Revised Willamette Basin Mercury TMDL

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Executive Summary

Water quality standards for mercury are in place to protect people from high levels of mercury exposure when eating fish. The Willamette River and many of its tributaries do not currently meet water quality standards for mercury and are included on Oregon's list of impaired waters under Clean Water Act §303(d). Mercury fish consumption advisories are in place throughout the Willamette Basin. The Clean Water Act requires a Total Maximum Daily Load to be developed for waters that are on the 303(d) list. In Oregon, the Oregon Department of Environmental Quality is responsible for developing and implementing TMDLs.

A Willamette Basin Mercury TMDL was first issued in 2006. This proposed revised Willamette Basin Mercury TMDL identifies sources of mercury, and how much mercury needs to be reduced in order to meet water quality standards. The revised evaluations included in this TMDL are more robust, using linked models and significantly more data than the 2006 TMDL. By far, the greatest source of mercury in the basin is from atmospheric deposition, which is mercury in the air falling onto the land or into the water. The mercury in air originates mainly from national and global sources rather than from sources in Oregon. Once mercury is deposited on the landscape, the major pathways to streams are erosion of sediment-bound mercury and surface runoff. Of the many different types of land use that exist within the Willamette Basin, forestry, agriculture and urban uses dominate across the basin. Point source discharges contribute significantly less mercury to streams than nonpoint sources. The contribution from point sources determined in this draft is also less than estimated in the 2006 TMDL. This TMDL specifies needed mercury reductions in two ways: nonpoint source load allocations and point source wasteload allocations. The accompanying Water Quality Management Plan describes DEQ's plan for implementing these allocations and actions to reduce mercury. Mercury minimization measures will be applied for both point and nonpoint source activities, with primary focus on reducing runoff and erosion from nonpoint source activities and urban stormwater. Effectiveness of these measures will be tracked, evaluated and improved, as warranted, to meet the standard.

There is inherent uncertainty in any analysis of complex physical, chemical and biological processes of mercury generation and transport in a very large riverine system like the Willamette Basin. DEQ used models and techniques that incorporate large amounts of water quality and land use data and information specific to the Willamette Basin. However, in order to evaluate these processes on this scale, the model and techniques used simplify these complex processes and the actual response of the system to the management measures is likely to vary from predictions to some degree. This drives the importance of ongoing monitoring, reporting, and adaptation of targets and measures over time.

DEQ convened a 25-member advisory committee in 2017 to provide input on source identification, allocations and development of an implementable Water Quality Management Plan for achieving required source reductions. Over the course of nine meetings, the committee listened to many hours of technical presentations, participated in complex discussions and provided valuable input from their constituent groups to aid DEQ in reaching complicated technical and policy decisions, which are reflected in this revised draft TMDL.

The draft TMDL and draft Water Quality Management Plan document needed mercury reductions and planned implementation through permits, best management practices, conservation practices, and other management strategies to reduce mercury entering streams to the degree that will be necessary for the eventual attainment of the mercury criterion and, ultimately, full restoration of the beneficial use of fish consumption and protection of aquatic life and wildlife throughout the Willamette Basin. The goals, objectives and approaches of this TMDL are consistent with the requirements of the federal Clean Water Act and Oregon Water Quality Laws and implementing regulations.

1. TMDL Introduction

This draft Willamette Basin Mercury TMDL was developed in cooperation between DEQ and EPA, along with EPA's watershed contractor, TetraTech, to address mercury impairments in the Willamette Basin to achieve the Oregon criterion for fish tissue concentrations of methylmercury. Mercury is a pollutant of global concern due to its widespread distribution in the environment and accumulation in aquatic biota. Methylmercury is a potent neurotoxin in humans and other vertebrates.

The draft TMDL document depends directly of the work done in the TMDL Technical Support Document, prepared by EPA's contractor, Tetra Tech, and presented as Appendix A: Technical Support Document. Sections 1 through 12 of this document summarize the work of the technical support document and describes how this work was used in the decision process of the draft TMDL. Cross-references are provided to relevant sections in the TMDL Technical Support Document from which reported results were drawn. The draft WQMP appears in in section 13 of this document and provides the framework for describing management efforts that will be put into action to attain the proposed Willamette Basin Mercury TMDL. This framework builds upon existing point and nonpoint source Implementation plans to outline a management approach for reducing mercury from all land uses in the basin. Reasonable assurance is provided in section 14, which describes an accountability framework for implementation of sector-specific or source-specific management strategies that will be carried out through regulatory or voluntary actions and monitoring and reporting on progress in meeting TMDL goals.

TMDL authority

DEQ is the Oregon state agency responsible for implementing the Clean Water Act in Oregon. The Clean Water Act allows for the delegation of responsibility for many Clean Water Act programs to states, which in Oregon is administered by the Oregon Environmental Quality Commission through Oregon Revised Statute. The commission has granted the DEQ Director authority to develop TMDLs and issue them as orders (Oregon Administrative Rule 340-042-0060). DEQ was granted authority by the commission to implement TMDLs through Oregon Administrative Rule 340-042 with special provision for agricultural lands and non-federal forest lands governed by the Agricultural Water Quality Management Act and the Forest Practices Act, respectively. The Clean Water Act requires EPA to approve or disapprove TMDLs that states submit. When a TMDL is officially submitted by a state to EPA, EPA has 30 days to take action on the TMDL. If EPA disapproves a TMDL, the CWA gives EPA 30 days to establish the replacement TMDL.

General TMDL approach

A TMDL, or total pollutant load to a waterbody, is the sum of individual waste loads allocated to point sources, load allocations assigned to non-point sources and loads assigned to background. The amount of pollutant that a waterbody can receive and still meet the applicable water quality standard is referred to as the "loading" or "assimilative capacity" of the waterbody, and it is calculated as the TMDL. Loading from all pollutant sources must not exceed the loading or assimilative capacity (also referred to as the TMDL) of a waterbody and must include an appropriate margin of safety.

Load allocations are portions of the loading capacity that are attributed to either natural background sources, such as soils, or from non-point sources, such as urban, rural agriculture, or forestry activities. Wasteload allocations are portions of the total load that are allotted to point sources of pollution, such as sewage treatment plants or industries. The wasteload allocations are used to establish effluent limits in discharge permits. Allocations can also be reserved for future uses, also known as the "reserve capacity." Allocations are quantified measures that assure water quality standards will be met and may distribute the pollutant loads between nonpoint and point sources. This general TMDL concept is represented by the following equation:

TMDL = Wasteload Allocation + Load Allocation + Reserve Capacity + Margin of Safety

Together, these elements establish the mercury loads necessary to meet the applicable water quality standards for mercury and protect human health, wildlife, aquatic life and other beneficial uses.

The components of the Willamette Basin Mercury TMDL are summarized in Table 1-1.

Table 1-1. Summary of Willamette Basin Mercury TMDL Components

TMDL Element	Legal Authority	Description
Name and Location	OAR 340-042-0040(4)(a)	This TMDL covers all State of Oregon perennial and intermittent streams in the Willamette Basin (Hydrologic Unit Code (HUC) 170900) (Figure 1-1).
Water Quality Standards	OAR 340-042-0040(c) OAR 340-041-0033(1); OAR 340-041-8033(1) Table 30; OAR 340-041-8033(3) Table 40 OAR 340-041-0004	Toxic Substances: (1) Toxic Substances Narrative. Toxic substances may not be introduced above natural background levels in 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 or aquatic life, wildlife or other designated beneficial uses. (2) Aquatic Life Numeric Criteria. Levels of toxic substances in waters of the state may not exceed the applicable aquatic life criteria as defined in Table 30 under OAR 340-041-8033. Table 30: Mercury (total) freshwater aquatic life chronic criteria 0.012 ug/L; (3) Human Health Numeric Criteria. The criteria for waters of the state listed in Table 40 under OAR 340-041-8033 are established to protect Oregonians from potential adverse health effects associated with long-term exposure to toxic substances associated with consumption of fish, shellfish and water.

