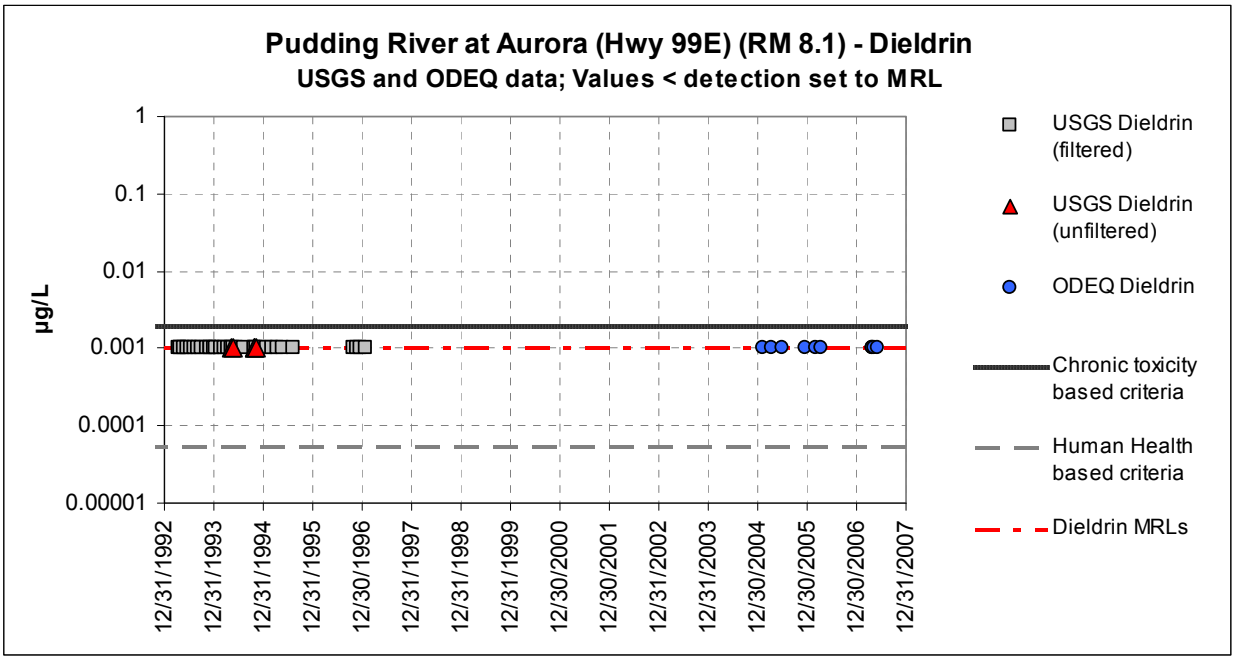

Figure 4 - 12: Pudding River at Aurora (RM 8.1) - "Worst Case" Dieldrin concentrations

Dieldrin - Agriculture Sites

Sampling was performed by both USGS and ODEQ at the Zollner Creek near Mt Angel USGS gage (Monitor-McKee Road Bridge, USGS Gage no. 14201300, ODEQ LASAR No. 10899). Dieldrin is a legacy pesticide which, presumably, has not been applied to Willamette Basin croplands for many years. Therefore, dieldrin concentrations should be declining. A number of significant exceedances of the State of Oregon 0.0019 µg/L chronic and 0.052 ng/L (0.000052 µg/L) human health based criteria were observed in the 1990s. Since then dieldrin has been detected only occasionally (Figure 4 - 13).

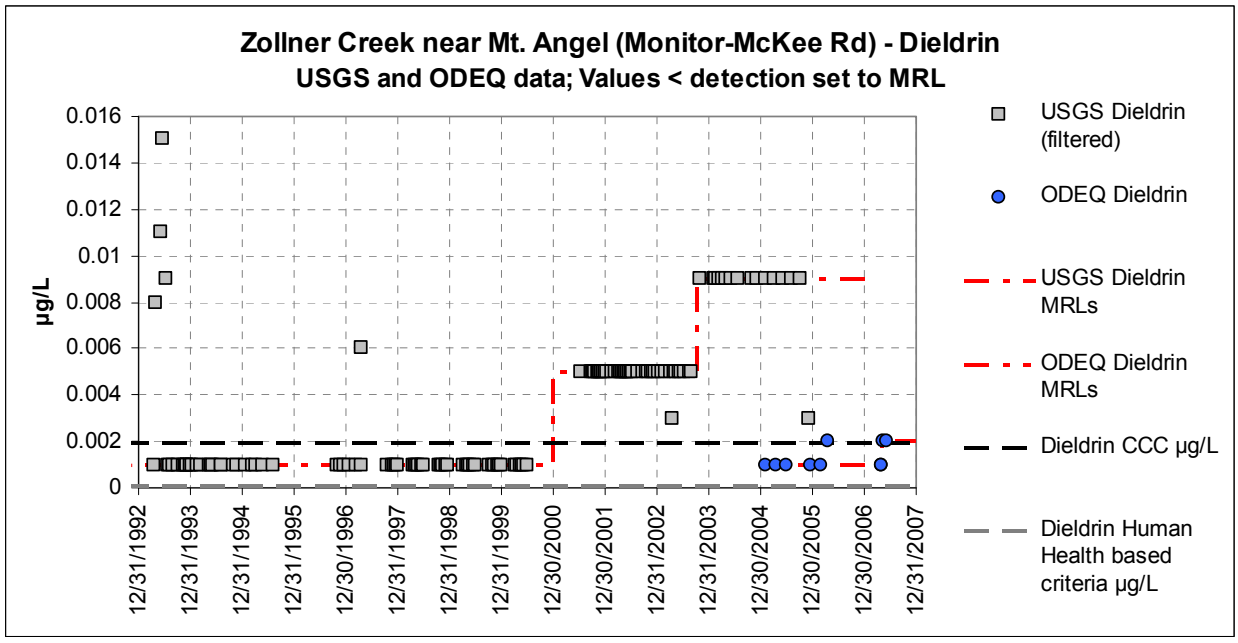

Figure 4 - 13: Zollner Creek near Mt. Angel - "Worst Case" Dieldrin concentrations

Since April, 1997, when a 0.006 µg/L concentration was observed, dieldrin has been detected by USGS only once in Zollner Creek, a 0.003 µg/L estimated concentration observed April, 2003. However, the low frequency of detection may be due to relatively high recent MRLs. The MRL for USGS analyses increased from 0.001 µg/L to 0.005 µg/L in 2000 and to 0.009 µg/L in 2002 (Figure 4 - 13). Therefore, it's inconclusive from this data whether concentrations greater than the 0.0019 µg/L chronic criteria occurred.

DEQ monitored Zollner Creek pesticides starting in 2005, with the MRL generally at 0.001 µg/L. Dieldrin was detected in 2 of 10 samples, with 0.002 µg/L detected April 2006 and 0.001 µg/L detected May 2007 (however, a field duplicate collected at the same time as the May 2007 sample had a concentration below detection, so the second detection may not be conclusive). Neither detection exceeded the chronic criterion, but both exceeded the very low human health based criterion.

Dieldrin - Forestry Sites

Dieldrin was not detected by either USGS or ODEQ at forestry sites.

Dieldrin - Fish tissue concentrations

Fish tissue dieldrin concentrations were measured by USGS in the Pudding River, Zollner Creek, and Little Abiqua Creek in 1992, 1993, and 1997 (Table 4 - 13). Dieldrin was not detected in fish tissue from Little Abiqua Creek or the Pudding River. However, dieldrin was detected in 3 out of 4 samples from Zollner Creek. In these samples dieldrin concentrations exceeded the DHS assumed action level for dieldrin of 2.3 µg/kg.

Table 4 - 13: Fish Dieldrin concentrations

Site No	Site	Sample Date	Body Part	Dieldrin Concentration wet weight µg/kg
14200400	Little Abiqua Creek Near Scotts Mills	9/15/1993	Organism, whole	< 5
14200400	Little Abiqua Creek Near Scotts Mills	9/15/1993	Organism, whole	< 5
14200400	Little Abiqua Creek Near Scotts Mills	8/15/1997	Organism, whole	< 5
14201300	Zollner Creek Near Mt Angel	9/7/1992	Organism, whole	24
14201300	Zollner Creek Near Mt Angel	9/7/1992	Edible portion	< 5
14201300	Zollner Creek Near Mt Angel	9/7/1993	Organism, whole	18
14201300	Zollner Creek Near Mt Angel	8/12/1997	Organism, whole	39
14202000	Pudding River At Aurora	9/8/1992	Edible portion	< 5
14202000	Pudding River At Aurora	9/21/1993	Edible portion	< 5

SUMMARY OF RECENT DATA REVIEW

Recent data collected by ODEQ supports the Pudding River listing for DDT and a TMDL has been developed to address it. DDT was detected in 2 of 6 USGS samples collected at Pudding River at Aurora (river mile 8.1) in 1993 and 1994. ODEQ detected DDT somewhat less frequently during 2005 to 2007. DDT was detected in 1 of 11 ODEQ samples, with the single detection containing an estimated 0.002 µg/L of 4,4'-DDT (both 4,4'-DDD and 4,4'-DDE were below detection).

Recent ODEQ monitoring shows that both Zollner Creek and Little Pudding River contain DDT concentrations that exceed water quality criteria. For the Zollner Creek near Mt. Angel site, DDT was detected in 3 of 10 ODEQ samples and, for the Little Pudding River at Rambler Road site, DDT was detected in 9 of 10 ODEQ samples. DEQ has developed a TMDL that also addresses the DDT impairment in Zollner Creek and the Little Pudding River.

Recent data collected by ODEQ supports the Zollner Creek listing for dieldrin. Dieldrin was detected in 2 of 10 ODEQ Zollner Creek samples, with 0.002 µg/L detected April 2006 and 0.001 µg/L detected May 2007 (although a field duplicate collected at the same time as the May 2007 sample had a concentration below detection, so the second detection may not be conclusive). Neither detection exceeded the chronic criteria, but both exceeded the very low human health based criteria. The data review also indicated that the Pudding River may also be impaired by dieldrin, though this impairment was not included on the 303(d) list. In two of five USGS samples collected in 1994, dieldrin concentrations did not exceed the aquatic life chronic criterion, but did exceed the human health based criterion. Dieldrin impairments in both Zollner Creek and the Pudding River are addressed with this TMDL.

According to the 303(d) list, five of five USGS samples from Zollner Creek exceeded the 0.46 ng/L human health based criteria for chlordane. A review of the data did not confirm these results, but rather found five Zollner Creek samples collected by USGS in which chlordane was not detected above 0.1 µg/L. Chlordane was measured in fish tissue in three of four samples from Zollner Creek collected by USGS. ODEQ did not detect chlordane in any of 30 samples collected 2005 to 2007 from Butte Creek, Little Pudding River, Pudding River, and Zollner Creek. While water column data does not support the listing, detection levels for chlordane are much higher than both aquatic life chronic and human health based criteria, so it cannot be concluded that the criteria are being met. Analyses of fish tissue performed by USGS in 1992, 1993, and 1997 showed that tissue concentrations of chlordane slightly exceeded Oregon Department of Human Services assumed action levels in 3 out of 4 samples collected from Zollner Creek. This suggests that Zollner Creek water column concentrations may have exceeded human health based criteria, at least prior to 1997. No chlordane was detected in fish tissue samples collected from Little Abiqua Creek or Pudding River and no tissue samples have been analyzed since 1997. DEQ has made a conservative assumption that chlordane measured in fish tissue may indicate water column concentrations exceeding the human health criterion and has developed a TMDL to address potential chlordane criteria exceedances in Zollner Creek.

LOADING CAPACITY

The load of a pollutant in a stream may be calculated as follows:

$$Load(\frac{g}{day}) = concentration\frac{ug}{L} * Q\frac{ft^3}{s} * 28.32\frac{L}{ft^3} * 86400\frac{s}{day} / 1{,}000{,}000\frac{\mu g}{g}$$

EPA guidance recommends the use of the long-term harmonic mean flow to implement human health criteria (Technical Support Document for Water Quality-based Toxics Control, EPA 505/2-90-001, March 1991, p.88). Therefore, long-term average human health based loading capacities for DDT, chlordane and dieldrin are derived as follows, with long-term harmonic mean stream flow used for Q:

$$LoadingCapacity(\frac{g}{day}) = criteria\frac{ug}{L} * Q\frac{ft^3}{s} * 28.32\frac{L}{ft^3} * 86400\frac{s}{day} / 1{,}000{,}000 \quad \text{Equation 1}$$

Loading capacities for DDT, the DDT metabolites DDE and DDD, and chlordane and dieldrin are shown for the three streams in Table 4 - 14. In addition to the metabolites, a loading capacity for total DDT (t-DDT = 4-4'-DDT + 4-4'-DDE + 4-4'-DDD) is provided. This is based on a target t-DDT concentration of 0.000554 µg/L, which sums the Table 20 human health criterion for 4-4'-DDT with the Table 33A criteria for 4-4'-DDE and 4-4'-DDD (0.000554 = 0.000024 + 0.00022 + 0.00031).

Table 4 - 14: Loading Capacities (g/day)

	Mean Flow (cfs)	Median Flow (cfs)	Harmonic Mean Flow (cfs)	4-4'-DDT	4-4'-DDE	4-4' DDD	Total DDT	Chlordane	Dieldrin
ODEQ Criteria Table	-	-	-	20	33A	33A	20 and 33A	20	33A[13]
Criterion (µg/L)	-	-	-	0.000024	0.00022	0.00031	0.000554	0.00046	0.000052
Zollner Creek	21.6	4.5	0.8	**0.00005**	**0.00043**	**0.00061**	**0.00108**	**0.00090**	**0.00010**
Little Pudding R	43.1	9.0	1.6	**0.00009**	**0.00086**	**0.00121**	**0.00217**	**0.00180**	**0.00020**
Pudding R at Aurora	1290	553	106.3	**0.00624**	**0.05722**	**0.08063**	**0.14408**	**0.11964**	**0.01352**

Unlike human health based criteria, which must be met on a long-term average basis, aquatic life chronic toxicity based criteria must be met on a 96-hr average basis. Therefore the loading capacity varies with flow. Loading capacities for such criteria are best described through the use load duration curves, which show allowable loads for all flow conditions (Figure 4 - 14 to Figure 4 - 19). The technical basis for development of load duration curves is included in Appendix F, but generally, the load duration curve illustrates pollutant loading across a range of stream flows. Historical stream flow data is used to estimate the likelihood that a certain flow would be exceeded, referred to as the exceedance probability. For example, low flows have a high exceedance probability and high flows have a low exceedance probability. Load duration curves for DDT, chlordane and dieldrin are presented below.

DDT

Load duration curves for DDT are presented for Pudding River at Aurora USGS gage (14202000) in Figure 4 - 14. This applies for the 303(d) listed reach of the Pudding River (RM 0 to 35.4). Load duration curves for DDT are also provided for Zollner Creek (Figure 4 - 15) and Little Pudding River (Figure 4 - 16), since available data shows that water quality criteria for DDT are exceeded in these streams and since

[13] Table 33A criterion used as target since more conservative than Table 20 criterion

these streams contribute to the exceedances in the Pudding River. Therefore, although Zollner Creek and Little Pudding River are not 303(d) listed for DDT, TMDLs are needed to address water quality criteria exceedances

In the figures, load duration curves for human health based criteria are presented in addition to curves for aquatic life chronic criteria. These illustrate that human health based criteria are much more conservative than aquatic life criteria. While, in general, loads should not exceed the values shown by these curves, the loading capacities for human health based criteria are not defined by these curves, but rather by the long-term average loads presented in Table 4 - 14.

Curves are provided for 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD. 4,4'-DDT curves are based on EPA approved Table 20 criteria. 4,4'-DDE, and 4,4'-DDD are based on Table 33A criteria. Table 33A criteria have not been approved by EPA but were adopted by the Oregon Environmental Quality Commission and, therefore, levels of toxic substances in waters of the state may not exceed the applicable criteria listed in either Tables 20 or 33A (OAR 340-041-0033).

The human health based criterion for 4-4'-DDT is roughly an order of magnitude less than the Table 33A human health based criteria for DDT metabolites 4-4'-DDE and 4-4'-DDD. Therefore, it is likely that if the 4-4'-DDT human health based criterion is met, then criteria for DDE and DDD will also be met.