		Table 40: Methylmercury fish tissue criteria 0.040 mg/Kg (See Section 3. Applicable Water Quality Standards) (4) Further degradation will be prevented by following Oregon's Antidegradation Policy (OAR 340-041-0004) that provides the requirements for making decisions when considering any increases in mercury load to streams and rivers in the Willamette Basin that DEQ has authority to regulate
Designated Beneficial Uses	OAR 340-042-0040(4)(c); OAR 340-041-0002(17); OAR 340-041-0340 Table 340A	Designated Beneficial Uses, Willamette Basin. The TMDL developed to meet the mercury water quality standards in OAR 340-041-041-0033(1), OAR 340-041-8033(1) Table 30, and OAR 340-041-8033(3) Table 40 is expected to be protective of all Willamette Basin designated beneficial uses including: fish and aquatic life, wildlife and hunting, fishing (See Section 2. Beneficial Uses).
Pollutant	OAR 340-042-0040(4)(b)	Methylmercury and total mercury (See Section 2. Beneficial Uses)
TMDL Target		The TMDL target is 0.14 ng/L of total mercury in the water column based on the simulated bioaccumulation of methylmercury for Northern Pikeminnow (See Sections 6.1 and 6.1.2)
Loading Capacity	OAR 340-042-0040(4)(d), 40 CFR 130.2(f)	The amount of total mercury in the water column that the Willamette Basin can receive and still meet water quality standards. Total Mercury loading capacity: 42.17 g/day (See Section 7.1. Loading Capacity)
Excess Load[1]	OAR 340-042-0040(4)(e)	The difference between the load for total mercury in the Willamette Basin and the loading capacity of the Willamette Basin. Total Mercury excess load: 318 g/day (See Section 7.2. Excess Load)
Sources	OAR 340-042-0040(4)(f)	Assessment of mercury sources in the Willamette Basin. Point Sources: 4 percent Nonpoint Sources: 96 percent (See Section 9. Source Assessment)
Waste Load Allocations	OAR 340-042-0040(4)(g), 40 CFR 130.2(h)	Wasteload allocations for point sources: • Wastewater Discharge Sector - 10 percent reduction g Total Mercury/day • Permitted Stormwater Sector - 75 percent reduction g Total Mercury/day (See Section 10.2. Wasteload Allocations for Point Sources)

1

Load Allocations	OAR 340-042-0040(4)(h), 40 CFR 130.2(g)	Load allocations for nonpoint sources: • General Nonpoint Source Sector: (Forestry, Agriculture, Water Impoundments, Water Conveyance Entities, Background) – 88 percent reduction g total mercury/day • Legacy Metals Mining Sector – 95 percent reduction g total mercury/day • Non-Permitted Urban Stormwater – 75 percent reduction g total mercury/day • Atmospheric Deposition – 11 percent reduction g total mercury/day (See Section 10.1. Load Allocations for Nonpoint Sources)
Reserve Capacity	OAR 340-042-0040(4)(k), 40 CFR 130.2(h)	Total Mercury allocations for future growth and new or expanded sources. An explicit reserve capacity of 1 percent g total mercury/day was used (See Section 12. Reserve Capacity)
Margin of Safety	OAR 340-042-0040(4)(i), 40 CFR 130.7(c)(2)	An implicit margin of safety that accounts for uncertainty related to the TMDL analyses. (See Section 11. Margin of Safety)
Seasonal Variation	OAR 340-042-0040(4)(j), 40 CFR 130.7(c)(2)	Seasonal variation and critical conditions for mercury bioaccumulation, loading and sources were considered. (See Section 8. Seasonal Variation and Critical Condition)

1.1. History of Willamette Basin Mercury TMDL

Starting in 1998, DEQ began identifying various waterbodies in the Willamette Basin as impaired due to elevated levels of mercury in fish tissue. This earlier work culminated in the development of the 2006 Total Maximum Daily Load for mercury in the Willamette Basin (Oregon Department of Environmental Quality, 2006). A TMDL is a means for implementing additional controls needed to restore and maintain the quality of water resources (U.S. Environmental Protection Agency, 1991). TMDLs represent the total pollutant loading that a waterbody can receive without exceeding water quality standards. In 2011, Oregon adopted human health criteria based on a revised fish consumption rate of 175 g/day (previously 17.5 g/day), which resulted in a mercury fish tissue criterion of 0.04 mg/kg, as methylmercury (previous TMDL target was 0.3 mg/kg). In 2012, EPA's approval of DEQ's Willamette Basin Mercury TMDL was challenged and in 2017, the U.S. District Court for Oregon ordered that the 2006 TMDL remain in place while EPA and Oregon evaluate the TMDL for reissuance consistent with the updated standard, initially by April 2019 and subsequently extended to November 2019.

The 2006 TMDL was developed and presented as an interim solution and at several points suggested the need for additional data collection and refinements of the analytical approach. The April 11, 2017 U.S. District Court, District of Oregon order (Northwest Environmental Advocates v. United States Environmental Protection Agency, 2017) stated that EPA and Oregon must complete a revised TMDL within two years. This order also adopts the earlier findings of Magistrate Judge Acosta (Northwest Environmental Advocates v. United States Environmental Protection Agency, 2016). Judge Acosta's findings highlighted DEQ and EPA declarations stating that the revision will "require analysis of factors affecting mercury pollution, including potential multiple sources, bioaccumulation patterns, and changes in the types of mercury being released and transformed in the entire complex river system," and the existing modeling "must be revised and incorporate all the new data related to mercury that has been gathered since the first TMDL" (page 14). Based on DEQ and EPA's completion of that described analysis, this TMDL targets the currently applicable Oregon fish tissue criterion for protection of human health and is expressed in terms of a daily load. DEQ also considered developing wasteload allocations for individual point sources, but determined that aggregated wasteload allocations were most appropriate. This determination aligns with the Clean Water Act, federal regulations, and EPA guidance specific to TMDL development when air deposition is the dominant source of mercury. Other important technical considerations that contributed to this decision were that combined point source loads contribute only one percent of the total basin load of mercury and the same minimization measures will be applied, regardless of the allocation being individual or aggregated. Distribution of the estimated 4.0 g/day of allowable mercury across 327 permitted wastewater discharges would be inequitable and difficult for implementation when the aggregated approach would be easier to implement and result in the same environmental benefit. The updated TMDL builds upon the existing TMDL modeling analysis, while also making substantial improvements.

1.2. Name and location

Per OAR 340-042-0040(a), this element describes the geographic area for which the TMDL is developed. This TMDL covers all perennial and intermittent streams in the Willamette Basin including the mainstem Willamette and Middle Fork Willamette.

Oregon's Willamette River is approximately 187 miles in length and is the 13th largest river in the lower 48 states in terms of stream flow. The average annual discharge to the Columbia River of 22.73 million acre-feet is nearly 15 percent of the total Columbia River flow (Kammerer, May 1990). The mainstem Willamette River flows to the north and through the City of Portland, Oregon near its confluence with the Columbia River. The Willamette Basin is bounded by the Cascades mountain range to the east and the Coast Range to the west.

1.2.1 HUCs, subbasins, and watersheds

The mainstem Willamette River includes flow from 12 major tributaries (Figure 1-1), collectively referred to as the Willamette Basin. DEQ uses the United States Geological Survey system of hydrologic delineation known as Hydrologic Unit Codes for all TMDLs. OAR 340-042-0030(4) defines Hydrologic Unit Code as "a multi-scale numeric code used by the USGS to classify major areas of surface drainage in the United States. The code includes fields for geographic regions, geographic subregions, major river basins and subbasins. The third field of the code generally corresponds to the major river basins named in OAR Chapter 340, Division 41. The fourth field generally corresponds to the subbasins typically addressed in TMDLs." HUCs often cross political or jurisdictional boundaries such as state, county or city limit boundaries. The twelve tributaries of the mainstem Willamette River roughly correspond to the 12 HUC8 watersheds (Figure 1-1 below).

Table 1-2. HUC8 codes and corresponding watershed names in the Willamette Basin.

HUC8 Code	Watershed name
17090001	Middle Fork Willamette River
17090002	Coast Fork Willamette River
17090003	Upper Willamette River
17090004	McKenzie River
17090005	North Santiam River
17090006	South Santiam River
17090007	Middle Willamette River
17090008	Yamhill River
17090009	Molalla-Pudding River
17090010	Tualatin River
17090011	Clackamas River
17090012	Lower Willamette River

Figure 1-1.Willamette Basin

1.2.2 Land use

Land use of the Willamette Basin is predominantly forest with mixture of agricultural and developed land. The most recent national data sets derived from remotely sensed data were used to create land use data for the revised TMDL. The details of the data set development and analysis are in Appendix A: Technical Support Document. The land use categories in the original data sources were aggregated to create more general land use categories that were used in the TMDL The areas of the general land use categories and the associated percent of the basin's total area are listed in Table 1-3. The spatial distribution of the general land use categories in the Willamette Basin is shown in Figure 1-2. As can be seen in Figure 1-2, most of the forest is in the mountainous regions along the boundaries of the basin with agriculture, developed and the other land uses nearer the river network and toward the lower regions of the basin. An important consideration is that the land use categories do not directly correspond to the land management. The different reasons for this limitation are discussed in Appendix A: Technical Support Document. For example, the agriculture category may not capture all of the different types of agriculture occurring in the Basin. The agriculture land use category used in the TMDL is the row crops land cover from the national data sets. Other types of agriculture occurring in the Willamette Basin may be grouped under other categories used in the TMDL. For example, pasture and hay areas in the original data source were aggregated under the grassland category used in the TMDL. Another example is orchards that may be grouped under shrubland in the TMDL. Also, the forest land use corresponds generally to the type of land cover and does not directly relate to the management of the area. In other words, forest land use does not directly relate to forestry practices and management that may be occurring in any particular area. This is also true for shrubland, which includes recently harvested forest lands with other land cover. The specific date ranges of the data sources are provided in Appendix A: Technical Support Document. The lack of land management information within the different land use categories is a limitation that affected the source assessment and the subsequent allocations of mercury in the TMDL.

Table 1-3. Land Use Areas and Percentages in Willamette Basin.

Land Use	Total Area (square miles)	Percent of Total Area
Agriculture	912	8.0%
Barren	102	0.9%
Developed	923	8.0%
Forest	5,920	51.6%
Grassland	1,902	16.6%
Shrubland	1,412	12.3%
Water	103	0.9%
Wetland	192	1.7%
Total	**11,466**	

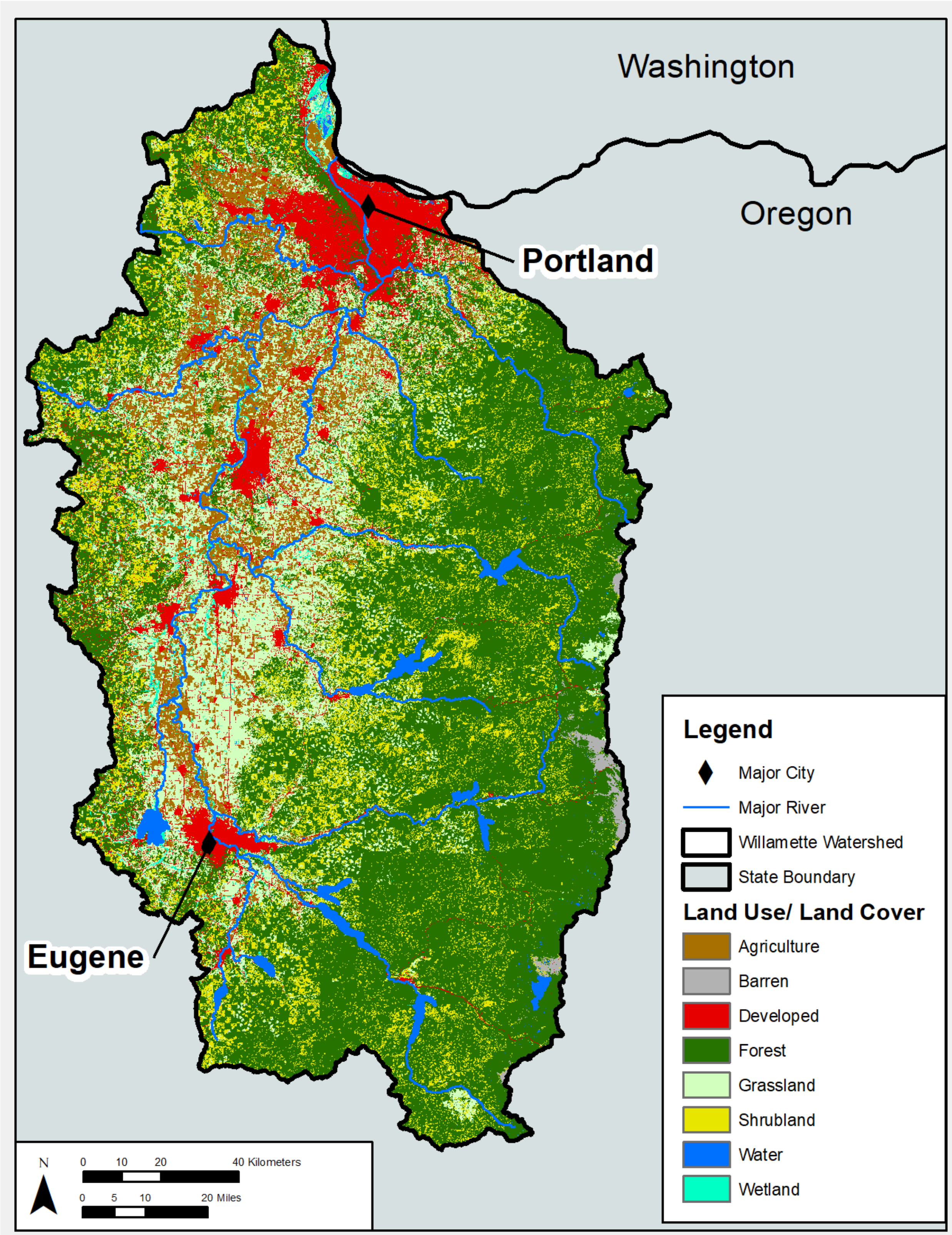

Figure 1-2. Land use distribution in Willamette Basin. Adapted from figure in Appendix: Technical Support Document.

1.2.3 Climate

Season and elevation are the biggest drivers of precipitation in the Willamette Basin. Annual precipitation in the basin is generally greatest between October and March. July and August are typically the driest months with less than 5 percent of total annual precipitation. Elevation plays an important role in the total amount of precipitation because the higher the elevation the greater the total precipitation. For example, the Willamette valley floor may receive 40 to 50 inches annual precipitation compared to the mountainous regions which may receive nearly 200 inches. The Coast Mountains receive more total precipitation, which arrives in the form of rain and some snow pack, while the precipitation in the Cascades comes primarily from snow pack.

1.2.4 Stream flow

The most important characteristic to note about stream flow in the Willamette Basin is that it is highly modified by dam and reservoir operations. Congress passed 15 flood control acts between 1938 and 1974 that affect the Willamette Basin and are implemented by the US Army Corps of Engineers. The purpose of the USACE dams is to provide flood control, navigation, hydroelectric power, and water in summer for irrigation and recreation. Dam operations have dramatically changed the natural flow patterns of the Willamette Basin streams by reducing peak flows in winter and artificially augmenting summer low flows. While these changes are beneficial for flood control, navigation, recreation, and irrigation, there are unintended consequences that influence water quality.

2. Beneficial uses

Oregon's beneficial uses are defined in OAR 340-042-0040(4)(c) as those uses of water that the state has identified for waters of the state. The beneficial uses of waters of the state are identified in state statute as the Oregon Environmental Quality Commission adopts by rule beneficial uses by basin. Water quality standards are also adopted by the commission to protect the most sensitive beneficial uses. The beneficial use(s) that is most sensitive to impairment by the pollutant or pollutants addressed in the TMDL will be specified.