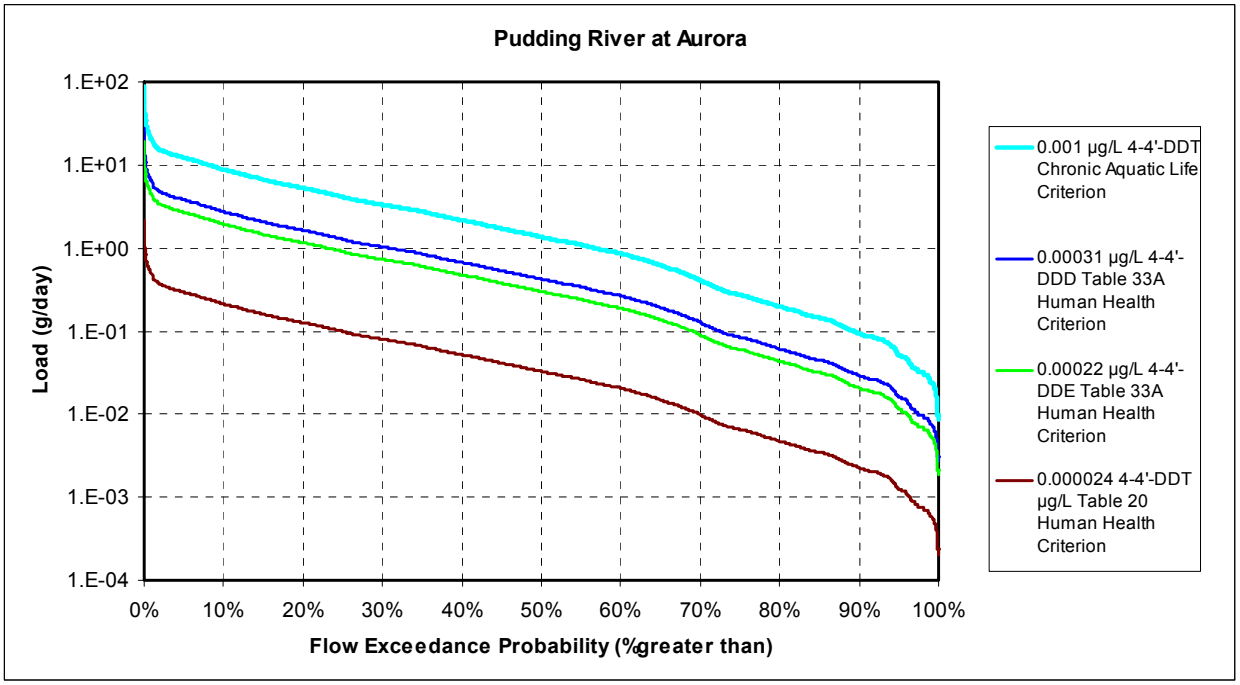

Figure 4 - 14: Pudding River 4-4'-DDT loading capacity load duration curve.

Figure 4 - 15 presents load duration curves for Zollner Creek. Stream flow for the curve is via the Zollner Creek near Mt. Angel USGS gage (14201300).

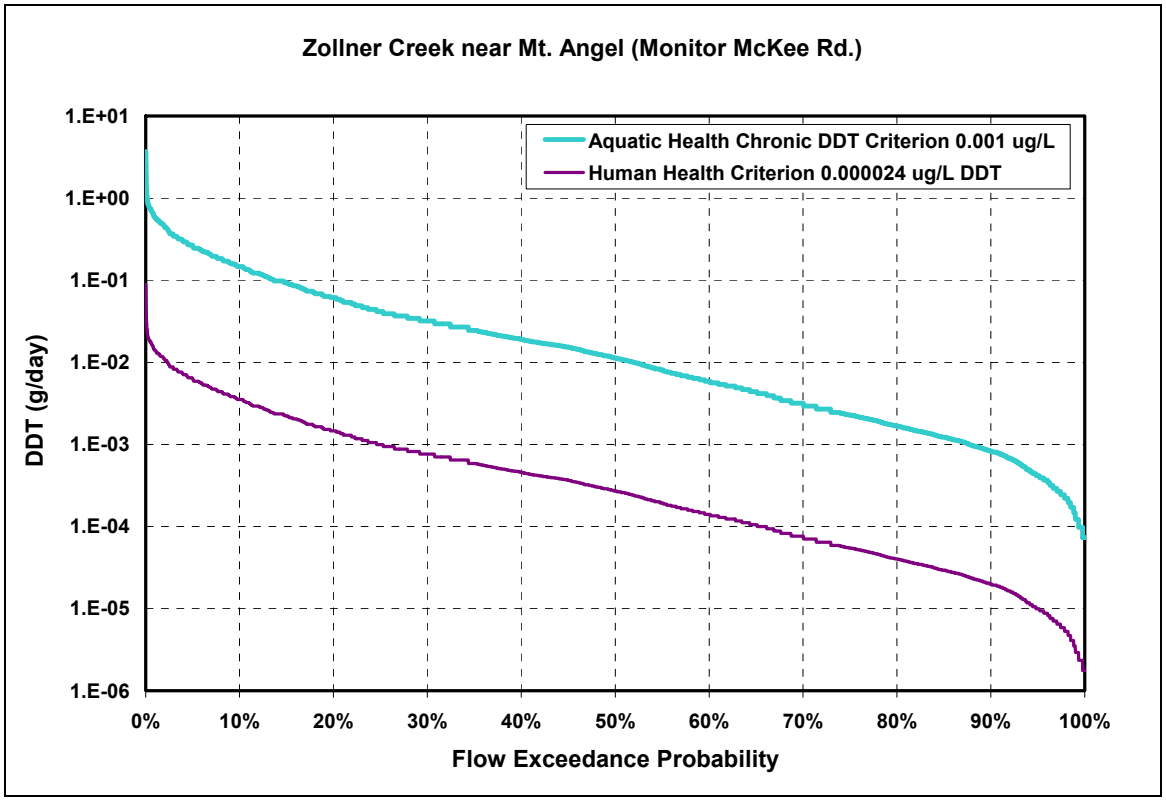

Figure 4 - 15: Zollner Creek 4-4'-DDT loading capacity load duration curve.

Figure 4 - 16 presents load duration curves for Little Pudding River. Stream flow for the curves is estimated at twice the flow at the Zollner Creek near Mt. Angel USGS gage (14201300). DEQ's justification for this flow estimate is explained in Appendix J in the section titled, "Little Pudding River Load Duration Curves."

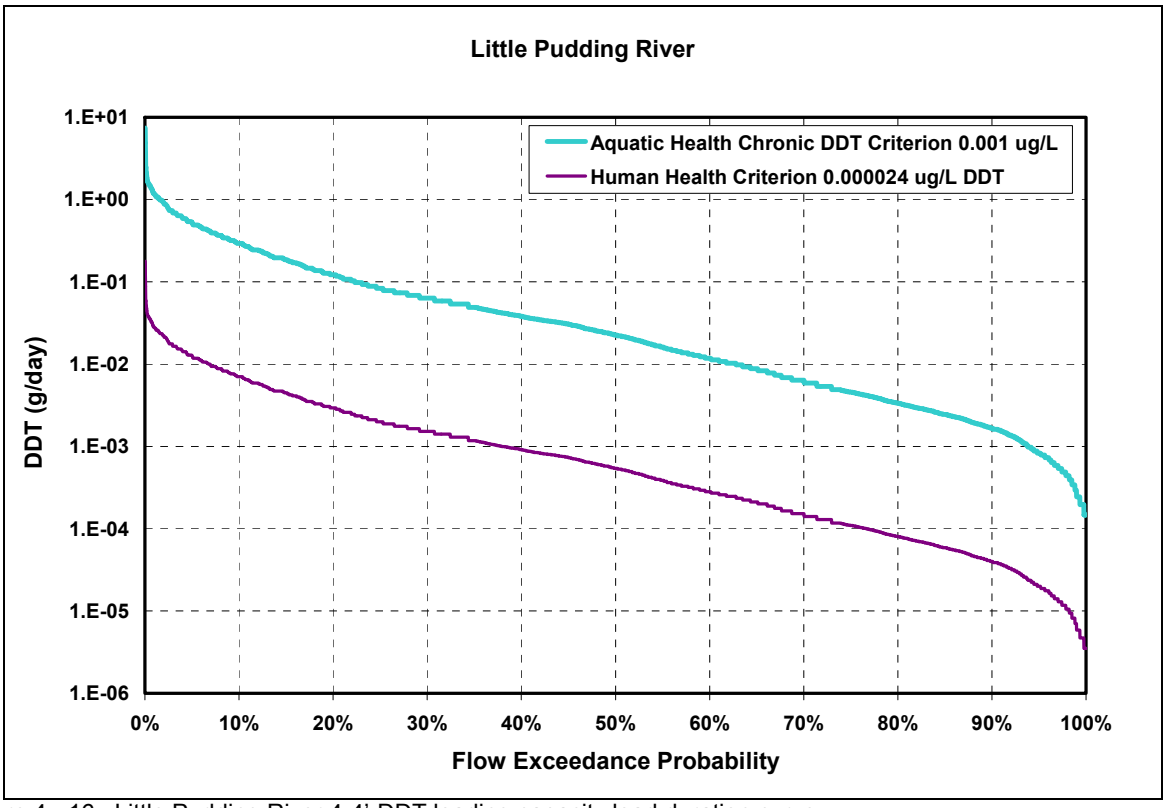

Figure 4 - 16: Little Pudding River 4-4'-DDT loading capacity load duration curve.

Chlordane

Load duration curves for chlordane are presented only for Zollner Creek (Figure 4 - 17). Zollner Creek is the only stream in the Subbasin 303(d) listed for chlordane and it is the only stream for which fish tissue action levels for chlordane were shown to be exceeded.

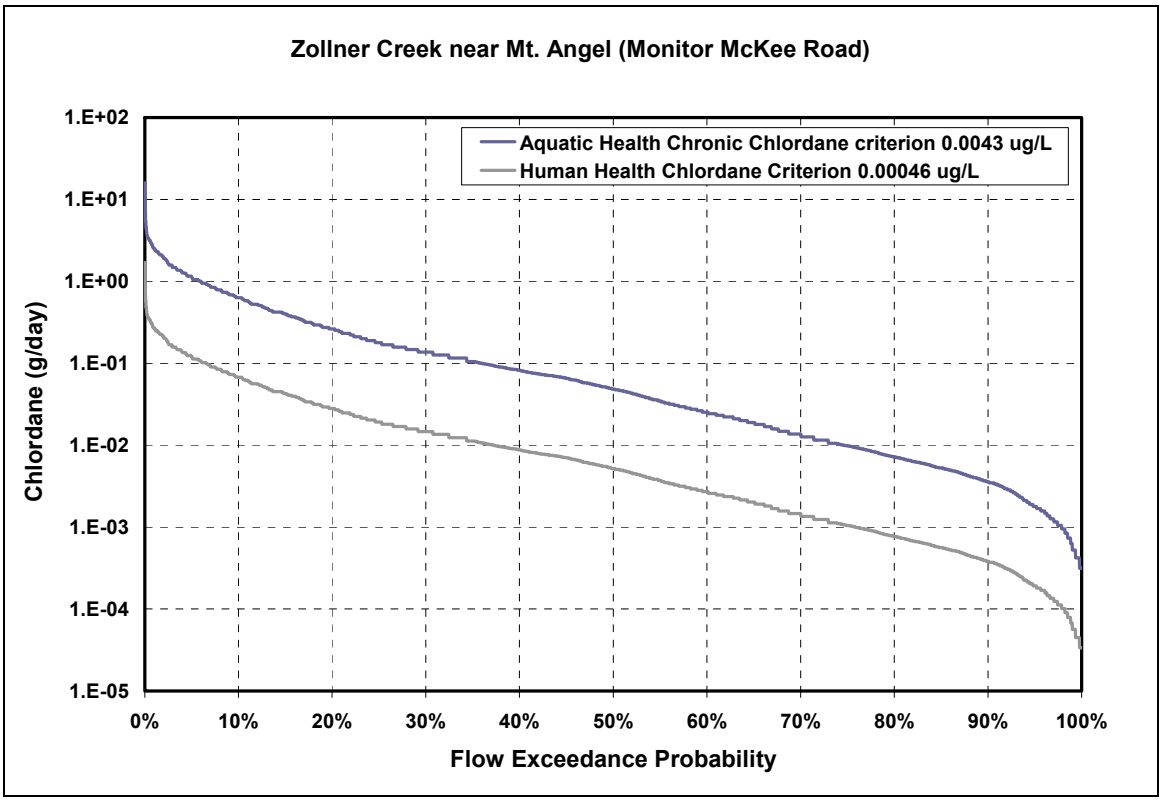

Figure 4 - 17: Zollner Creek chlordane loading capacity load duration curve.

DIELDRIN

Load duration curves for dieldrin are presented only for Pudding River at Aurora and Zollner Creek (Figure 4 - 18 and Figure 4 - 19). Zollner Creek contains elevated water column and fish tissue concentrations of dieldrin and is 303(d) listed for dieldrin due to criteria exceedances. The Pudding River at Aurora is not 303(d) listed for dieldrin, but water column concentrations in the stream have at times been shown to exceed water quality criteria. Therefore, a TMDL is needed to address water quality criteria exceedances.

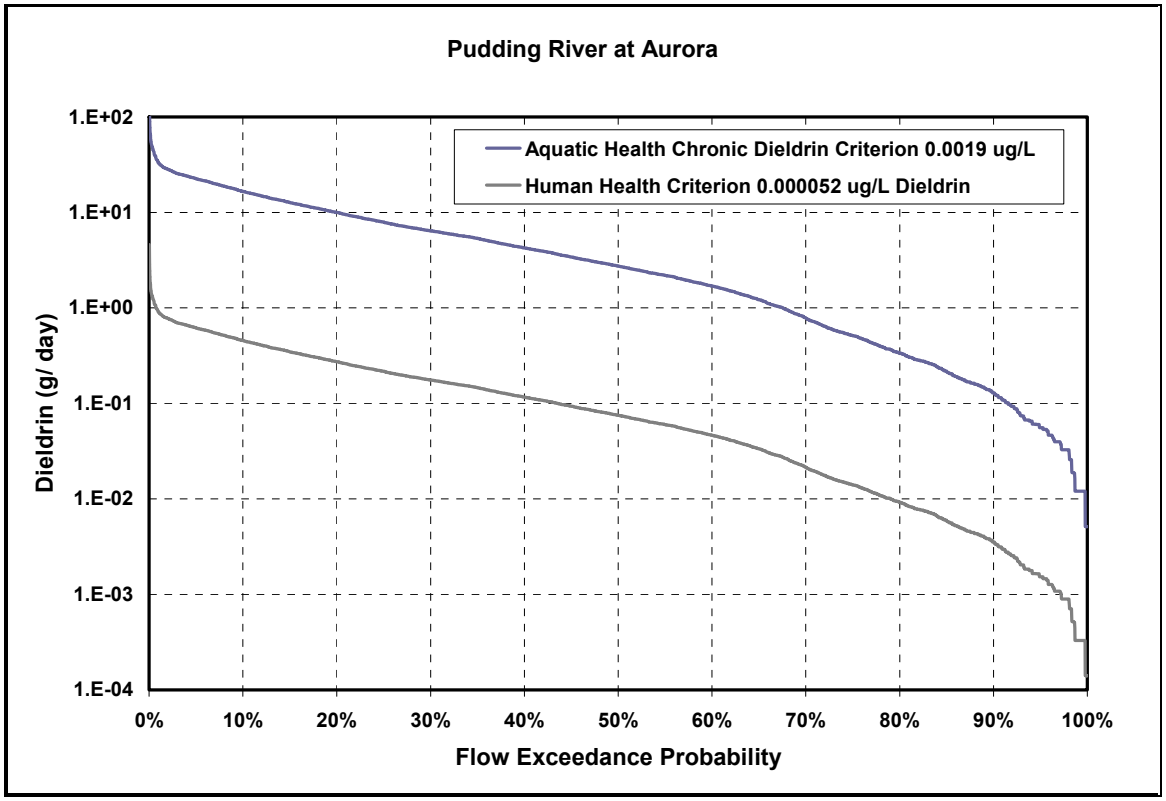

Figure 4 - 18: Pudding River dieldrin loading capacity load duration curve.