This TMDL identifies the beneficial uses in the TMDL geographic area and is developed to protect the most sensitive beneficial uses.

According to OAR 340-041-0340, water quality in the Willamette Basin must be managed to protect a range of beneficial uses (see Table 340A, August 2005). The TMDL was developed to meet applicable water quality standards to protect the most sensitive beneficial uses impaired by mercury, which are: Fish and Aquatic Life; Wildlife and Hunting; and Fishing (fish consumption). The beneficial use of fishing applies to the entire mainstem Willamette River and its tributaries. Meeting water quality standards for the most sensitive beneficial uses will be protective of all other uses.

As well as lack of attainment of water quality criteria, multiple fish consumption advisories issued for the Willamette Basin by the Oregon Health Authority indicate that this beneficial use is not currently being attained. The revised TMDL for mercury is designed to restore the beneficial use of fishing to the Willamette River and its tributaries.

Fish consumption advisories for mercury are currently in place for bass in all Oregon waters; for all resident fish (except stocked, fin-clipped rainbow trout 12-inches or less) in the Dorena and Cottage Grove Reservoirs; and the entire mainstem Willamette River from its mouth on the Columbia River southward to Eugene, including the Coast Fork Willamette up to the Cottage Grove Reservoir (Oregon Health Authority, 2019). The initial fish consumption advisory for the mainstem Willamette River, dated February 13, 1997, advised the public of elevated mercury levels in the edible fish tissue of bass and northern pikeminnow (squawfish) and recommended specific limits for consumers who eat these fish caught anywhere in the mainstem river system (from the mouth of the river upstream to the Cottage Grove Reservoir). The average level of mercury found in bass and northern pikeminnow was 0.63 mg/kg. To determine if there is risk to human health from consuming mercury in fish, Oregon Health Authority first compares mean concentration found in tissue of a particular species to current screening values of 0.2 mg/kg for vulnerable populations and 0.6 mg/kg for the general population (Oregon Health Authority, 2016; Hillwig, 2019). This is similar to the value used (0.35 mg/kg) for the fish consumption advisories in place for the 2006 TMDL.

3. Applicable water quality standards

Water Quality Standards: This TMDL was developed to meet the applicable water quality standards for protection of the most sensitive beneficial uses. The applicable water quality standards are: OAR 340-042-0040(c); OAR 340-041-0033(1); OAR 340-041-8033(1) Table 30; OAR 340-041-8033(3) Table 40.

The current methylmercury fish tissue criterion in Table 40 is 0.04 milligrams of methylmercury per kilogram of fish tissue. It is based on a fish consumption rate of 175 grams/day and has been in place since 2011. This replaces the previous TMDL target referenced in Chapter 3 of the 2006 Willamette Basin Mercury TMDL. The currently applicable rules are excerpted below:

1. Toxic Substances Narrative. Toxic substances may not be introduced above natural background levels in 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 or aquatic life, wildlife or other designated beneficial uses.
2. Aquatic Life Numeric Criteria. Levels of toxic substances in waters of the state may not exceed the applicable aquatic life criteria as defined in Table 30 under OAR 340-041-8033. Table 30: Mercury (total) freshwater aquatic life chronic criterion 0.012 ug/L;
3. Human Health Numeric Criteria. The criteria for waters of the state listed in Table 40 under OAR 340-041-8033 are established to protect Oregonians from potential adverse health effects associated with long-term exposure to toxic substances associated with consumption of fish, shellfish and water. Table 40: Methylmercury fish tissue criteria 0.040 mg/Kg
4. Antidegradation. Further degradation will be prevented by following Oregon's Antidegradation Policy (OAR 340-041-0004) that provides the requirements for making decisions when considering any increases in mercury load to streams and rivers in the Willamette Basin that DEQ has authority to regulate

The 2006 TMDL development included modeling that generated a bioaccumulation factor for the Willamette River for several species of fish. In addition, the TMDL developed a translator to convert the dissolved methylmercury water concentration to a water concentration for total mercury in ng/L. Through these procedures, the TMDL derived water column targets for total mercury in ng/L based on the bioaccumulation factor for the most sensitive species modelled, the Northern pikeminnow (*Ptychocheilus oregonensis*), at the 50th percentile of the fish tissue data distribution. In 2018, an EPA contractor conducted the modelling needed to update the water concentration value based current methylmercury criterion of 0.04 mg/kg. The revised water column concentration of 0.14 ng/L total mercury was used to update the TMDL.

The Oregon Health Authority cites federal reports by EPA in 2001 and USGS in 2008 in estimating that 90 percent of the mercury found in fish tissue is in the methylated form (Oregon Health Authority, 2016). The average fish tissue concentration for mercury in a number of fish species in the Willamette Basin currently exceeds the 0.040 mg/kg criterion. The current freshwater 'acute' criterion for mercury is 2.4 ug/L and the freshwater 'chronic' criterion is 0.012 ug/L (12 ng/L) for the protection of aquatic life (as presented in the Table 30 Water Quality Criteria Summary; OAR 340-041-0033).

This TMDL is being developed to meet the human health criterion, which is the most protective, and will therefore be protective of other uses and applicable criteria.

4. Mercury water quality impairments

The latest water quality assessments relative to mercury for the Willamette Basin from Oregon's 2012 Integrated Report (http://www.deq.state.or.us/wq/assessment/rpt2012/results.asp) identified several segments of the Willamette River and its tributaries as not meeting water quality standards. Those waters currently assessed as requiring a TMDL (Category 5) are shown in Figure 4-1. Waters for which mercury impairments were addressed by the 2006 TMDL are indicated in the last column of Table 4-1. Segments that were listed in Category 5 in the Willamette Basin after the completion of the 2006 TMDL are also addressed in this revised TMDL.

Table 4-1. 303(d) Listings for Mercury in the Willamette Basin

Name	Miles	HUC 8	Assessed	Affected Use	Category	2006 TMDL
Amazon Diversion Canal (A3 Drain)	0 to 3.9	17090003	2010	Fishing	5	X
Amazon Creek Diversion Canal	0 to 6.6	17090003	2010	Fishing	5	X
Yamhill River	0 to 11.2	17090008	2012	Human health	5	
Coast Fork Willamette/ Cottage Grove Reservoir	28.5 to 31.3	17090002	2012	Resident fish and aquatic life; Anadromous fish passage; Drinking water	5	X
Row River/ Dorena Lake	7.3 to 11.9	17090002	2012	Drinking water; Resident fish and aquatic life; Anadromous fish passage	5	X
Clackamas River	0 to 83.2	17090011	2012	Human health	5	
Tualatin River	0 to 80.7	17090010	2012	Human health	5	
Multnomah Channel	0 to 21.7	17090012	2012	Human health	5	
Middle Fork Willamette River	0 to 82.2	17090001	2012	Human health	5	
Coast Fork Willamette River	0 to 38.8	17090002	2012	Human health	5	X
Coast Fork Willamette River	31.3 to 38.8	17090002	2012	Aquatic life; Human health	5	X
McKenzie River	0 to 84.8	17090004	2012	Human health	5	
Dennis Creek	0 to 1.4	17090002	2012	Aquatic life; Human health	5	X
Santiam River	0 to 26.2	17090005	2012	Human health	5	
Willamette River	0 to 186.6	17090003 17090007 17090012	2012	Human health	5	X
Notes: Information from 2012 Integrated Report as of May 2019. Category 5 = Water quality limited, TMDL needed.						

Note: The most recent Integrated Report in Oregon was approved by EPA December 20, 2018, with no changes to mercury impairments in the Willamette Basin.

Figure 4-1. Mercury Impairments in the Willamette Basin

5. Summary of Mercury TMDL development and approach

5.1. Mercury cycling in the environment

This TMDL was developed to achieve the Oregon criterion for fish tissue concentrations of methylmercury. Mercury in higher trophic level fish is present largely as methylmercury, which is a potent neurotoxin in humans and other vertebrates. Mercury is a pollutant of global concern due to its widespread distribution in the environment and accumulation in aquatic biota. Most releases of mercury into the environment are to the atmosphere in an inorganic form; however, almost all human exposure to mercury is to an organic form, methylmercury, through the consumption of contaminated fish (Eagles-Smith, et al., 2018; Munthe, et al., 2007). Mercury released into the atmosphere has a long atmospheric lifetime (~6-12 months) which allows for its widespread distribution prior to deposition (Lindberg, et al., 2007; Schroeder & Munthe, 1998). As a result, elevated levels of methylmercury in fish tissue occur even in remote ecosystem (Chetelat, et al., 2015; Fitzgerald, Engstrom, Mason, & Nater, 1998; Trip & Allan, 2000). Most of the mercury in fish originates form dietary exposure, with minimal direct uptake by fish from the water (Hall, Bodaly, Fudge, Rudd, & Rosenberg, 1997). Therefore, differences in trophic position, foraging behavior, and diet can have a large impact on how much mercury is present in a given fish species (Driscoll, et al., 2007; Eagles-Smith, et al., 2016a).

Mercury is deposited from the atmosphere via wet (rain and snow) and dry deposition processes (Lindberg, et al., 2007; Wright, Zhang, & Marsik, 2016). Watershed characteristics and associated land use activities have a large influence on how much atmospherically deposited mercury is sequestered in the soil, re-emitted to the atmosphere, or mobilized in surface water (Domagalski, et al., 2016; Eckley, et al., 2016; Hsu-Kim, et al., 2018). In addition to atmospheric deposition, some watersheds may also have point sources of mercury pollution (e.g. mines or other industries that utilize mercury containing materials) and/or may contain soils geologically enriched with mercury that can contribute to mercury levels in water and fish (Domagalski, et al., 2016; Kocman, et al., 2017; Smith, Cannon, Woodruff, Solano, & Ellefsen, 2014). The Willamette Basin receives most of its mercury from atmospheric deposition that originates from trans-Pacific sources (Strode, et al., 2008).

The form of mercury that bioaccumulates in fish tissue is almost exclusively methylmercury (Driscoll, et al., 2007; Munthe, et al., 2007). Therefore, it is important to understand the environmental processes impacting mercury methylation. Anaerobic bacteria perform mercury methylation, which can involve sulfate and iron reducing bacteria as well as methanogenic bacteria (Christensen, et al., 2016; Ullrich, Tanton, & Abdrashitova, 2001; Warner, Roden, & Bonzongo, 2003). The amount of methylmercury produced in the environment is a result of two main factors: 1) the availability of inorganic mercury and 2) the presence and activity of microorganisms capable of methylizing mercury (Marvin-DePasquale, et al., 2009). Typically, only a relatively small amount of the total inorganic mercury present is in a form that is available to methylating microorganisms (Hsu-Kim, et al., 2018; Marvin-DePasquale, et al., 2009). In general, mercury that is tightly bound to sediment or particles is less available for microbial methylation than mercury that is in the dissolved phase and/or bound to dissolved organic carbon (Benoit, Gilmour, Heyes, Mason, & Miller, 2002; Graham, Aiken, & Gilmour, 2012; Hsu-Kim, Kucharzyk, Zhang, & Deshusses, 2013). Factors that affect methylating microorganisms include the presence of anoxic (oxygen-free) conditions, nutrients, terminal electron acceptors (such as sulfate, ferric iron, etc.), and organic matter (Hsu-Kim, et al., 2018). Because the microorganisms responsible for methylation require anoxic conditions, methylation tends to occur in sediments and the stagnant waters in wetlands and thermally stratified lakes and reservoirs.

Landscape variables can have a large influence on the fate of atmospherically deposited mercury. For example, when mercury is deposited to a natural forested watershed, the vast majority of the mercury is retained in vegetation and soil and only a relatively small amount is exported in runoff (Balogh, Nollet, & Offerman, 2005; Domagalski, et al., 2016; Hsu-Kim, et al., 2018; Shanley, et al., 2008). The retention of mercury in watersheds is due to its binding to sulfur function groups associated with soil organic matter (Obrist, et al., 2016; Skyllberg, Xia, Bloom, Nater, & Bleam, 2000). Watershed land uses such as forestry, agriculture, and urbanization have all been shown to decrease the retention of atmospherically deposited mercury and enhance its mobilization into adjoining waterbodies (Eckley, et al., 2015; Eckley & Branfireun, 2009; Hsu-Kim, et al., 2018). Water impoundments, such as reservoirs have been shown to have elevated fish methylmercury levels relative to natural lakes and free-flowing rivers (Willacker, et al., 2016). The variables that have been shown to enhance fish methylmercury levels in reservoirs include a shift from a lotic to lentic foodweb, the development of anoxic conditions in the bottom water, the accumulation of organic matter and inorganic mercury from settling particles, and water-level fluctuations enhancing sulfate and organic carbon cycling (Eckley, Luxton, Goetz, & McKernan, 2017; Hsu-Kim, et al., 2018). Overall, these landscape variables can have a large impact on how much atmospherically deposited ends up bioaccumulating in fish tissue (Eagles-Smith, et al., 2016b).

5.2. Mercury TMDL approach

Determining the TMDL linkage between total mercury loads and attaining fish tissue concentrations of methylmercury to protect human health is complicated because of the many intervening kinetic and transport processes. Methylmercury is produced under anoxic conditions, which can occur within a river or watershed. Within a river, methylmercury production mostly occurs within the sediment, with the quiescent water of backwater channels potentially having higher rates of methylation. Within a watershed, wetlands or areas with saturated soils can often provide important locations for methylmercury production. The relative importance of internally produced (within the waterbodies and their sediments) or externally produced (within soils and groundwater prior to reaching waterbodies) sources of methylmercury has not been assessed for the Willamette Basin. Methylmercury monitoring data are available primarily from the water column. The simplified conceptual framework used in this TMDL is that the long-term average methylmercury concentration in the water column depends on total mercury concentrations in the sediment, which in turn, depend on rates of total mercury loading from upstream. The complex transformations between different forms of mercury are not explicitly simulated; rather, they are approximated by an empirical relationship between observed methylmercury and total mercury in the water column, as described in the following sections.

The TMDL report depends directly of the work done in the TMDL Technical Support Document, prepared by EPA's contractor, Tetra Tech, and presented as Appendix A: Technical Support Document. This TMDL document summarizes the work of the technical support document and how this work was used in the decision process of the TMDL. Cross-references are provided in this TMDL document to sections in the technical support document from which reported results were drawn.

Linked models were used to determine the relationship between fish tissue concentrations of methylmercury (or MeHg) and various sources of total mercury (or THg) in the Willamette Basin. These models estimated the load capacity, calculated the excess load, identified sources and linked the sources of total mercury in the Willamette Basin to the concentrations in the river system. The first model used was the Food Web Model. The Food Web Model simulates bioaccumulation and predicts fish tissue concentrations of methylmercury based on exposure concentrations in the water column. This relationship is then used to estimate mercury exposure concentrations that are consistent with attaining the water quality standard for methylmercury in fish tissue. Next, a mercury translator equation was used to estimate the total mercury in the water river system. At this point, the load capacity of total mercury for a target fish species was estimated. The difference between the load capacity and the median of observed total mercury concentrations from throughout the Willamette Basin was used to calculate the excess load. The third model used was a Mass Balance Model, which evaluated contributions of various sources of total mercury within the Willamette Basin and linked the sources to observed total mercury in water of the river system. The models linked together and the different forms of mercury among those links is shown below in Figure 1-1. The three model components were calibrated for the current conditions using recent data for methylmercury in fish tissue, forms of mercury in water and various input data that characterizes the sources of total mercury in the Willamette Basin and the processes that control the fate and transport of the sources. Details on each modeling step are presented below.