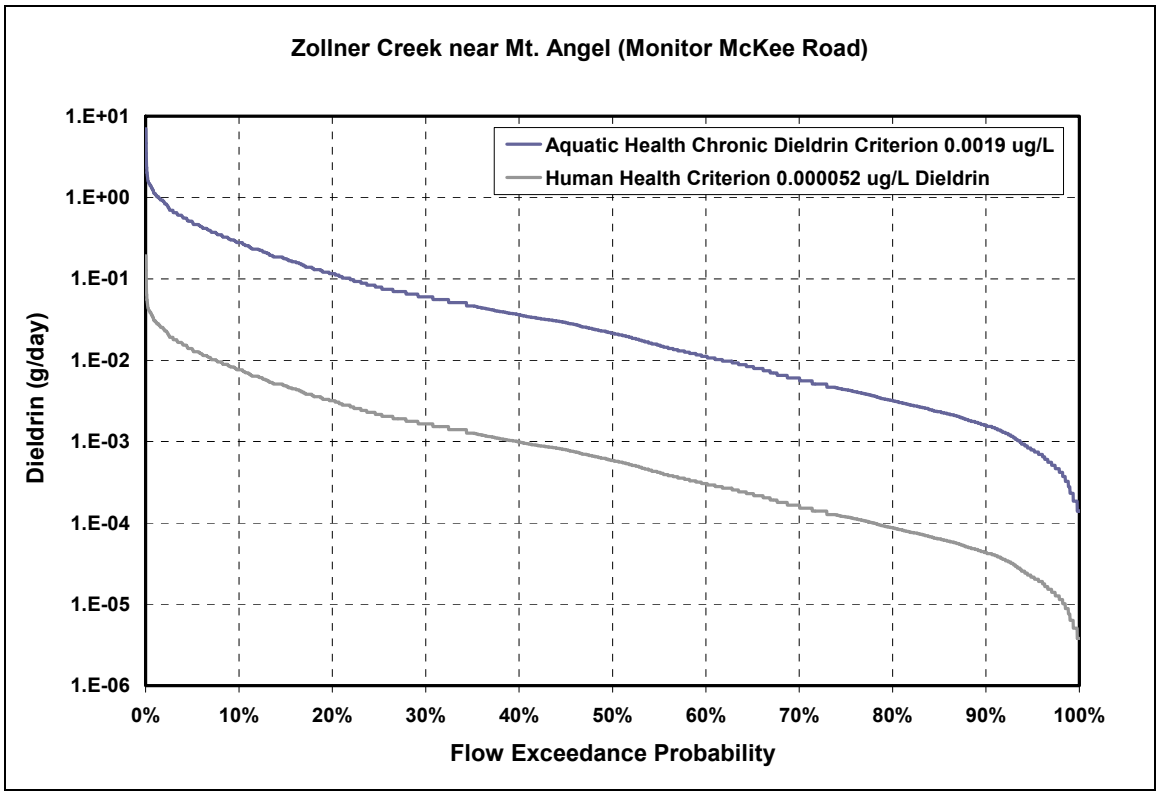

Figure 4 - 19: Zollner Creek dieldrin loading capacity load duration curve.

EXCESS LOADS

A review of existing data indicates that DDT and dieldrin water column concentrations exceed State of Oregon water quality criteria. In addition, DDT, chlordane and dieldrin fish tissue concentrations exceed assumed State of Oregon action levels. Therefore, these waterbodies contain excess loads of these pollutants. The excess load for a pollutant is the difference between the current pollutant load and the pollutant load that can be assimilated by a water body (the loading capacity) without violating water quality standards.

For human health based criteria, loading capacities are long-term averages. If current long-term average loads are known, excess loads can be calculated by subtracting the loading capacities shown in Table 4 - 14 from current loads. For DDT, chlordane, and dieldrin, insufficient data is available to determine long-term average loads, partly because observed concentrations are often below detection. Therefore, instead of comparing current long-term average loads to loading capacities, observed average concentrations are estimated and compared to human health criteria to determine excess loads and required percent reductions.

In order to calculate averages in cases where some of the observations are above detection levels and some are below, values below detection are set to ½ of detection levels and included in the dataset along with values above detection levels. An example of such a case is Zollner Creek 4,4'-DDT (see Figure 4 - 24). In cases where all observations are below detection, no determination can be made regarding what, if any, percent reductions are required. An example of such a case is Zollner Creek 4,4'-DDD (see Figure 4 - 26).

For aquatic life criteria, loading capacities are 96-hr averages and, consequently, vary with flow. In order to determine excess loads relative to aquatic life criteria, individual observations are assumed to represent 96-hr averages and are compared to aquatic life criteria to determine excess loads and

required percent reductions. An example of such a case is Little Pudding River 4-4'-DDT (see Figure 4 - 28). As shown, for high flow conditions a percent reduction of up to 98% is needed to meet aquatic life criteria. For low flow conditions a percent reduction up to 88% is required. In addition, in order to meet human health criteria, a reduction in long-term average concentrations of more than 99% is required.

In addition to excess loads based on human health and aquatic life criteria, excess loads may be estimated using fish tissue concentrations. An example is shown in Figure 4 - 27.

The following describes required percent reductions for DDT, chlordane, and dieldrin though the use of load duration curves and other plots. In addition, required percent reductions are summarized below in the Load Allocations section.

DDT

Water column data for DDT is available for the Pudding River at Aurora, Little Pudding River, and Zollner Creek. In addition, fish tissue data is available for Pudding River at Aurora and Zollner Creek.

Pudding River

All 4,4'-DDT detections in the Pudding River occurred during high flow conditions (Figure 4 - 20). Only one ODEQ measurement, an estimated value, was above detection. Two USGS measurements, both from 1994, were above detection. All transition and low flow measurements were below the 0.001 µg/L detection level. Based on the detections, up to 50% reductions are required at high flows to meet aquatic life chronic criteria. Calculating the average concentration by setting all non-detects to ½ of detection levels produces an average concentration estimate of 0.00072 µg/L. In order to meet the Table 20 human health criterion of 0.000024 µg/L, the estimated long-term average concentration would need to be reduced by approximately 97%. In order to meet the less conservative Table 33B human health criteria of 0.00022 µg/L (approved by Oregon Environmental Quality Commission but not effective since not approved by EPA), an approximately 69% reduction is needed.

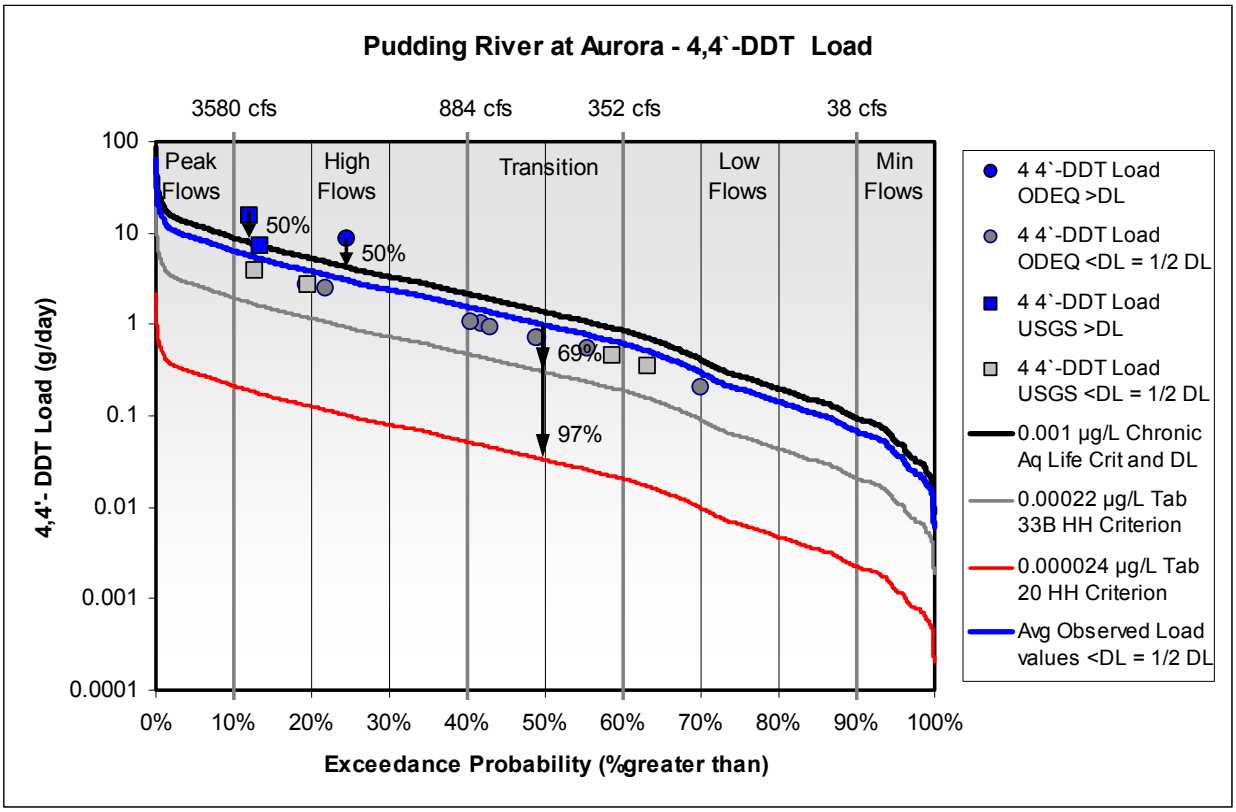

Figure 4 - 20: Pudding River 4,4'-DDT Excess Loads

All recent 4,4'-DDE measurements for the Pudding River, including all those by ODEQ, were below detection (Figure 4 - 21). Two concentrations were measured by USGS in 1994 at the 0.001 µg/L detection level. Calculating the average concentration by setting all non-detects to ½ of detection levels produces an average concentration estimate of 0.00056 µg/L. In order to meet the Table 33A human health criterion of 0.00022 µg/L, the estimated long-term average concentration would need to be reduced by approximately 61%.

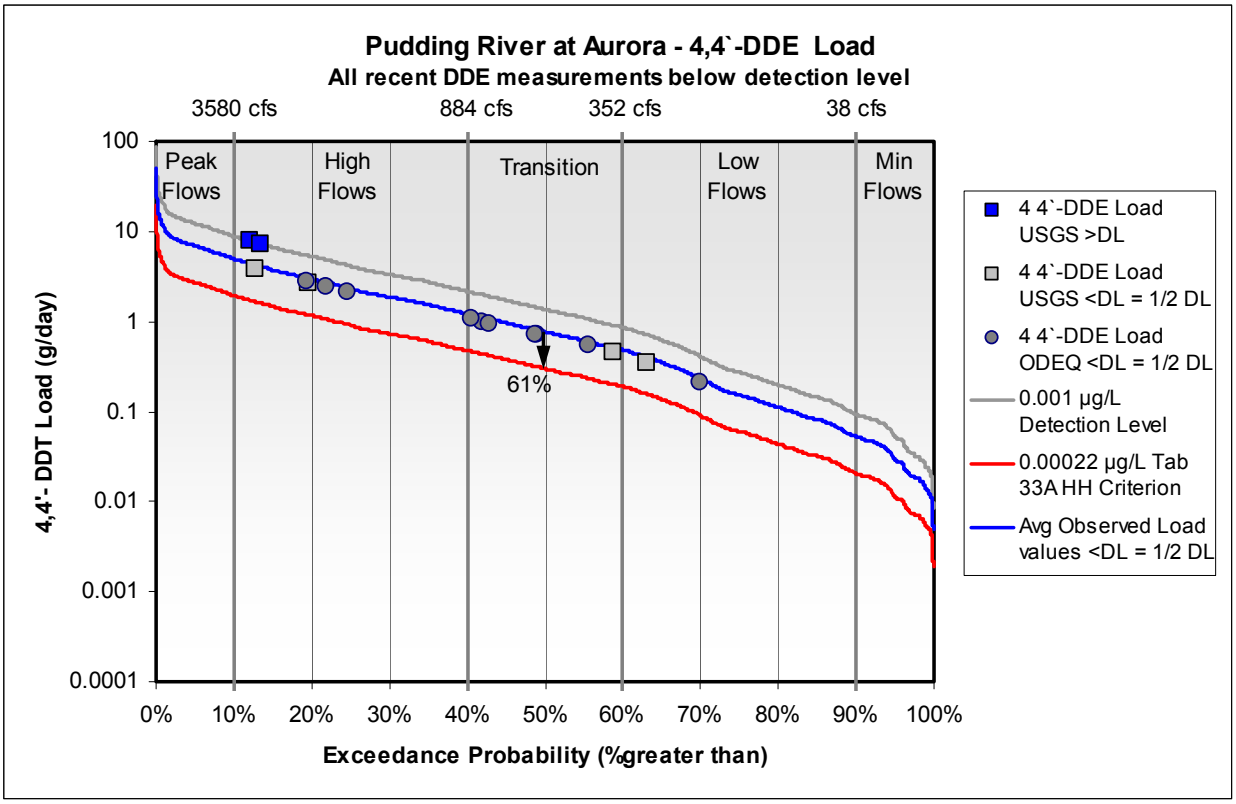

Figure 4 - 21: Pudding River 4,4'-DDE Excess Loads

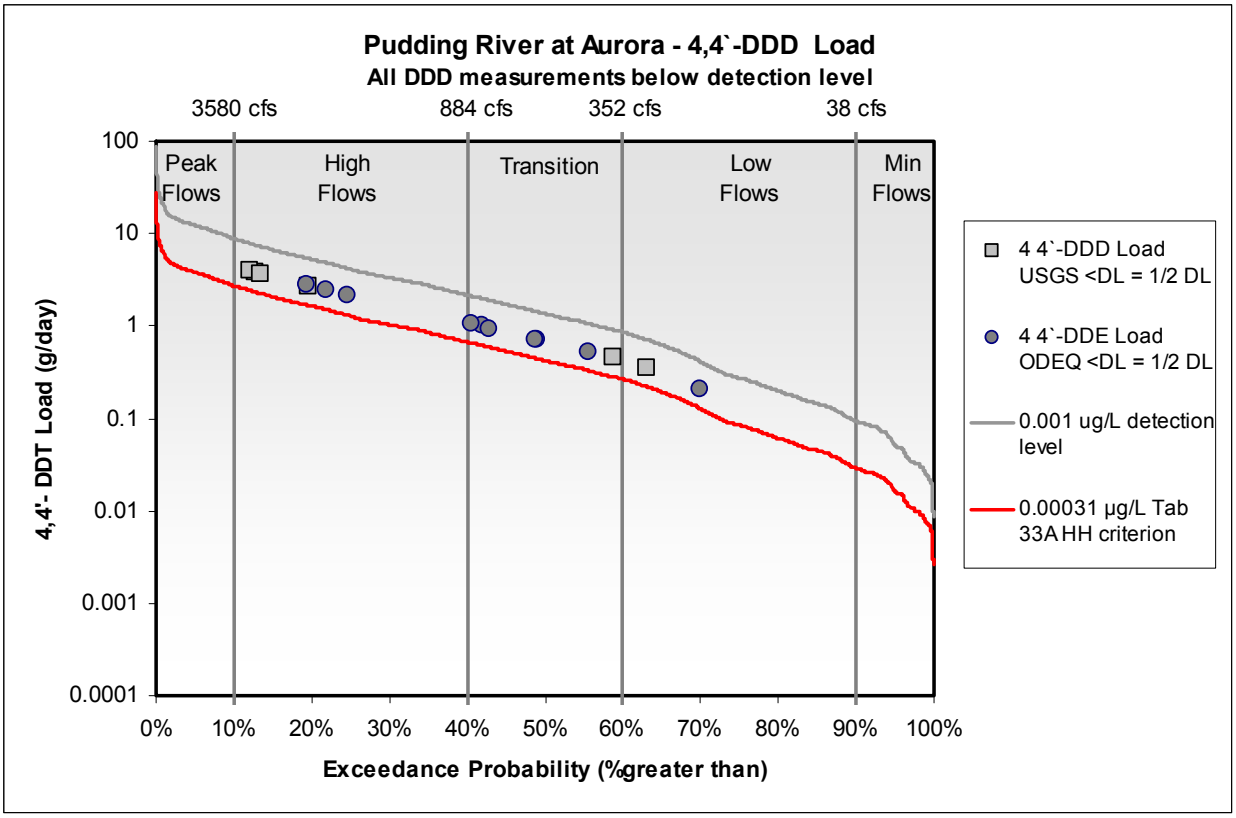

Figure 4 - 22: Pudding River 4,4'-DDD Excess Loads

All Pudding River 4,4'-DDD measurements were below detection (Figure 4 - 22). Therefore, excess loads and required load reductions could not be derived from water column data.