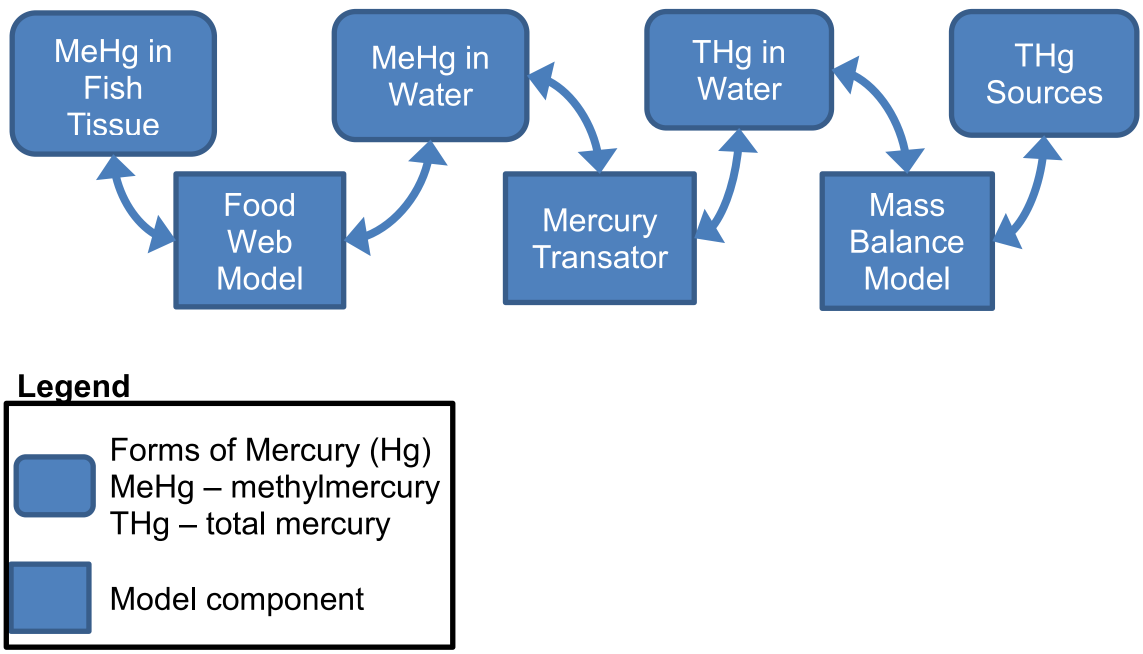

Figure 5-1. Linked models and forms of mercury used to develop the Willamette Basin Mercury TMDL.

6. Explanation of models and current mercury load

The conceptual framework used in this TMDL is that the long-term average methylmercury concentration in the water column depends on rates of total mercury loading from upstream. Linked models were used to connect fish tissue concentrations of methylmercury to sources of total mercury in the Willamette Basin. These models estimated the load capacity, calculated the excess load, identified sources and linked the sources of total mercury to the concentrations in the river system. Details of each component of the models and calculation of the current mercury loads is discussed in the remainder of this section.

6.1. Explanation of models

DEQ's approach to determining the load capacity the revised TMDL is based on two fundamental methodological components: a basin-specific aquatic food web model to estimate methylmercury biomagnification; and a translator equation that calculates the total mercury concentration in the water column, using methylmercury biomagnification information. This approach allows relation of the fish tissue concentration of methylmercury to a load capacity based on total mercury concentration in the water column of the Willamette River and its tributaries. The total mercury concentration can then be related to total mercury sources entering the Willamette River and its tributaries. The discussion below contains a more detailed technical presentation of the analytical tools utilized in the development of the load capacity for this mercury TMDL.

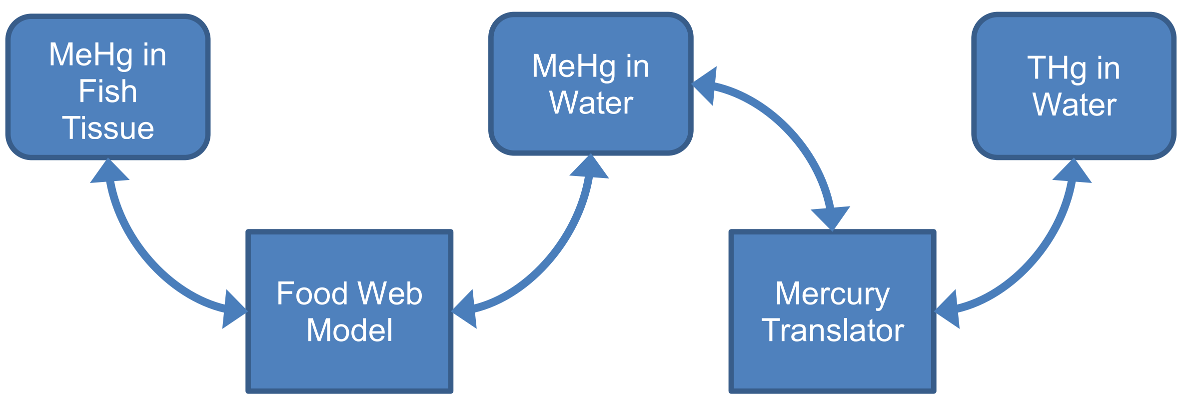

Figure 6-1. Conceptual model for estimating load capacity from fish-tissue MeHg to water column THg.

6.1.1 Food Web Model

A model of the magnification of mercury through the food web was used to relate fish tissue methylmercury concentrations to the total mercury concentrations in the surface waters of the Willamette Basin. This was done using the Food Web Model, which was the same model used in the 2006 TMDL. The Food Web Model is a peer reviewed model (Hope, 2003) that simulates the concentration of mercury in different fish species located at different levels in the food chain (or trophic levels). The basic concept in the Food Web Model is that as one fish species eats other fish species with low mercury concentration in their tissue, mercury will concentrate in the tissue of the predator at levels greater than the prey. The species and the respective trophic levels used in this analysis are listed in Table 6-1. These are the fish species for which total mercury target concentrations in the water were estimated consistent with attaining the water quality standard for levels of methylmercury in the fish tissue. These species reside in Willamette Basin waters year round, so are better indicators of mercury accumulation based on pollutant sources in Oregon. The Food Web Model was calibrated using water quality and fish tissue data collected in the Willamette Basin since 2002. This dataset was documented in the Willamette River Basin Mercury Data Summary (Schmidt, 2018). The methods and results of the model update and calibration are presented in the TMDL Technical Support Document in Appendix A: Technical Support Document.

Table 6-1. Fish Species and Associated Topic Levels using in Food Web Model

Species	Trophic Level
Bluegill (BLU)	Level 3
Carp (CAR)	Level 3
Cutthroat Trout (CTT)	Level 3
Rainbow Trout (RBT)	Level 3
Largescale Sucker (LSS)	Level 3
Largemouth Bass (LMB)	Level 4
Smallmouth Bass (SMB)	Level 4
Northern Pikeminnow (NPM)	Level 4

The Food Web Model is a probabilistic model and allows for the incorporation of uncertainty and risk into the analysis. The Food Web Model is run many times (10,000 times) and input data for each run is taken from random selections of values from the statistical distributions of the input data for the Willamette Basin. Estimation of these statistical distributions was a main component of the calibration of the Food Web Model. The specific information, statistical distributions and estimated parameters for the updated Food Web Model are in Section 3 of Appendix A: Technical Support Document. The output data from the Food Web Model was used with the translator equation to obtain datasets of total mercury concentrations in the waters of the Willamette Basin for each of the fish species listed in Table 6-1.

The Food Web Model also estimated biomagnification for each fish species, which is a measure of how much methylmercury will concentrate in the tissue of fish species within the food web. Several statistics of the distributions of the biomagnification values from the Food Web Model are listed in Table 6-2. These estimates were compared to national values developed by EPA for trophic levels 3 and 4 (ref) and are shown in Figure 6-2. The estimated values fall near or within 90% confidence intervals by trophic level on the national values (see Figure 6-2). DEQ considered this sufficient indication that the biomagnification estimates specifically for the Willamette Basin were within the acceptable ranges of values for similar food webs in the US.

Table 6-2. Biomagnification (L/kg) estimates from Food Web Model for fish species.

Fish Species	Median	5th Percentile	95th Percentile
Bluegill	1.90E+06	1.34E+06	7.76E+06
Carp	2.52E+06	1.92E+06	6.77E+06
Cutthroat Trout	4.72E+05	3.00E+05	2.23E+06
Rainbow Trout	2.27E+06	1.40E+06	1.15E+07
Largescale Sucker	2.16E+06	1.63E+06	5.97E+06
Largemouth Bass	5.02E+06	3.48E+06	1.83E+07
Smallmouth Bass	7.66E+05	4.62E+05	4.30E+06
Northern Pikeminnow	1.81E+06	1.18E+06	7.21E+06

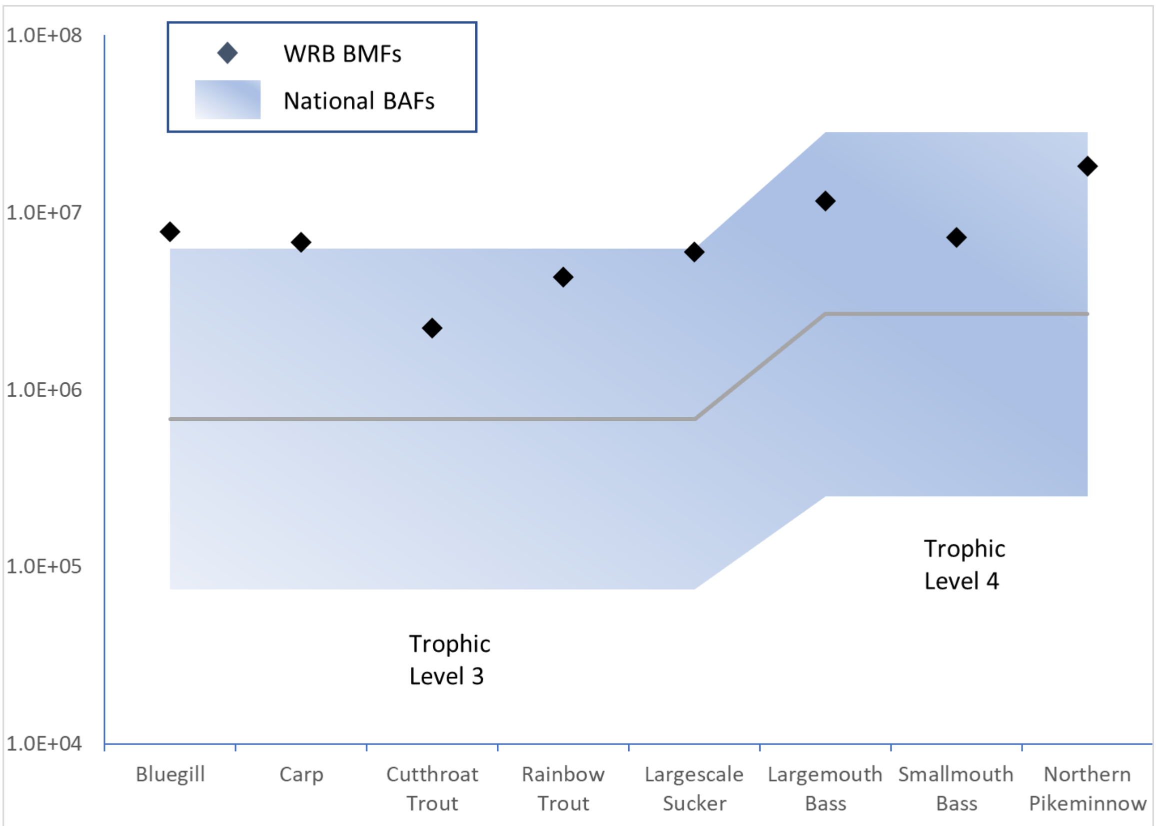

Figure 6-2. Comparison of Food Web Model biomagnification estimates to national values bioaccumulation factors values (U.S. Environmental Protection Agency, 2010a). Blue band represents the 5th to 95th percentile of the national BAF estimates. Relationship between BMF and BAF are discussed more in TSD.

6.1.2 Mercury translator equation

DEQ used the information about dissolved methylmercury for the different fish species from the Food Web Model to relate the dissolved methylmercury in fish tissue to total mercury concentrations in water. This was done because total mercury supplies the pool of mercury available for methylation and because total mercury can be related to mercury sources in the Willamette Basin. In the same manner in the 2006 TMDL, DEQ used an empirical translator equation go from dissolved methylmercury information to total mercury in water column for the different fish species using more recent observed data. DEQ used this empirical relationship to represent the complex, non-linear methylation process that depends on temperature, carbon, sulfur, reduction/oxidation conditions, and other variables. The details of the translator equation development are given in Section 4 of Appendix A: Technical Support Document.

As explained in the TMDL Technical Support Document, consideration was needed around issues of data censoring, non-contemporaneity of total mercury and dissolved methylmercury data, as well as spatial and seasonal variability of the translator equation. These issues were addressed as follows. To address data-censoring concerns, all of the data was used in the translator development and methods that provide robust statistical approaches were used for the censored portion of the data. The non-contemporaneity of the data was addressed using the medians of the dissolved methylmercury and total mercury data, which were calculated for the entire period the data was collected. To address spatial variation, medians of dissolved methylmercury and total mercury concentrations were calculated for each HUC8 in which data was collected. Because the ratios of these medians tended to be consistent among the HUC8s, DEQ considered this sufficient evidence that a single translator equation would be effective. For seasonal variation, translator equations for two seasons (June through October and November through May) were considered. Different slopes for the translator equations were found for the two seasons with a larger slope for the warmer months. The slope estimates and associated statistics are listed in Table 6-3. The increased uncertainty of the slope estimates for the seasons, as opposed to the entire year, is evident in the larger slope standard error and wider confidence intervals compared to the single slope estimate for the entire year (see Table 6-3). The final translator equation used the entire year slope estimate (see Figure 6-3).

Table 6-3. Slope estimates and associated statistics for translator equation.

Season	Slope Estimate[1] (unitless)	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Slope Standard Error	Slope p-value
Entire Year	0.0160	0.0147	0.0174	0.0006	<0.0001
June through October	0.0347	0.0300	0.0393	0.0021	<0.0001
November through May	0.0070	0.0057	0.0083	0.0057	<0.0001

[1] Weighted least-squares method was used to estimate the slope. The weights were the number of observations for each HUC8 used to calculate the medians of dMeHg and THg.