Two fish tissue concentrations were measured at Pudding River at Aurora (Figure 4 - 23). Both showed detectable and significant concentrations of total DDT (t-DDT = DDT + DDE + DDD). The first measurement ranged from 56 to 71 µg/kg t-DDT and the second 71 to 86 µg/kg t-DDT. These concentrations approach but do not exceed the Oregon DHS assumed action level of 100 µg/kg.

Due to the small amount of fish tissue data available, it is appropriate to provide for a margin of safety. A margin of safety is provided by targeting fish tissue concentration equal to ½ of the DHS action level, in this case 50 µg/kg. To meet a 50 µg/kg target, a 30% reduction in fish tissue concentrations is required. Note, however, that percent reductions needed to meet water column concentrations exceed this amount, so the water column based percent reductions determine the DDT reductions required.

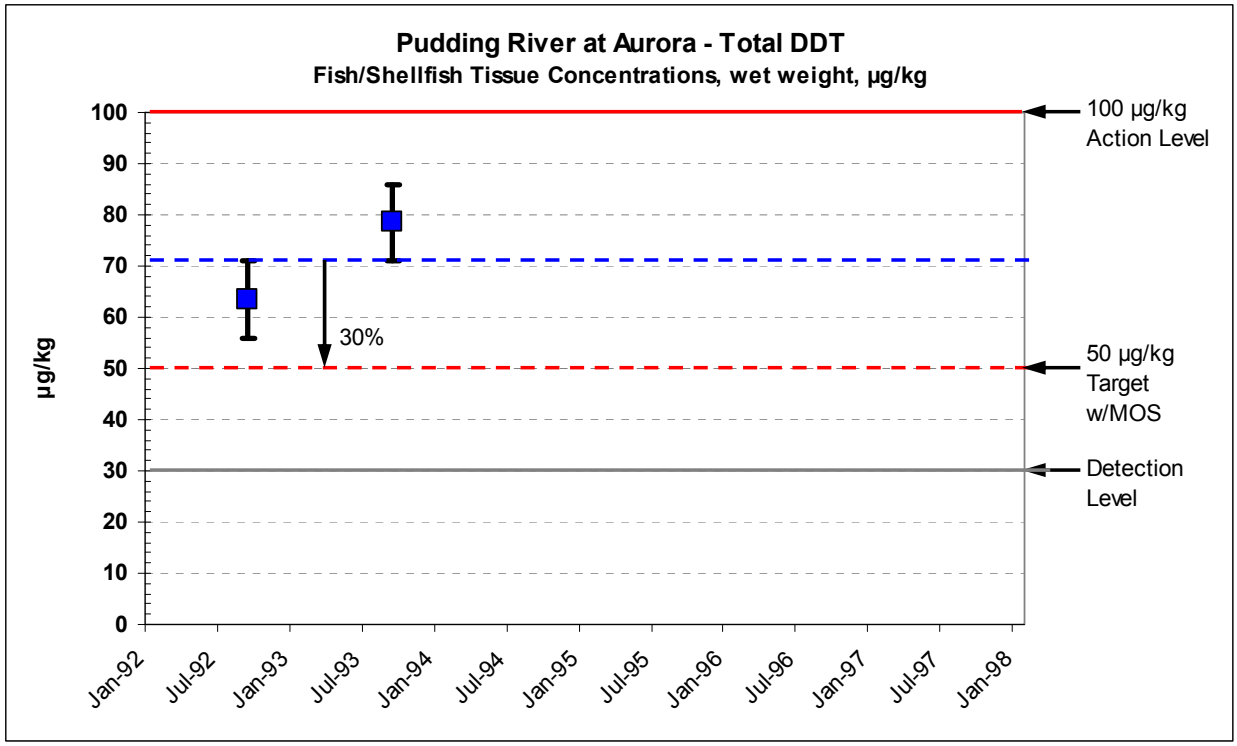

Figure 4 - 23:: Pudding River Total DDT Fish Tissue Concentrations

For DDT, since DDT strongly associates with solids, excess loads may be estimated using observed relationships between t-DDT (total DDT = DDT + DDE + DDD) and total suspended solids (TSS). Excess loads for t-DDT are the differences between current total suspended solids (TSS) loads and the TSS loads that will reduce t-DDT concentrations to levels that meet both chronic and human health criteria. DEQ has developed a relationship that correlates t-DDT concentrations with total suspended solids (TSS) concentrations in the Little Pudding River and a mass balance model that predicts Pudding River t-DDT loading from t-DDT loading in the Little Pudding River and Zollner Creeks. Both models are explained in detail in Appendix J and target TSS target concentrations designed to meet t-DDT targets in the Pudding River are presented in the Load Allocations section.

Zollner Creek

4,4'-DDT was detected in Zollner Creek during high and transition flow conditions (Figure 4 - 24). Calculating the average concentration by setting all non-detects to ½ of detection levels produces an average concentration estimate of 0.0041 µg/L. In order to meet the Table 20 human health criterion of 0.000024 µg/L, the estimated long-term average concentration would need to be reduced by approximately 99%. In order to meet the less conservative Table 33B human health criteria of 0.00022 µg/L (approved by Oregon Environmental Quality Commission but not effective since not approved by EPA), an approximately 95% reduction is needed. Similar reductions are also needed to meet aquatic life chronic criteria.

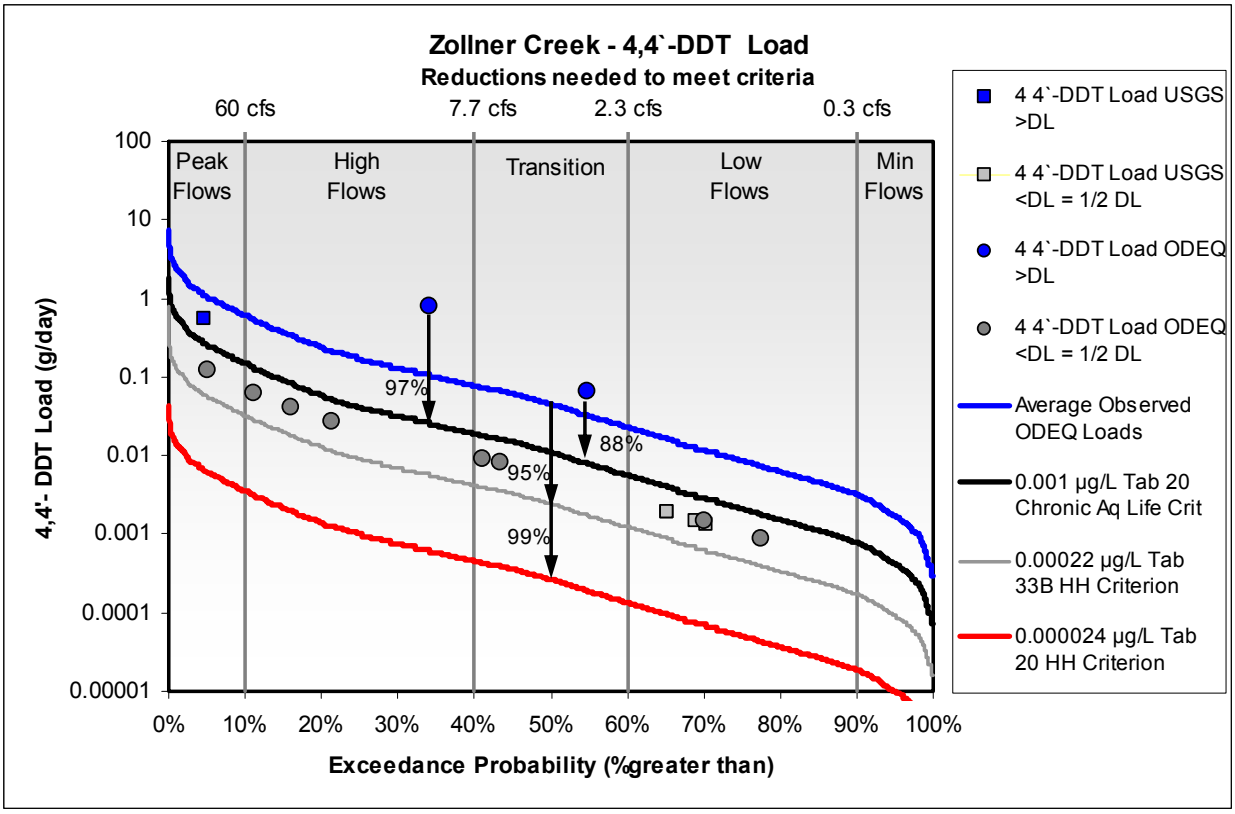

Figure 4 - 24: Zollner Creek 4,4'-DDT Excess Loads

4,4'-DDE was detected in Zollner Creek during high flow conditions (Figure 4 - 25). Calculating the average concentration by setting all non-detects to ½ of detection levels produces an average concentration estimate of 0.00075 µg/L. In order to meet the Table 33A human health criterion of 0.00022 µg/L, the estimated long-term average concentration would need to be reduced by approximately 71%.

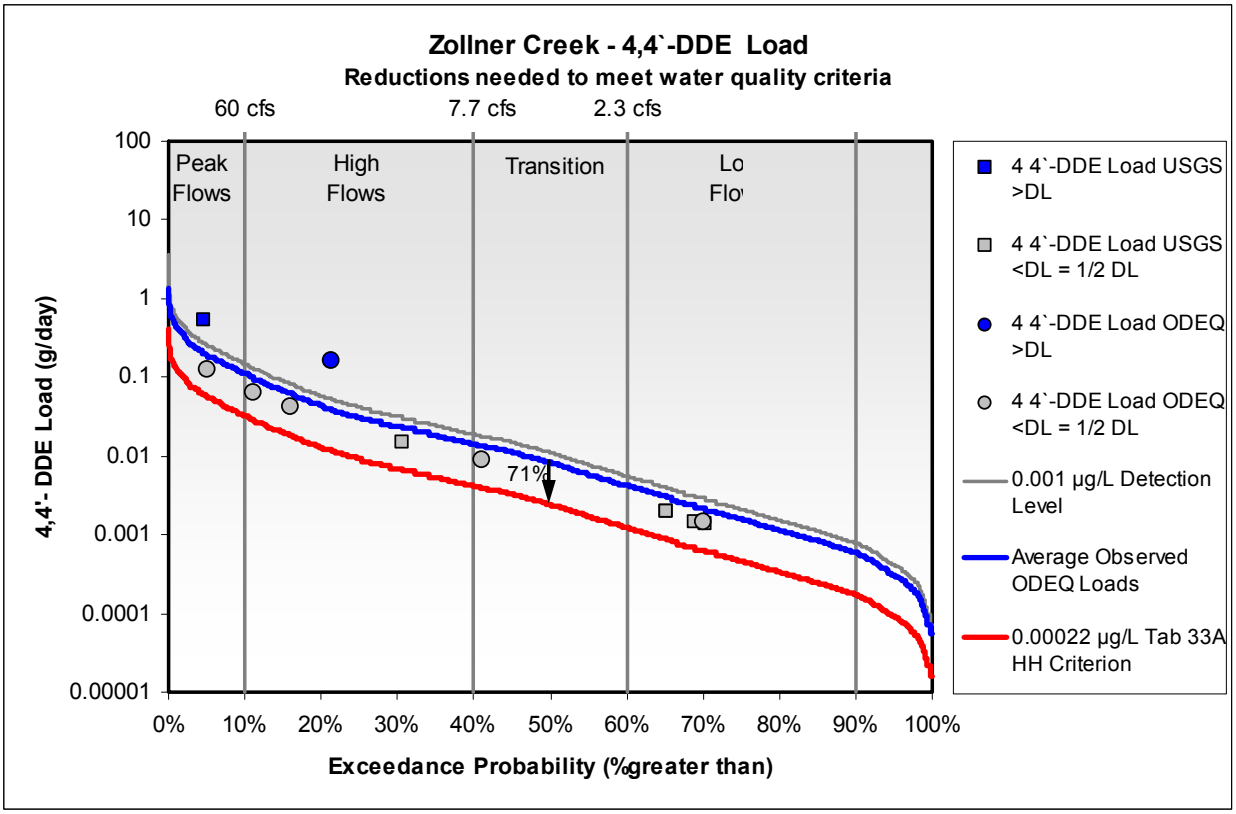

Figure 4 - 25: Zollner Creek 4,4'-DDE Excess Loads

4,4'-DDD was not detected in Zollner Creek. Therefore, necessary percent reductions could not be determined for DDD (Figure 4 - 26).

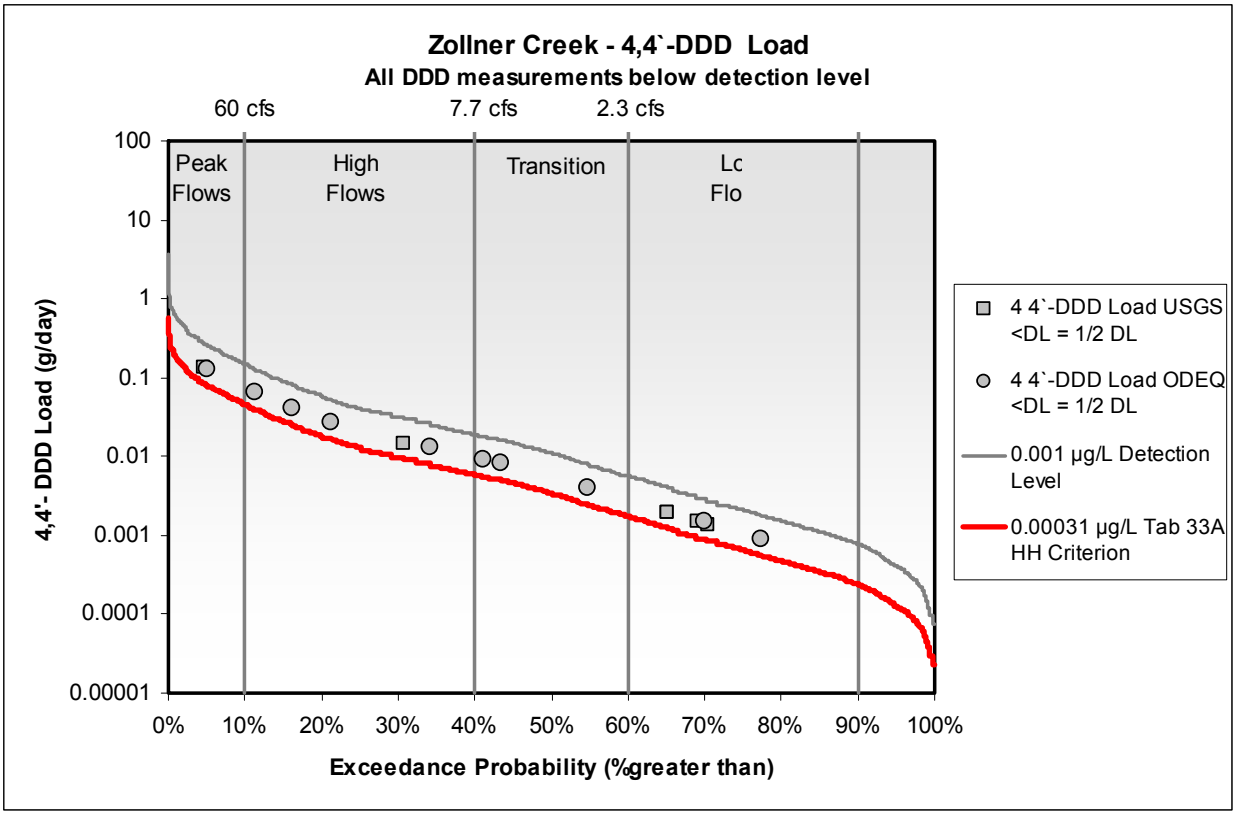

Figure 4 - 26: Zollner Creek 4,4'-DDD Excess Loads

Zollner Creek fish tissue t-DDT concentrations are of concern (Figure 4 - 27). Two of four measurements approached the 100 µg/kg DHS assumed action level, while a third was more than 6 times greater than the action level. Based on average concentrations, a 52% reduction in fish tissue concentrations is needed.

Due to the small amount of fish tissue data available, a margin of safety is provided by targeting a fish tissue concentration equal to ½ of the DHS action level. In the case of t-DDT, this is 50 µg/kg. To meet a 50 µg/kg action level, a 76% reduction in fish tissue concentrations is required.

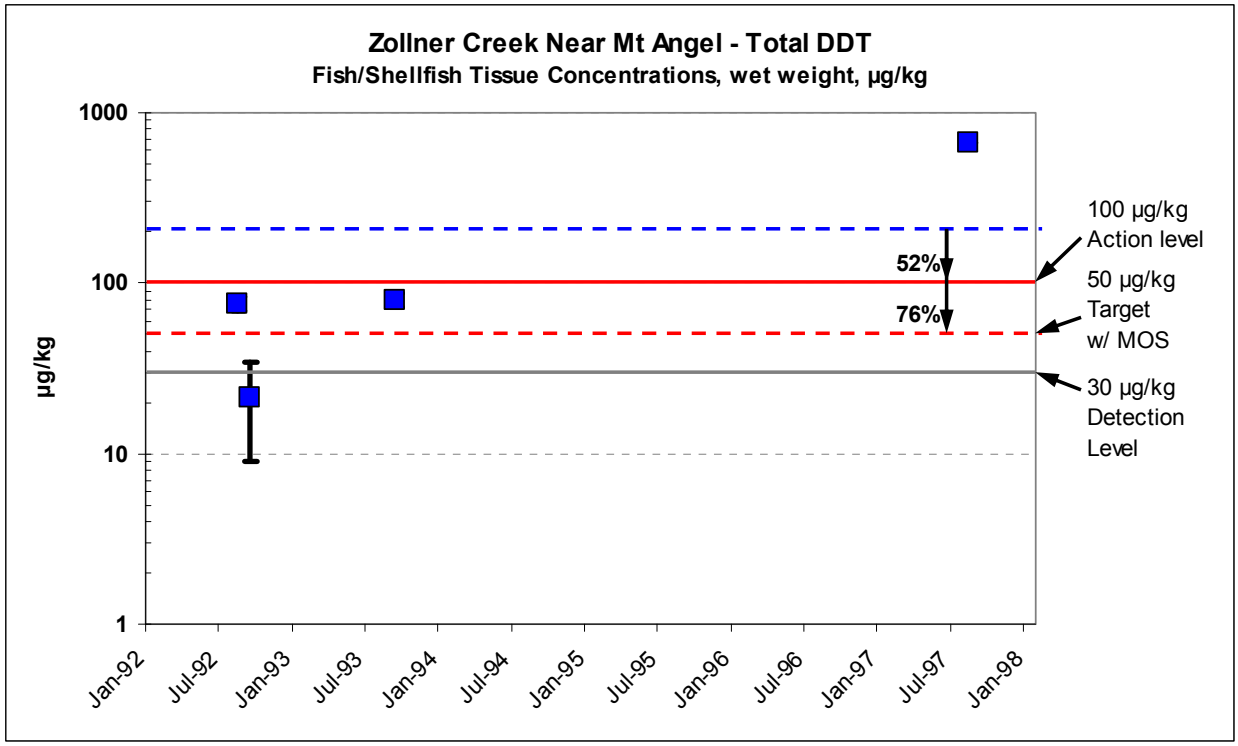

Figure 4 - 27: Zollner Creek Total DDT Fish Tissue Concentrations

Little Pudding River

Monitoring performed by ODEQ indicates that the Little Pudding River contains unusually high levels of DDT. Nearly all measurements were above detection, with most well above the chronic aquatic life criterion (Figure 4 - 28). Reductions of up to 98% are needed for high flow conditions and 88% for low flow conditions simply to meet the chronic criterion. Greater than 98% reductions in long-term average concentrations are required to meet the applicable human health criterion. Even if the proposed Table 33B human health criterion, which is an order of magnitude larger than the current Table 20 criterion, were to be approved by EPA, 98% percent reductions would still be required. Although flow from the Little Pudding River comprises only a small percentage of the total flow of the Pudding River, the data suggests that it is a major source of the DDT loads to the Pudding River.

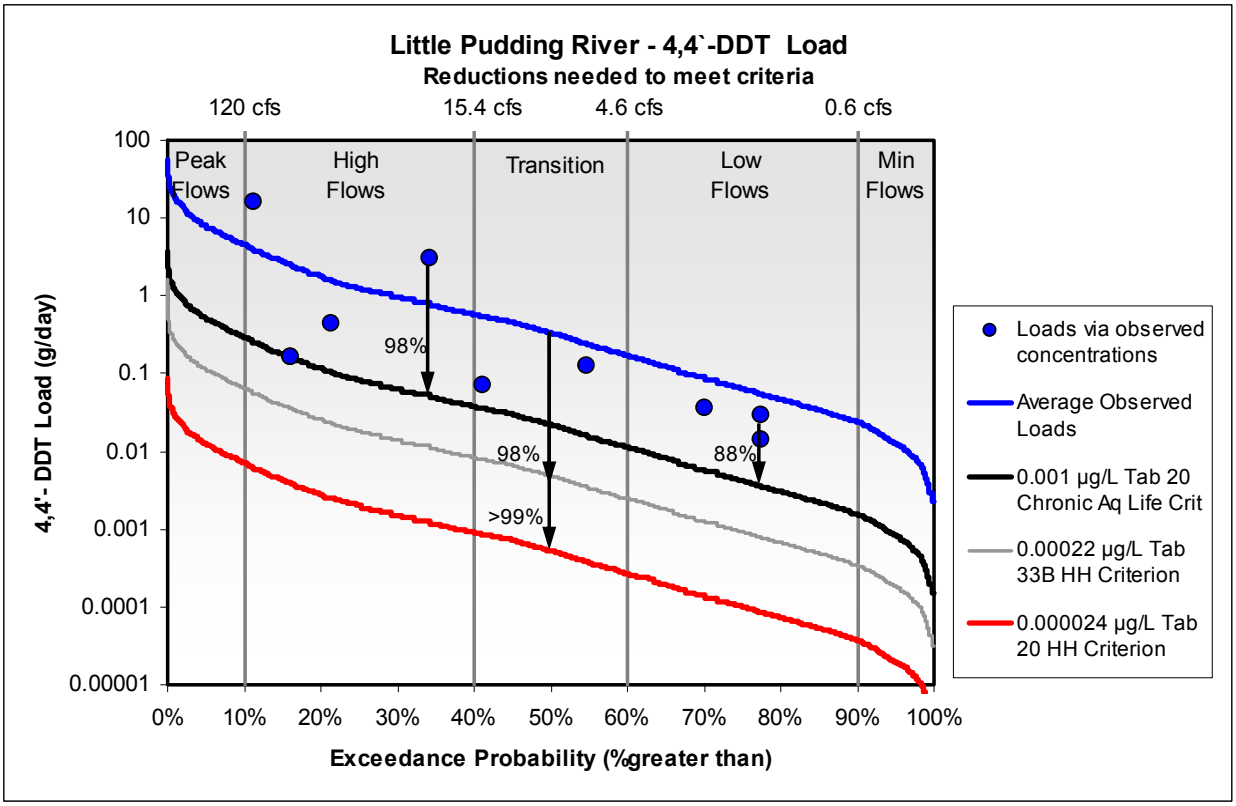

Figure 4 - 28: Little Pudding River 4,4'-DDT Excess Loads

ODEQ measured concentrations of 4,4'-DDE and 4,4'-DDD in the Little Pudding River are also virtually all above detection (Figure 4 - 29 and Figure 4 - 30). Large reductions long-term average concentrations of both metabolites are needed to meet human heath criteria (96% for DDE and 95% for DDD).

No fish or shellfish tissue data is available for Little Pudding River. Considering the high water column concentrations in this stream, future monitoring should consider measuring Little Pudding River fish tissue concentrations for DDT and other chlorinated pesticides.

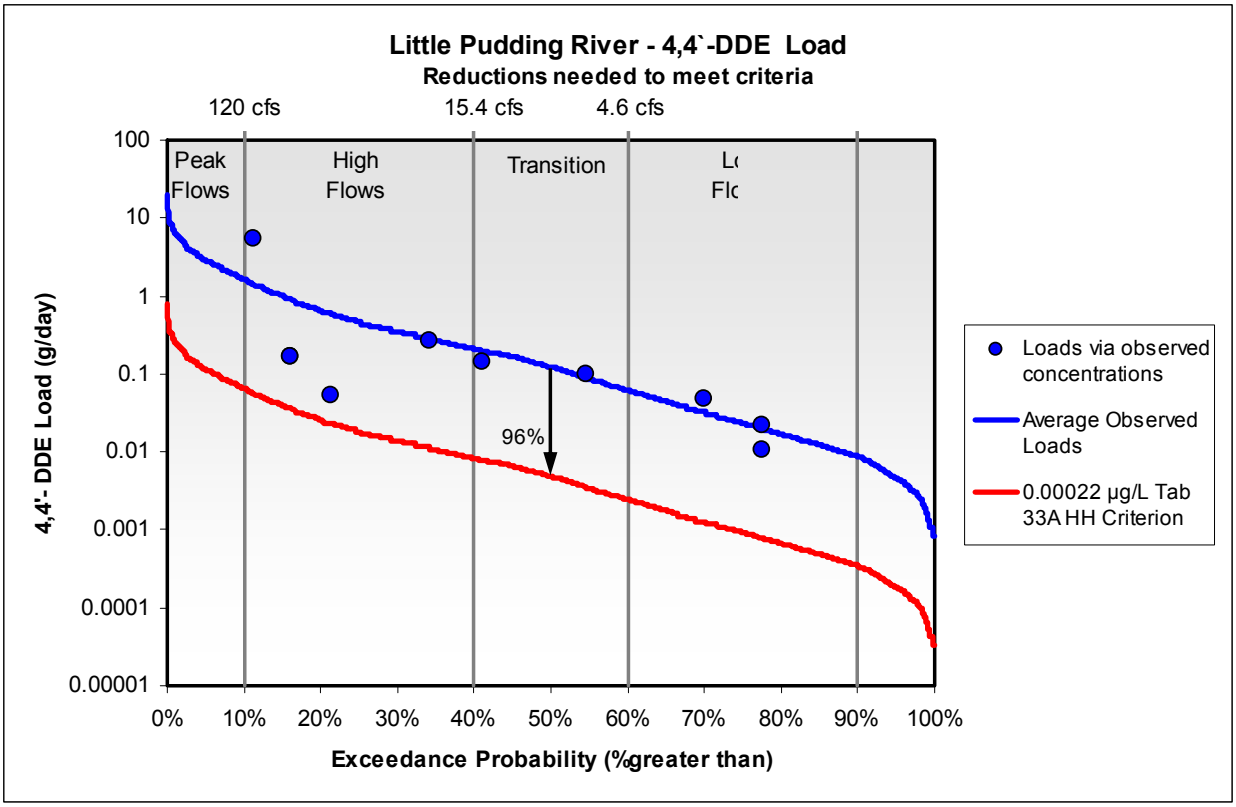

Figure 4 - 29: Little Pudding River 4,4'-DDE Excess Loads

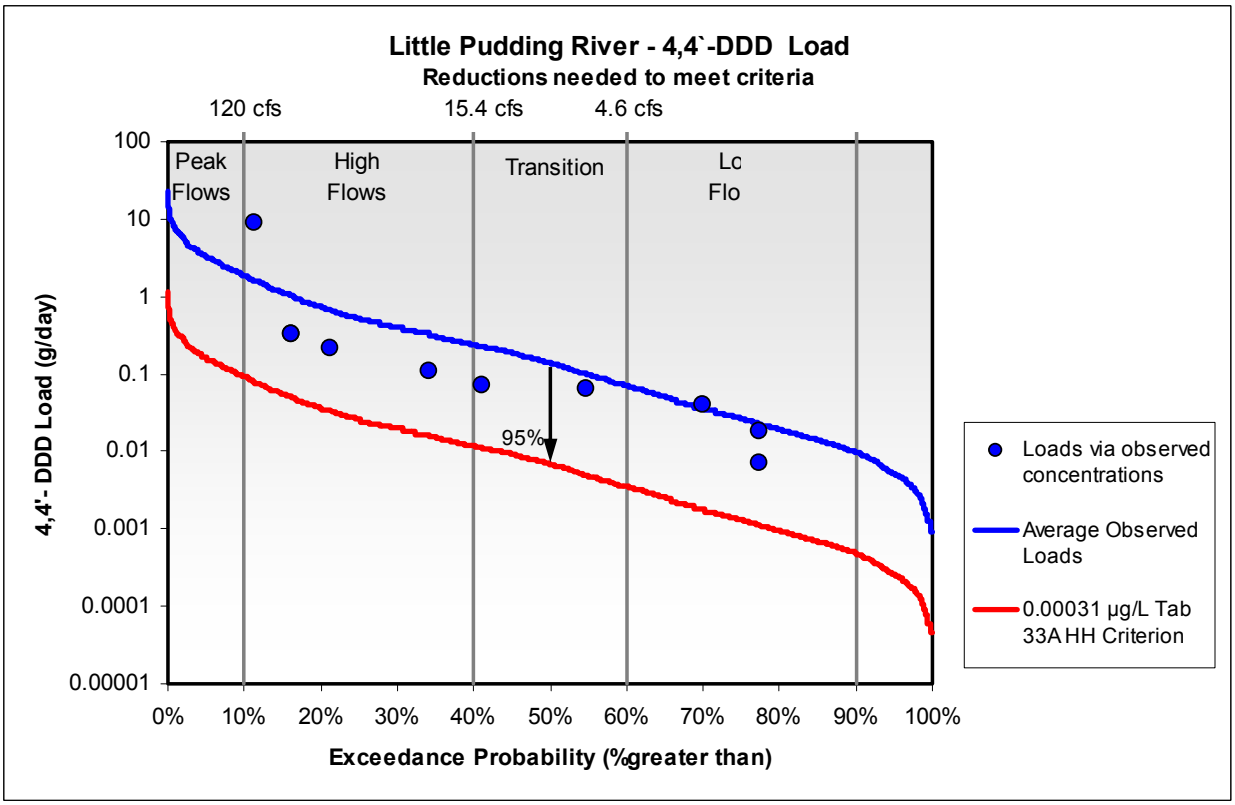

Figure 4 - 30: Little Pudding River 4,4'-DDD Excess Loads

CHLORDANE

Only a limited amount of water column data for chlordane is available for the Pudding River at Aurora, Little Pudding River, and Zollner Creek. All measured water column concentrations were below detection. However, while chlordane was detected in none of the samples, the 0.1 µg/L minimum detection level for chlordane is much greater than both the 0.0043 ug/L chronic aquatic life criterion and the 0.00046 ug/L human health criterion. Therefore, it cannot be concluded from the data that chlordane water column criteria are met.

Fish tissue data is available for the Pudding River at Aurora and for Zollner Creek. The data shows high levels in Zollner Creek (Figure 4 - 31), but not in Pudding River (Figure 4 - 32). The elevated chlordane levels support the 303(d) listing of Zollner Creek for Chlordane (Pudding River and Little Pudding River are not 303(d) listed for chlordane). Based on this data, a 14% reduction in average fish tissue chlordane concentrations is required for Zollner Creek. However, since percent reductions for chlordane are based solely on a small amount of fish tissue data, it is appropriate to provide a margin of safety by targeting a fish tissue concentration equal to ½ of the DHS action level. In the case of chlordane, this is 13.5 µg/kg. To meet a 13.5 µg/kg fish tissue target, a 57% reduction in Zollner fish tissue concentrations is required. No reduction is required for Pudding River, since observed concentrations are below detection.

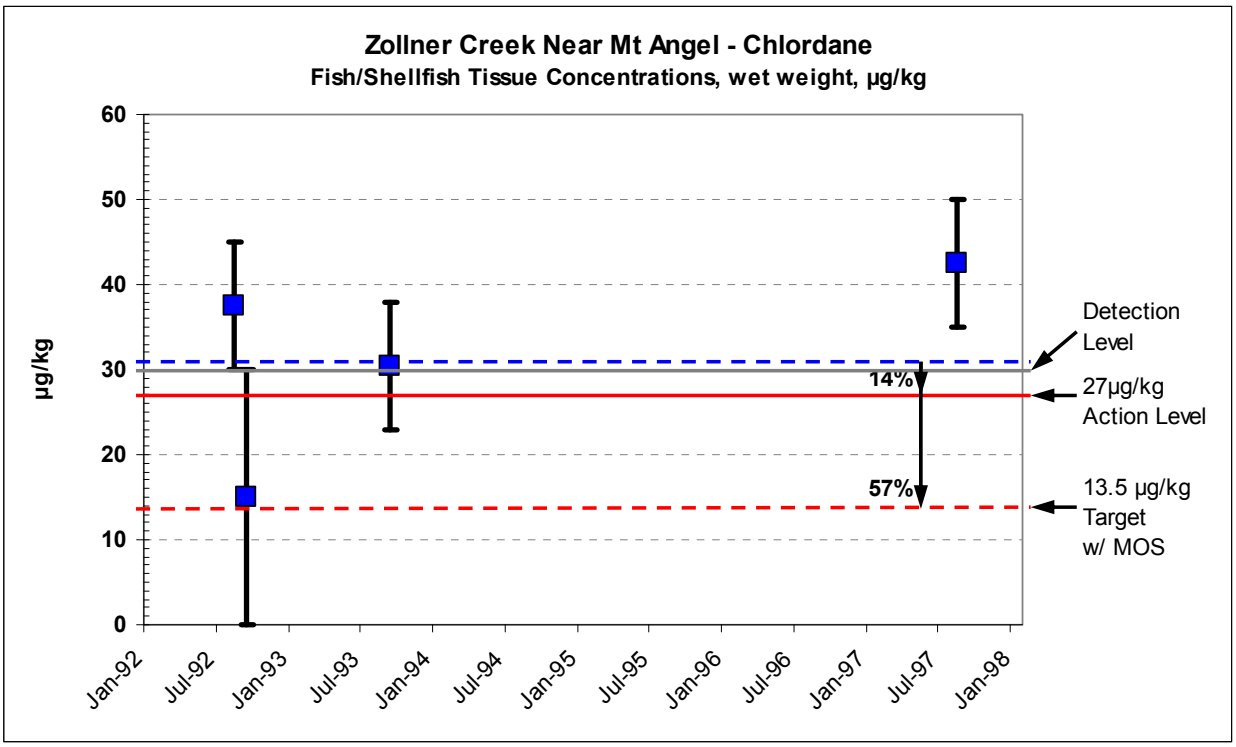

Figure 4 - 31: Zollner Creek Chlordane Fish Tissue Concentrations

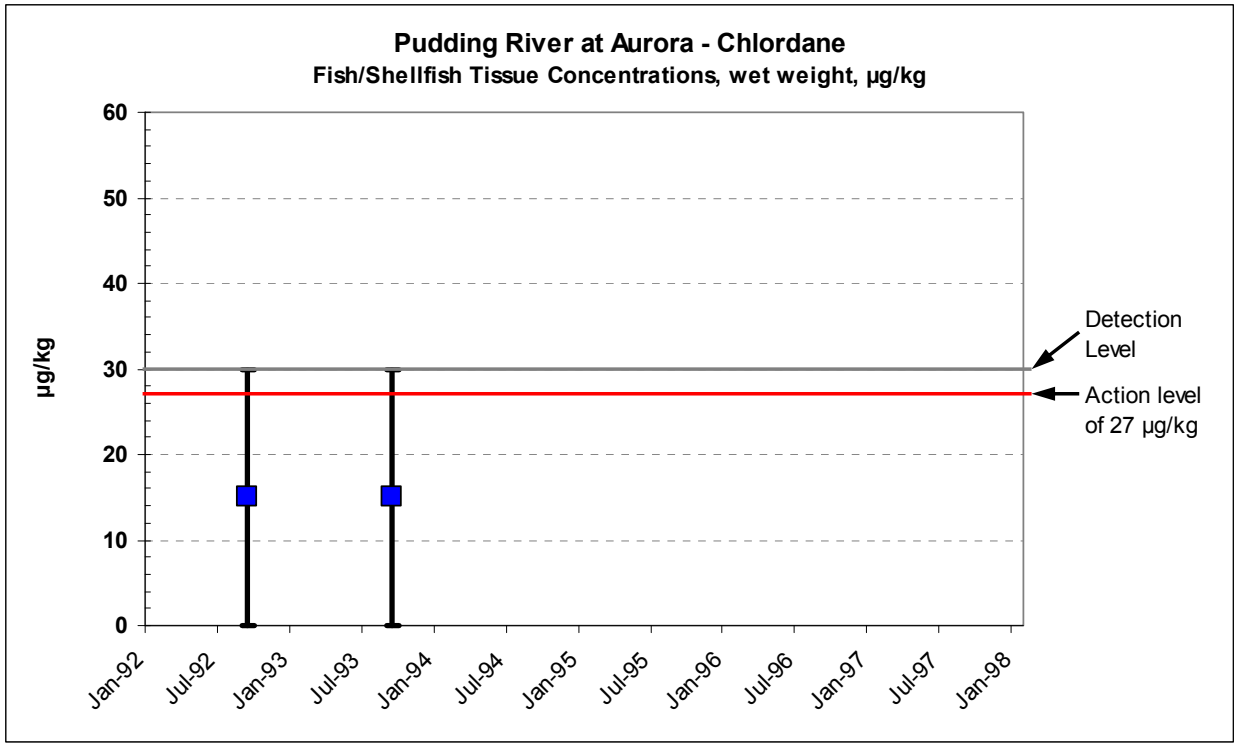

Figure 4 - 32: Pudding River Chlordane Fish Tissue Concentrations

DIELDRIN

Water column data for dieldrin is available for the Pudding River at Aurora, Little Pudding River, and Zollner Creek. In addition, fish tissue data is available for Pudding River at Aurora and Zollner Creek.

Pudding River

Figure 4 - 33 is a load duration plot for dieldrin in the Pudding River at Aurora. None of the samples collected in the Pudding River by either USGS or ODEQ exceeded the aquatic life chronic criterion. Dieldrin was detected in none of the 10 samples collected recently by ODEQ for which dieldrin concentrations were reported and in none of 34 samples collected by USGS that were filtered prior to analysis. However, dieldrin was detected in 2 of 5 unfiltered USGS samples. Detected concentrations equaled the typical MRL for the method of 0.001 µg/L. While these concentrations are less than the 0.0019 µg/L chronic criterion, they significantly exceed the 0.052 ng/L (0.000052 µg/L) human health based criterion.

The USGS Dieldrin detections occurred during a high flow conditions. Calculating the average concentration by setting all non-detects to ½ of detection levels produces an average concentration estimate of 0.00052 µg/L. In order to meet the Table 20 human health criterion of 0.000054 µg/L, the estimated long-term average concentration would need to be reduced by approximately 85%. To meet the more conservative Table 33A human health criterion of 0.000076 µg/L, the estimated long-term average concentration would need to be reduced by approximately 90%.

Dieldrin was not detected in the limited amount of fish tissue available for the Pudding River (Figure 4 - 34).

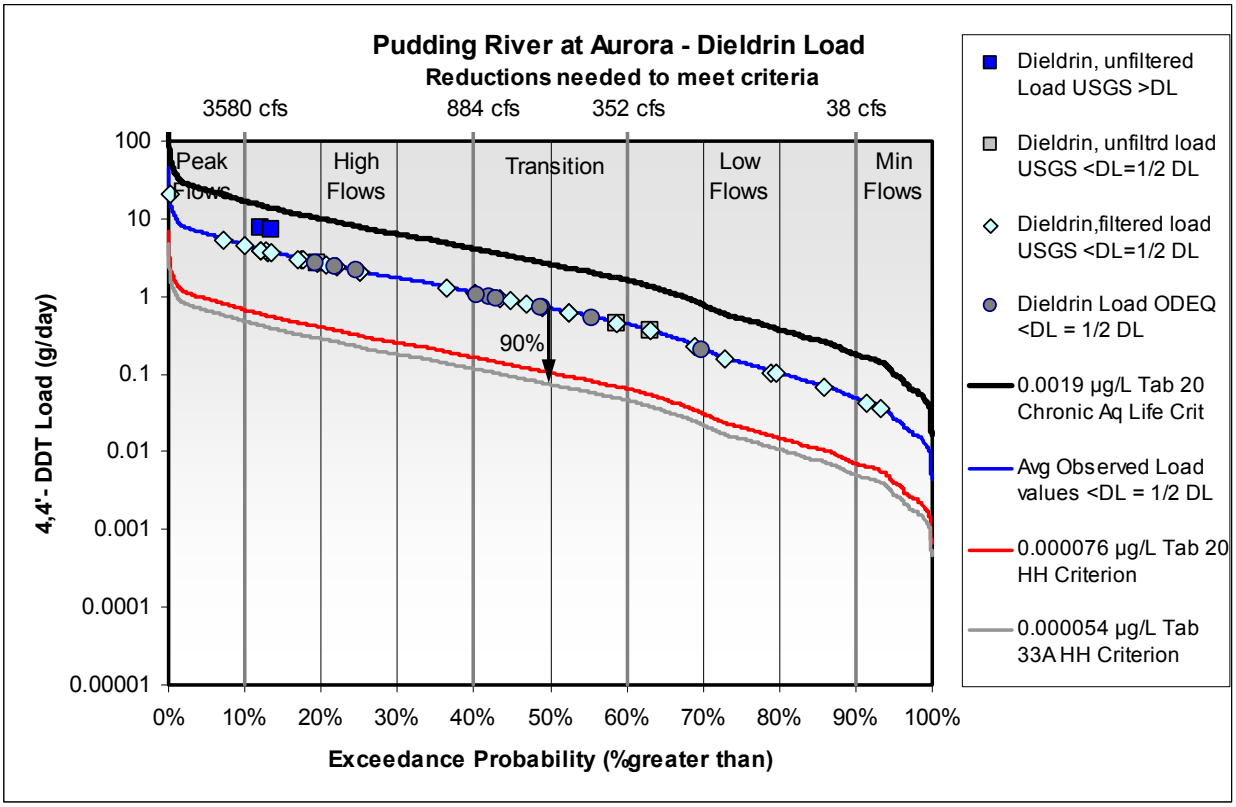

Figure 4 - 33. Pudding River Dieldrin Excess Loads

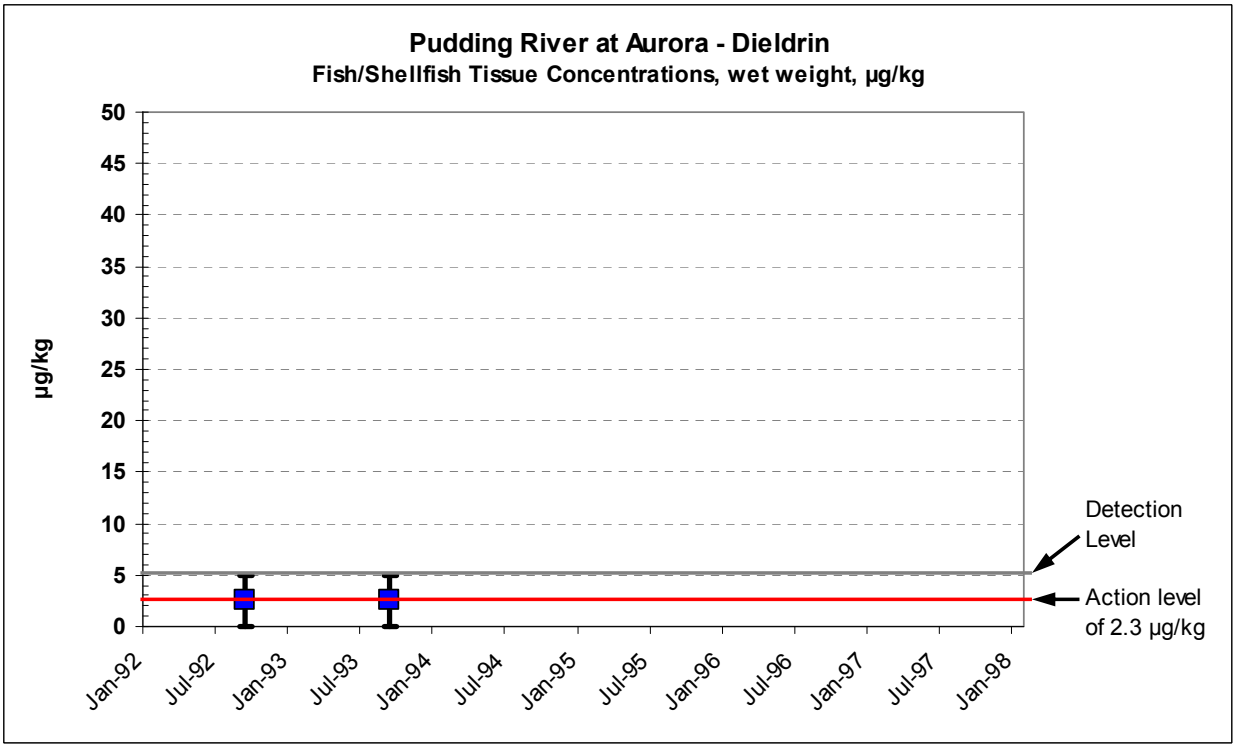

Figure 4 - 34: Pudding River Dieldrin Fish Tissue Concentrations

Zollner Creek

Two load duration plots for dieldrin are presented for Zollner Creek (Figure 4 - 35 and Figure 4 - 36). The first shows all of the available data, while the second shows only data since 1994. As shown previously (Figure 4 - 13), dieldrin concentrations appear to have declined since the early 1990's. Therefore, data prior to 1994 has not been used to determine excess loads and establish load allocations. Even without use of this data, however, large reductions in dieldrin are still required. As shown in Figure 4 - 36, the data indicates that a 68% reduction is needed to meet chronic aquatic life criteria during high flows and a 92% reduction is needed in long-term average loads.

Fish tissue data supports a similar reduction in long-term average concentrations (Figure 4 - 37). Based on average concentrations, this data indicates that an 89% reduction in dieldrin is needed to meet the DHS action level of 2.3 µg/kg

Due to the small amount of fish tissue data available, a margin of safety is provided by targeting a fish tissue concentration equal to ½ of the DHS action level. In the case of dieldrin, this is 1.15 µg/kg. To meet a 1.15 µg/kg fish tissue target, a 95% reduction in fish tissue concentrations is required.

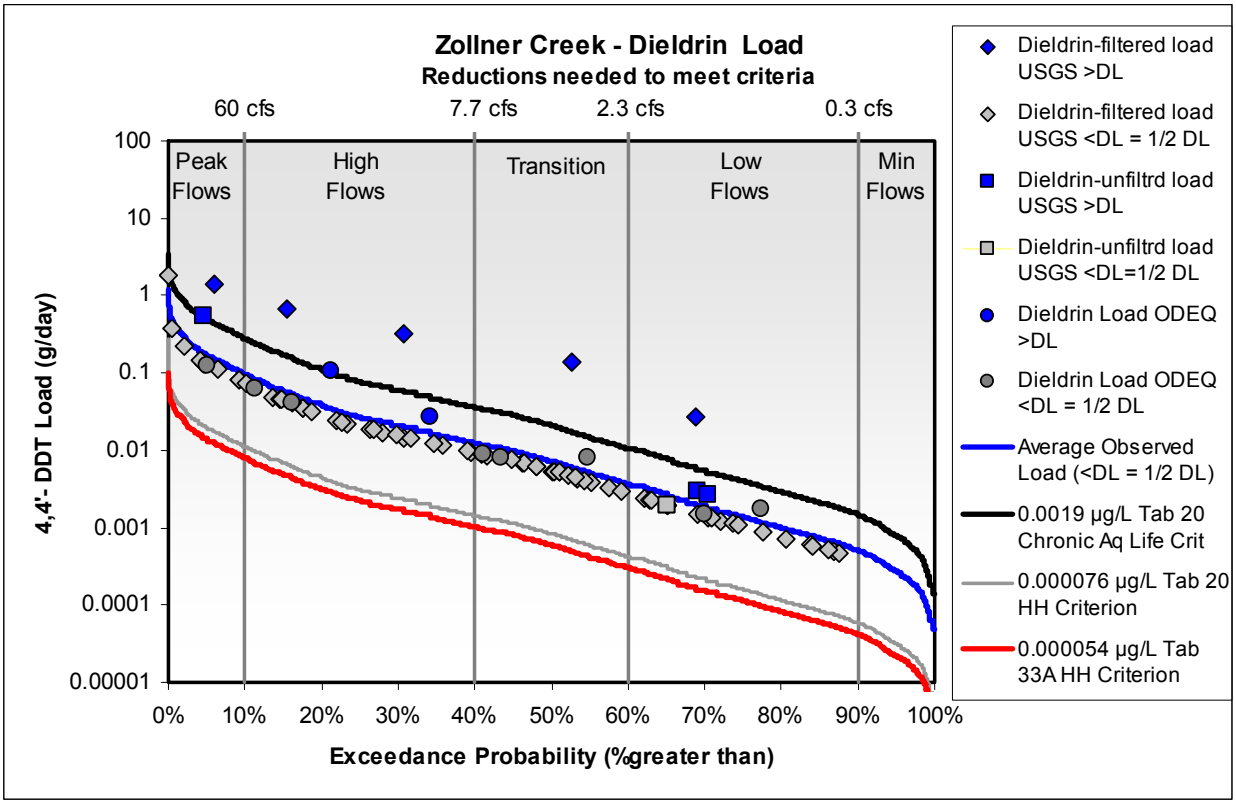

Figure 4 - 35: Zollner Dieldrin Excess Loads (all data)

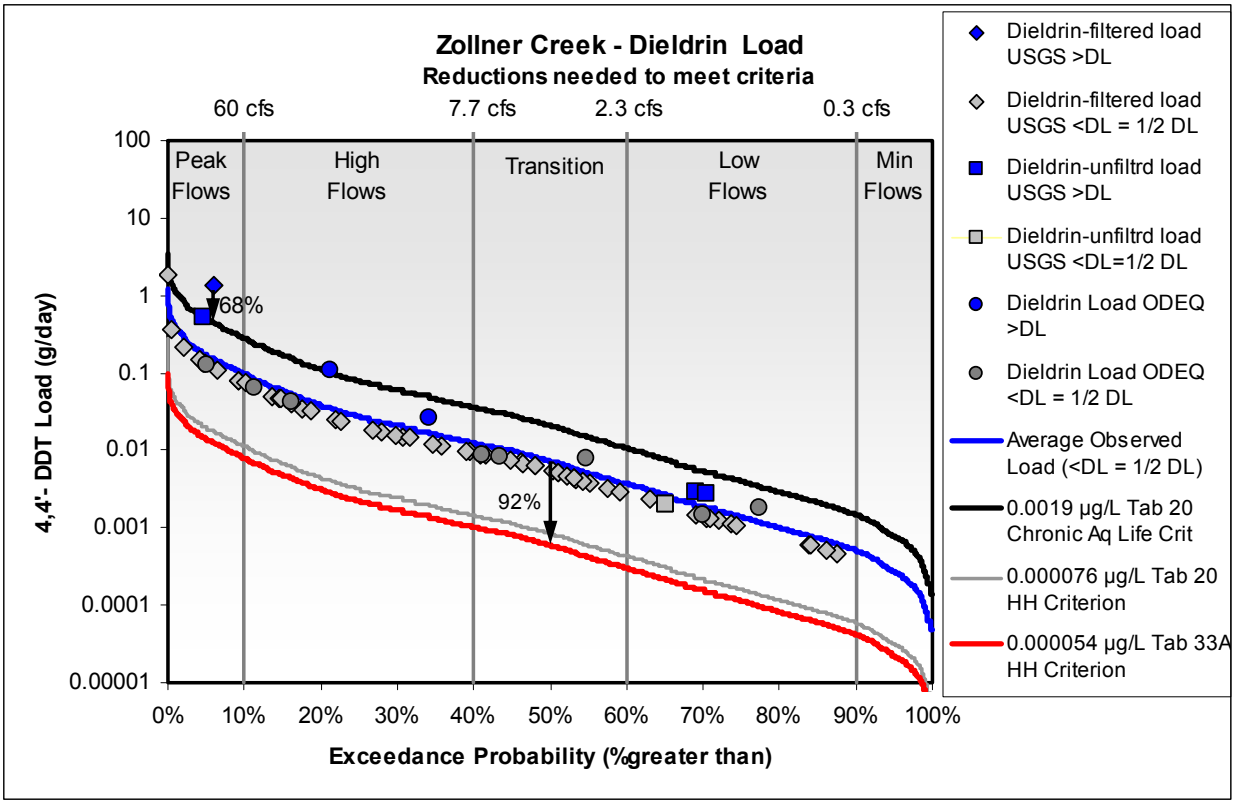

Figure 4 - 36: Zollner Dieldrin Excess Loads (all data more recent than 1993).

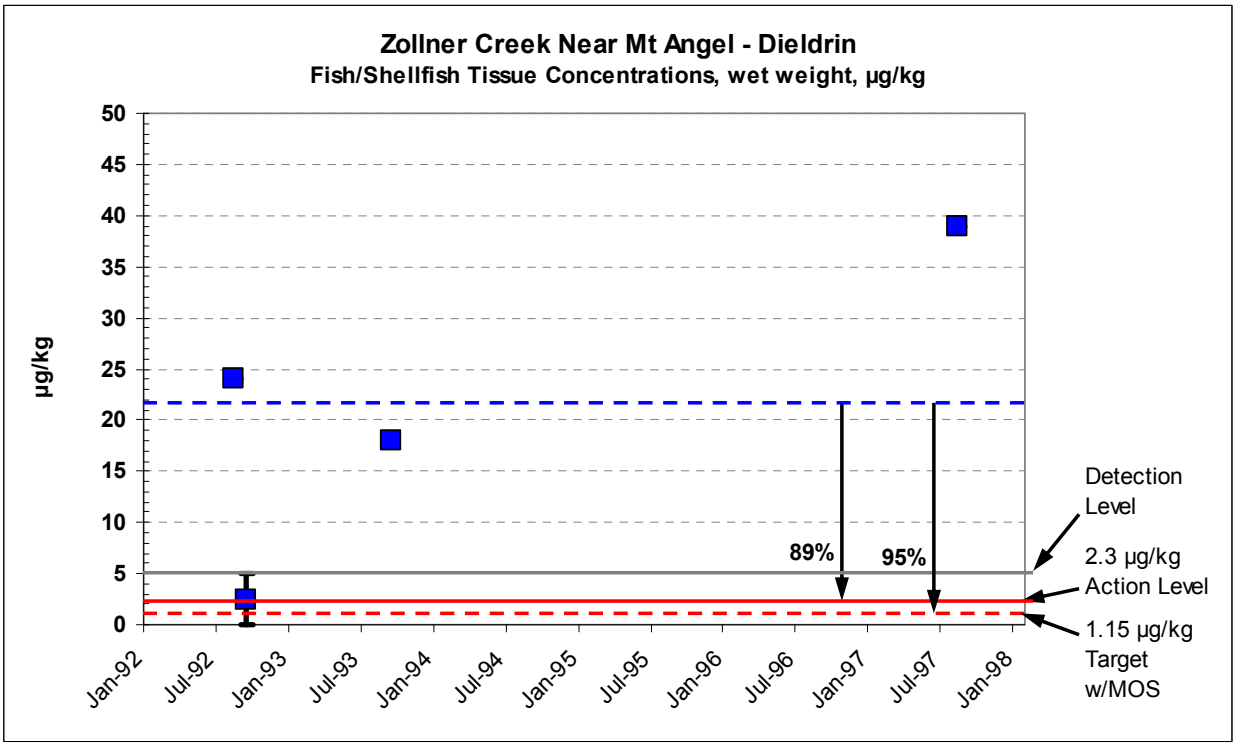

Figure 4 - 37:Zollner Creek Dieldrin Fish Tissue Concentrations

Little Pudding River

The Little Pudding River is not included on the 303(d) list for dieldrin. A review of available data indicated that all measurements were below detection. In addition, no fish tissue data is available for the Little Pudding River. Therefore, since the available data does not indicate that there is an excess load of dieldrin in the Little Pudding River, load allocations are not provided for the Little Pudding River for dieldrin.

ALLOCATIONS

WASTELOAD ALLOCATIONS

Wasteload allocations are required for legacy pesticides for those point sources which may contribute to water quality standards violations in water quality limited reaches. The Pudding River from RM 35.4 to RM 0 is water quality limited for DDT and dieldrin. ODEQ monitored for DDT and dieldrin at a station five miles upstream from the listed reach, Pudding River near Mt. Angel at RM 40.7 (Saratoga Rd, inactive USGS Gage 14201000, LASAR 31877). Neither DDT nor dieldrin was detected at this site. Downstream from this site the streams Zollner Creek and Little Pudding River enter the River. Monitoring shows that both Zollner Creek and Little Pudding River contribute DDT to the Pudding River and that Zollner Creek contributes dieldrin. While monitoring at the Pudding River near Mt. Angel station does not indicate that wasteload allocations are needed for DDT or dieldrin for point sources above this site, it is not clear whether or not wasteload allocations are needed for point sources below this site. Point sources downstream of this site include wastewater treatment plants (WWTP) for the cities of Aurora, Woodburn, Gervais, Mt. Angel, JLR, LLC/Bruce Pac, Norpac Foods, and Columbia Helicopter.

Several of the WWTPs are publicly owned treatment works (POTWs) that treat domestic wastewater. Since the collection system for such a treatment plant is likely to contain connections to surface water (infiltration/inflow, combined sewers, etc.), legacy pesticides such as DDT and dieldrin could enter the wastewater being treated and be discharged to the river. Therefore, since these POTWs discharge to the water quality limited reach and may contribute to water quality standards violations observed at the Pudding River at Aurora station (gage 14202000, LASAR 10917), which is the monitoring station upon which the Pudding River 303(d) listing for DDT is based, wasteload allocations have been provided for them.

Other NPDES permitted dischargers which discharge to the reach of the Pudding River that is water quality limited for DDT include JLR, LLC/Bruce Pac; Norpac Foods; and Columbia Helicopter. JLR and Norpac Foods are food processing facilities which are unlikely to contribute loads of either DDT or dieldrin to the Pudding River. Columbia Helicopter is a groundwater remediation site which is also unlikely to contribute loads of DDT or dieldrin to the Pudding River. Since these facilities are not likely to contribute loads of DDT or dieldrin, they have not been provided with wasteload allocations.

Several point sources, including the City of Hubbard WWTP, discharge to Mill Creek, which is a tributary to the reach of the Pudding River that is water quality limited for DDT. Mill Creek enters the Pudding River downstream from the Pudding River at Aurora station. Therefore, any DDT or dieldrin present in Mill Creek or Senecal Creek, a tributary to Mill Creek, would not contribute to water quality standard violations at this site. No monitoring data was located for DDT for these streams, but monitoring was performed for dieldrin by USGS at the Senecal Creek at Fellers Rd. station (shown in Figure 4 - 1). No dieldrin was detected at this site (0 detections in 6 measurements). Since these streams do not influence concentrations at the Pudding River at Aurora station and since neither DDT nor dieldrin has been detected in them, no wasteload allocations have been provided in this TMDL for DDT or dieldrin for point sources which discharge to Mill Creek or Senecal Creek.

At this time, each point source in Table 4 - 15 is allotted a DDT and dieldrin wasteload allocation that equals the facility's current conditions. Each facility's WLA also requires that the facility cause no measurable increase in in-stream DDT and dieldrin concentrations.

Table 4 - 15: Point sources receiving current conditions wasteload allocations for DDT and dieldrin.

Facility Name	Receiving Stream	River Mile	Wasteload Allocation
City of Woodburn Wastewater Treatment Plant	Pudding River	21.4	Current conditions
City of Aurora Wastewater Treatment Plant	Pudding River	8.8	Current conditions
City of Gervais Wastewater Treatment Plant	Pudding River	31.2	Current conditions
City of Mt. Angel Wastewater Treatment Plant	Pudding River	34	Current conditions

LOAD ALLOCATIONS

10% of the loading capacity is set aside as Reserve Capacity (see below). The remaining 90% is allocated to nonpoint sources (Table 4 - 16). Nonpoint sources include loads from agricultural and urban land use categories.

Table 4 - 16: Loading Capacities (g/d) allocated to nonpoint sources

	4-4'-DDT	4-4'-DDE	4-4' DDD	Total DDT	Chlordane	Dieldrin
Zollner Creek	0.00004	0.00039	0.00055	0.00098	0.00081	0.00009
Little Pudding R	0.00008	0.00078	0.00109	0.00195	0.00162	0.00018
Pudding R at Aurora	0.00562	0.05150	0.07256	0.12968	0.10767	0.01217

Load Allocations required to meet loading capacities allocated to nonpoint sources (Table 4 - 17) are provided as required percent reductions in pollutant loads and concentrations and by a surrogate measure: total suspended solids (TSS) targets.

Required Percent Reductions

Percent reductions for DDT, chlordane, and dieldrin required to meet criteria and action levels are summarized in Table 4 - 17. Reductions in "higher flows," "transition flows" and "lower flows" columns are required to meet criteria designed to prevent adverse impacts on aquatic life. "Long-term average" reductions are required to meet water column criteria designed for protection of human health (fish consumption only). "Fish Tissue" reductions are fish tissue concentration reductions required to meet targets set to 50% of DHS assumed action levels.

Table 4 - 17: Percent Reductions required to meet water column criteria and fish tissue targets.

Parameter	Stream	High Flows (<40th %tile) To meet Chronic Aquatic Life Criteria	Transition Flows (40th –60th %tiles) To meet Chronic Aquatic Life Criteria	Lower Flows (>60th %tile) To meet Chronic Aquatic Life Criteria	Long-Term Average To meet Human Health Criteria	Fish Tissue To meet Target
4,4'-DDT	**Pudding River**	**50%**	0%	0%	**97%**	-
	Zollner Creek	**97%**	**88%**	0%	**99%**	-
	Little Pudding R.	**98%**	0%	0%	**>99%**	-
4,4'-DDE	**Pudding River**	NA[1]	NA	NA	**61%**	-
	Zollner Creek	NA	NA	NA	**71%**	-
	Little Pudding R.	NA	NA	NA	**96%**	-
4,4'-DDD	**Pudding River**	NA	NA	NA	unknown[2]	-
	Zollner Creek	NA	NA	NA	unknown	-
	Little Pudding R.	NA	NA	NA	**95%**	-
Total DDT (t-DDT)	**Pudding River**	-	-	-	-	**30%**
	Zollner Creek	-	-	-	-	**76%**
	Little Pudding R.	-	-	-	-	No data
Chlordane	**Pudding River**	unknown	unknown	unknown	unknown	0%
	Zollner Creek	unknown	unknown	unknown	unknown	**57%**
	Little Pudding R.	unknown	unknown	unknown	unknown	No data
Dieldrin	**Pudding River**	0%	0%	0%	**90%**	0%
	Zollner Creek	**68%**	0%	0%	**92%**	**95%**

[1] NA – Not applicable because there are no applicable aquatic life criteria for this DDT metabolite
[2] Unknown because all recent values are below detection

Load allocations in terms of required percent reductions in long-term averages are specified in Table 4 - 18. These are based either on water column concentrations or fish tissue data, whichever is more conservative. In addition, water column concentrations must meet aquatic life chronic and acute criteria.

Table 4 - 18: Load Allocations as required reductions in long-term average concentrations.

Parameter	Stream	Load Allocations as Required Percent Reductions in long-term average concentrations
4,4'-DDT	Pudding River	97%
	Zollner Creek	99%
	Little Pudding R.	>99%
4,4'-DDE	Pudding River	61%
	Zollner Creek	71%
	Little Pudding R.	96%
4,4'-DDD	Little Pudding R.	95%
Total DDT (t-DDT)	Pudding River	30%[1]
	Zollner Creek	76%[1]
Chlordane	Zollner Creek	57%[1]
Dieldrin	Pudding River	90%
	Zollner Creek	95%[1]

[1] Based on fish tissue data with additional margin-of-safety applied

Total Suspended Solids Concentration Targets

As a partial measure designed to meet total DDT (t-DDT) water column targets and fish tissue action levels in the Pudding River, load allocations are expressed by a surrogate measure: total suspended solids (TSS) concentration targets. The t-DDT concentration to be met is 0.000554 µg/L, which is the sum of Table 20 human health criterion for 4-4'DDT, the Table 33A human health criterion for 4-4'-DDE, and the Table 33A human health criterion for 4-4'-DDD (0.000024 + 0.00022 + 0.00031 = 0.000554 µg/L). TSS targets were developed for the Pudding River, Zollner Creek and the Little Pudding River.

The effect of TSS reductions on t-DDT load in the Pudding River is based on DEQ's modeling that relates TSS and t-DDT concentrations in the Little Pudding River (multiple linear regression model explained in Appendix J) and predicts Pudding River t-DDT loads from Little Pudding and Zollner Creek t-DDT loads (mass balance model explained in Appendix J).

Since Zollner Creek and Little Pudding River are the primary contributors of t-DDT to the Pudding River, load allocations (via surrogate target TSS concentrations) are provided for both of these streams. While Zollner Creek and Little Pudding River contain t-DDT concentrations sufficient to warrant 303(d) listing, the load allocations provided in this TMDL are designed to meet chronic and human health based water quality targets for t-DDT in the Pudding River and thereby address the current 303(d) listing.

A mass-balance model was used to estimate TSS maximum concentrations at which water quality targets for t-DDT in the 303(d) listed reach of the Pudding River would be met. In order to be consistent with other TMDLs for DDT in the Willamette Basin, the target TSS maximum concentration for all streams was set first to 15 mg/L, which is the target TSS concentration for Johnson Creek that is specified in the Willamette Basin TMDL: Lower Willamette Subbasin (ODEQ, 2006). Further reductions in the TSS

targets were made in the model so that the chronic and human health t-DDT criteria would be met in the Pudding River. The 15 mg/L TSS target in the Pudding River and Zollner Creek was sufficient to accomplish this but a further reduction in the Little Pudding River TSS target was necessary.

The TSS target for the Little Pudding River, which has a much higher t-DDT:TSS ratio than other streams, was further reduced until the 90th percentile model calculated t-DDT concentration in the Pudding River equaled the chronic toxicity criteria. The resultant target TSS maximum concentration for the Little Pudding River to meet criteria in the Pudding River is 7 mg/L. The TSS targets for the Pudding River, Zollner Creek and Little Pudding River are listed in Table 4 - 19. The values in Table 4 - 19 are load allocations in terms of the surrogate measure TSS concentration.

The chronic criterion is specified as a 96-hour average. Therefore, 96-hour average concentrations of TSS near the mouths of all streams which may contribute DDT to the Pudding River, including Zollner Creek, should not exceed 15 mg/L. Furthermore, 96-hour average concentrations of TSS near the mouth of Little Pudding River should not exceed 7 mg/L.

Table 4 - 19: Load allocations as target TSS 96-hr concentrations

Stream	TSS (mg/L) as 96-hour average (surrogate load allocations)
Pudding River	15
Zollner Creek	15
Little Pudding River	7

Model calculated concentrations in the Pudding River for these load allocations are presented in the form of a concentration duration plot in Figure 4 - 38. As shown, if the TSS targets are met, the model indicates that the chronic criterion for t-DDT should not be exceeded more than 10% of the time in the Pudding River. Furthermore, t-DDT should rarely if ever be detected in the stream.

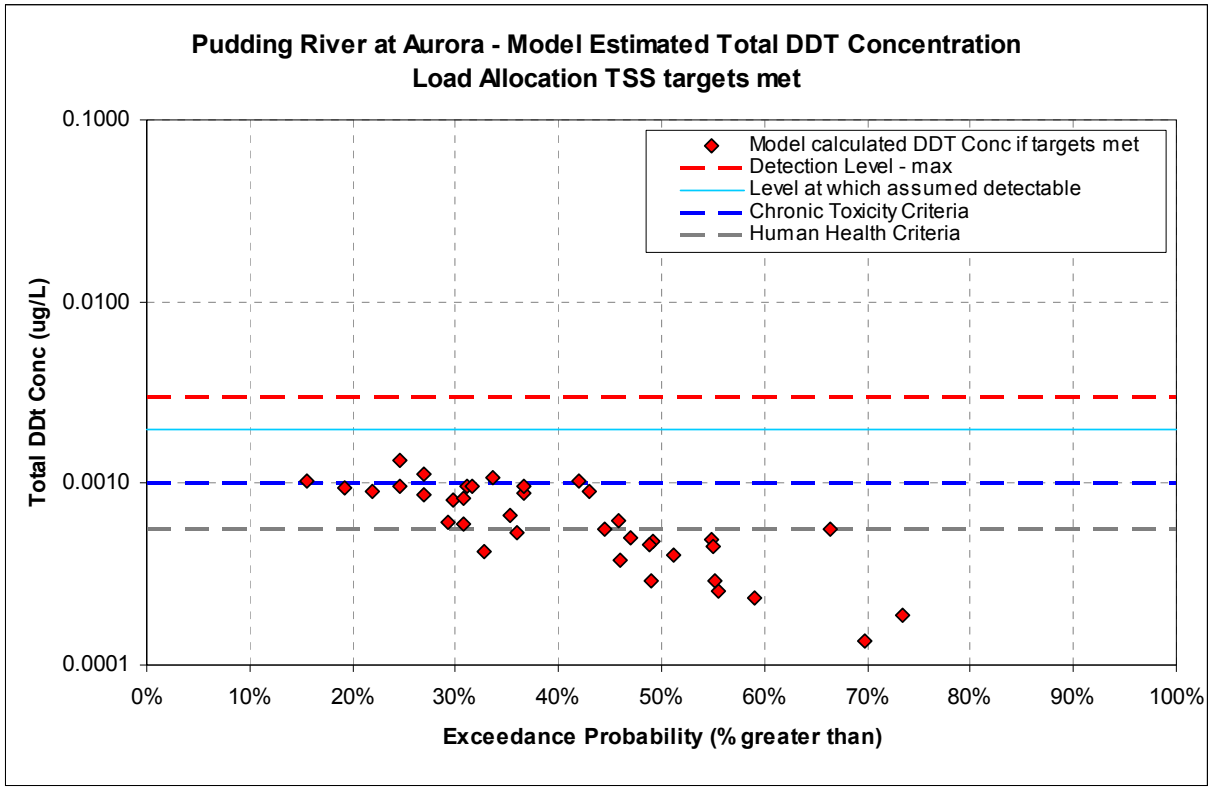

Figure 4 - 38: Duration plot of model estimated t-DDT concentrations – Load Allocations.
Based on 37 dates of paired ODEQ TSS and flow data.

Model average concentrations if the TSS targets are met are shown in Table 4 - 20. As shown, "background" Pudding River concentrations in the absence of DDT loads from Zollner Creek and Little Pudding River are calculated to not exceed the 0.554 ng/L (0.000554 µg/L) human health based criteria. With the Zollner and Little Pudding allocated loads, the average concentration will not exceed 0.670 ng/L. Actual average concentrations will be less than these values, because actions to limit 96-hour TSS concentrations to the 15 and 7 mg/L targets specified will not only significantly reduce maximum concentrations, but will also reduce concentrations on all other days. Therefore, resultant average concentrations at all locations in the Pudding River should not exceed the human-health based criterion if the allocated TSS targets are met.

Model calculated current and load allocation target t-DDT loads for the Pudding River at Aurora are presented in Figure 4 - 39.

Table 4 - 20: Model Calculated Average Concentrations if Load Allocation TSS Targets met.

	Average t-DDT (µg/L)
Little Pudding R at Rambler Rd	0.00470
Zollner Creek nr Mt. Angel	0.00207
Pudding River at Aurora	0.00067
Pudding River Background	0.00054

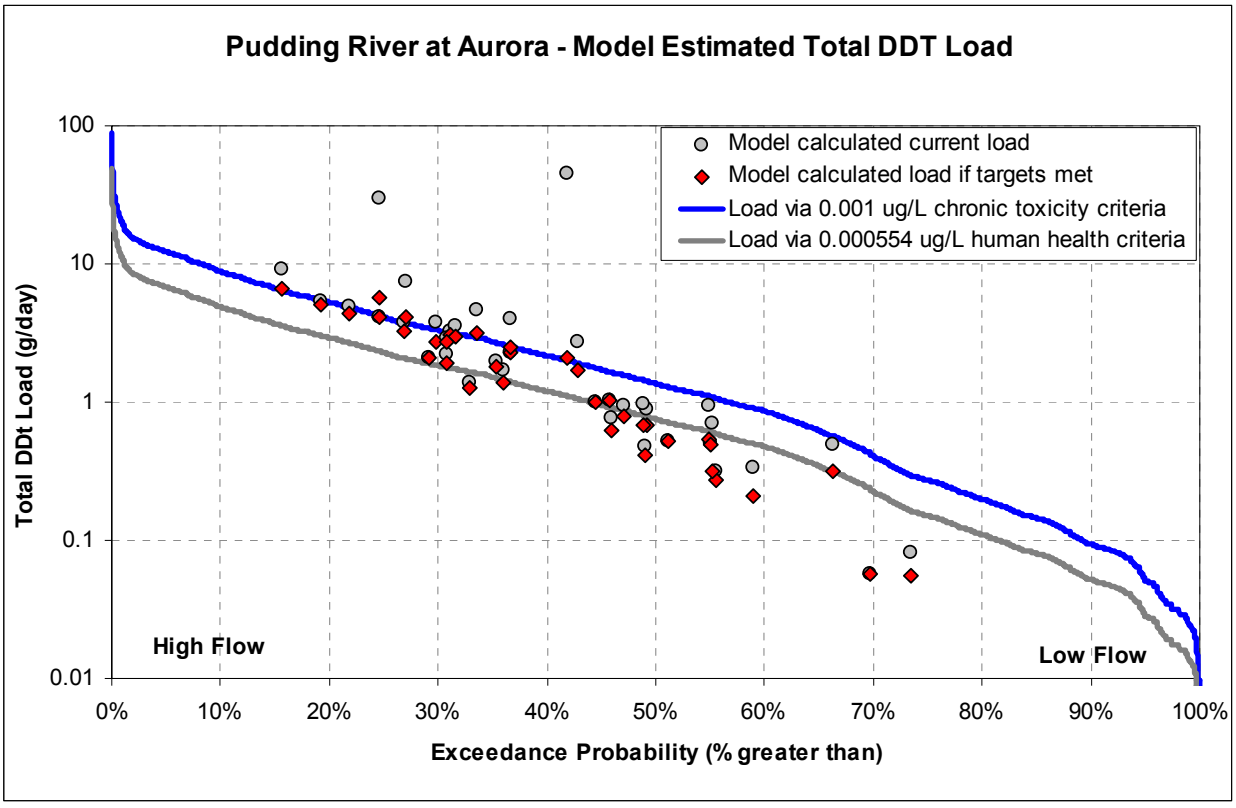

Figure 4 - 39: Load Duration plot of model estimated t-DDT loads – Current and Load Allocation conditions

The load allocations will result in reductions in average t-DDT concentrations of more than 58% in Zollner Creek and more than 65% in Little Pudding River. While the load allocations are quite stringent and possibly sufficient to meet water quality criteria for t-DDT in Zollner Creek, they will likely not be sufficient to meet criteria in Little Pudding River due to the high quantities of t-DDT associated with suspended sediment in this stream.

The multiple linear regression model developed for the Little Pudding River, which relates t-DDT to TSS and flow, indicates that an 86% reduction in TSS concentrations in the Little Pudding River would still result in t-DDT concentrations which exceed the 0.001 µg/L chronic criteria 50% of the time. In order to eliminate chronic toxicity criteria exceedances, TSS concentrations would need to be reduced more than 90% from current concentrations to 1 mg/L. Such low TSS levels are probably unattainable in any stream, let alone one dominated by agriculture such as the Little Pudding. Additional study is needed to determine the sources of DDT loads to the Little Pudding River and determine actions necessary to address them. While the TSS surrogate load allocations provided in this TMDL may not eliminate criteria exceedances in the Little Pudding, they will, if met, significantly reduce the high DDT concentrations currently present in this stream. Therefore, while achievement of these TSS measures will significantly reduce DDT levels in the Little Pudding River and Zollner Creek, additional measures will be needed as described below and in the Water Quality Management Plan in order to meet Load Allocations as Percent Reductions specified in this TMDL for the Little Pudding River and Zollner Creek.

Since water column concentrations of chlordane have not been detected, it is not possible to determine what actions should be taken to reduce chlordane loads to streams. It is possible that actions to meet TSS targets specified by the DDT TMDL, coupled with decay of chlordane over time, will result in fish tissue action levels being met. Additional monitoring is recommended to determine if fish tissue action levels are still being exceeded and to determine whether the 303(d) listing for chlordane is still appropriate.

Trend tests show that concentrations for dieldrin have been declining over time. Although dieldrin does not associate as strongly with sediment as does DDT, it is anticipated that the significant TSS reductions developed for Zollner Creek by the Pudding River DDT TMDL and ongoing decay of dieldrin over time should result in the achievement of both chronic toxicity and human health based criteria for dieldrin.

Additional Measures

Meeting the TSS allocations should result in t-DDT levels which meet t-DDT water column targets in the Pudding River and prevent exceedances of fish tissue action levels in the Pudding River. However, meeting the TSS allocations may not be enough to ensure that the very low Table 20 human health criteria for 4-4'-DDT is met. Meeting the TSS allocations also will not be adequate to meet DDT criteria in Zollner Creek and the Little Pudding River and also may not be sufficient to meet all criteria for dieldrin criteria in the Pudding River and Zollner Creek. Therefore, the TSS allocations will be augmented by further research on potential hot spots and source reductions in the Zollner Creek and Little Pudding River watersheds. This research is described in more detail in the Water Quality Management Plan (Chapter 7 of this TMDL).

MARGIN OF SAFETY

Margins of safety are included in this TMDL to account for uncertainty and to insure that water quality standards are achieved when load and wasteload allocations are met. Margins of safety may be provided by explicit reductions in load and wasteload allocations, or they can be implicit in the procedures used for analysis and modeling.

DEQ has not set explicit margins of safety in this TMDL. The margin of safety for this TMDL is implicit in conservative assumptions and procedures. Margins of safety were provided by :

- Specifying the most conservative percent reductions based on water column and fish tissue data;
- Targeting fish tissue concentrations that are ½ of DHS assumed action levels for t-DDT, chlordane, and dieldrin;
- Specifying total suspended solids concentration targets in addition to specifying percent reductions for DDT, chlordane, and dieldrin;

- Specifying percent reductions for 4-4'-DDT, 4-4'-DDE and 4-4'-DDD, in addition to specifying percent reductions for total DDT; and

- Targeting Table 33A criteria in cases where Table 33A criteria are more conservative than Table 20 criteria.

RESERVE CAPACITY

Reserve capacities for the DDT, dieldrin, and chlordane are set equal to 10% of the loading capacity for these pollutants. The pollutants of concern are pesticides that are no longer used commercially and are not expected to increase in the environment. While changing land use, such as increased development and associated soil disturbance could increase the delivery of these pollutants to streams, DEQ does not intend to allow for an increase in pollutants from such activities. Future development and associated soil disturbance would have to comply with the load allocations and TSS targets specified in this TMDL. However, in the event that a point or other source is determined through future monitoring to contribute loads of DDT, dieldrin, or chlordane to streams, a portion of the reserve capacity could be provided as a wasteload allocation. Reserve capacity will be available for use by point sources or nonpoint sources by application to DEQ.

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