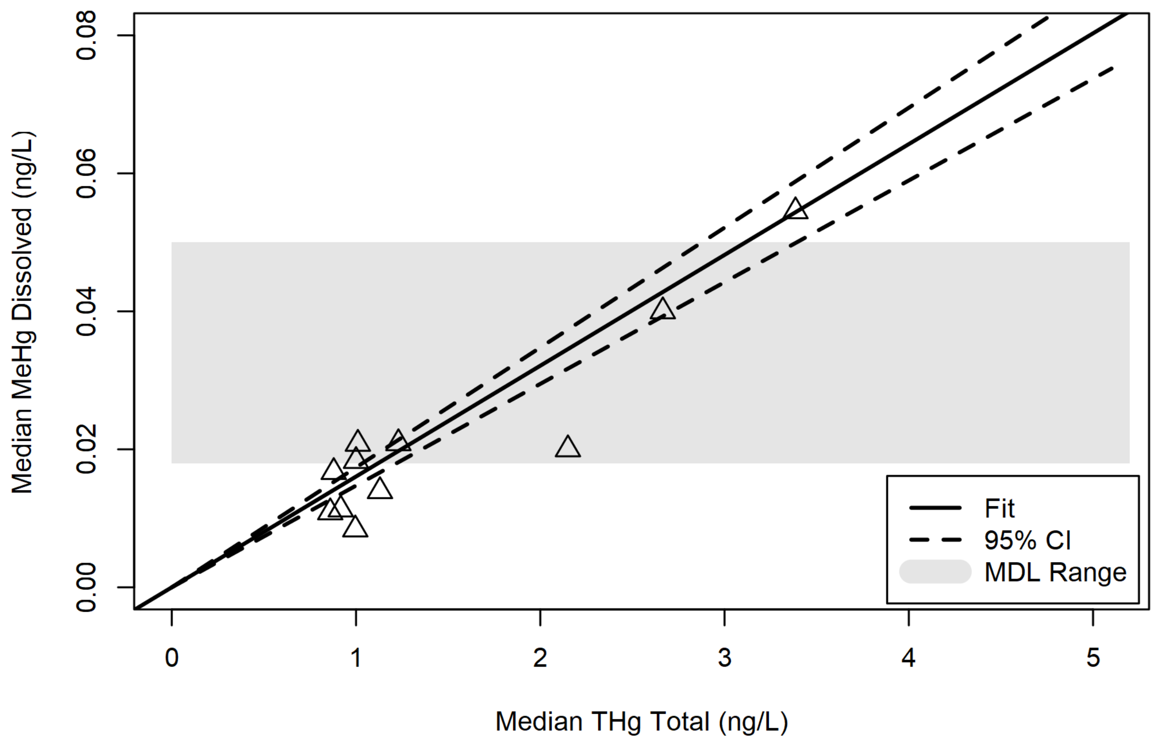

Figure 6-3. Final Mercury Translator Model: Aggregated, Year-round, Zero-Intercept Model by HUC8 Weighted by Sample Size. MDL is minimum detection limit of methylmercury laboratory method. The triangles are the median pairs of dissolved methylmercury and total mercury for each HUC8.

The final step is to estimate the total mercury target level for each fish species based on the updated fish tissue concentration. The details of the estimation of the total mercury target levels for the fish species considered in Section 4.3 of Appendix A: Technical Support Document. The same formula used by Hope in the 2006 TMDL was used for this calculation and is given as:

$$TL_n = \left[\frac{TC}{BMF_{ME,n} \cdot \Omega}\right] \cdot CF$$

where:

- TL_n is the total mercury target level for the nth fish species (ng/L),
- TC is the revised fish tissue criterion for MeHg in fish (0.040 mg/kg),
- $BMF_{ME,\,n}$ is the biomagnification factor for the nth fish species (L/kg – see Table 6-2),
- Ω represents the Mercury Translator (0.0016 from slope estimate in Table 6-3), and
- CF is a conversion factor ($1 \cdot 10^6$ ng/mg).

All of the values for the parameters in the equation for TL_n are the same for all the fish species except the biomagnification factor, which was simulated using the Food Web Model for each fish species. Furthermore, 10,000 simulations were run using randomly selected values from multiple input parameter distributions to get a biomagnification factor distribution for each species, and ultimately a species-specific distribution of target total mercury concentration. The medians of the target total mercury levels for each fish species were calculated from these data sets. The confidence intervals of the median target total mercury levels were estimated directly using a bootstrapping method, which does not rely on assumptions about the statistical distributions of the datasets.

The final estimates of the target total mercury levels and associated confidence intervals for each fish species are listed in Table 6-4. The median target level total mercury in Northern Pikeminnow of 0.14 ng/L was used as to calculate a single load capacity of total mercury for the entire Willamette Basin. DEQ selected this target level for the development of the TMDL because this was the lowest total mercury concentration among the fish species and considered the most protective. This is the same fish species that was used to develop the target in the 2006 TMDL.

Table 6-4. Species-specific Surface Water THg Target Levels to Meet a Fish Tissue Concentration of 0.040 mg/kg MeHg.

Species	Median THg Target Levels (ng/L)	Lower 95% Confidence Limit on Median	Upper 95% Confidence Limit on Median
Bluegill	0.32	0.32	0.38
Carp	0.37	0.37	0.41
Cutthroat Trout	1.11	1.11	1.31
Largemouth Bass	0.22	0.22	0.26
Largescale Sucker	0.42	0.42	0.47
Northern Pikeminnow	0.14	0.14	0.15
Rainbow Trout	0.58	0.58	0.69
Smallmouth Bass	0.35	0.35	0.40

6.1.3 Linkage analysis using Mass Balance Model

As detailed in the TMDL Technical Support Document, the linkage of mercury sources to the levels of total mercury in the Willamette River and its tributaries was analyzed using a Mass Balance Model. Figure 6-1 shows this connection in a conceptual model form. The 2006 TMDL mass balance used simplified delivery ratios for total mercury loads delivered from atmospheric deposition and soil erosion to the waters of Willamette Basin. This revision of the mercury TMDL used a detailed source characterization and a comprehensive watershed model called Hydrological Simulation Program – FORTRAN (HSPF) to more robustly simulate the generation and transport of total mercury within the Willamette Basin. The main vectors for total mercury that DEQ considered were dissolved forms from precipitation, permitted discharges, surface runoff and groundwater, along with mercury attached to eroded soils and stream sediment. The Mass Balance Model estimated the fluxes of these vectors into and through Willamette Basin. The processes simulated in the HSPF model allowed for estimates of the distribution of mercury in the water column and sediment.

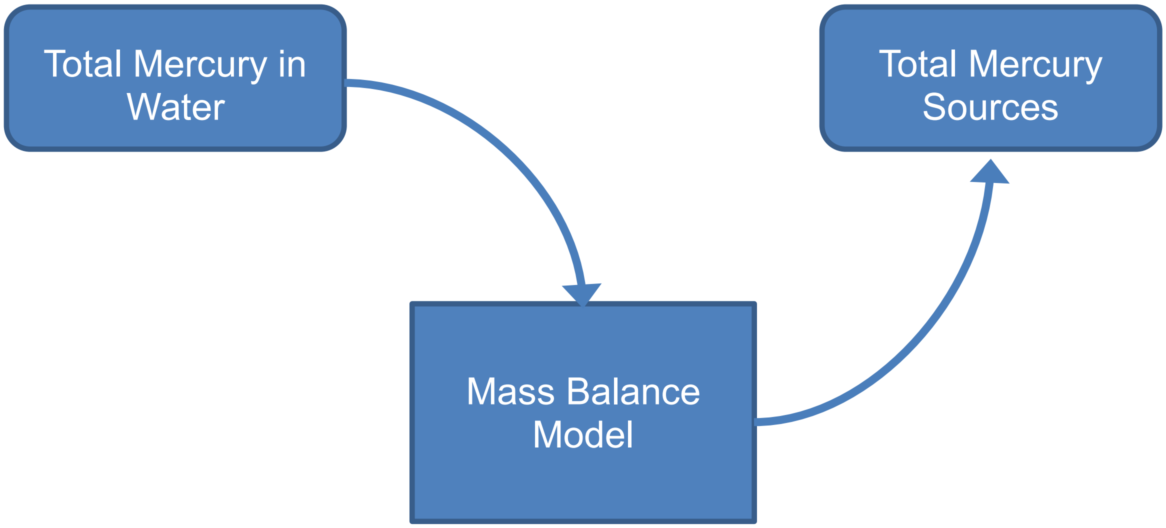

Figure 6-4. Conceptual model of linking total mercury source in the watershed to total mercury in the streams and rivers of the Willamette Basin.

DEQ used the results of the Mass Balance Model estimate the overall mercury load in the Willamette Basin and distribute the load to different source categories. These source categories are at the top of Figure 6-5 and included permitted point sources and nonpoint sources. The nonpoint sources were broken down further by source, land use, and methods of transport. These methods of transport were direct to water, overland flow, resurfacing groundwater, and erosion of soil. An example of how a nonpoint source was represented is mercury from wet atmospheric deposition in rain onto agricultural land (a pervious land use type) moved to stream network by overland flow. The distribution of the mercury sources allowed DEQ to investigate the relative contributions and to develop allocations. The relative contributions of the sources were calculated as the ratio of the source load to the total load estimated using the Mass Balance Model. The development of the model and how the Willamette Basin was represented is described in detail in Appendix A: Technical Support Document.

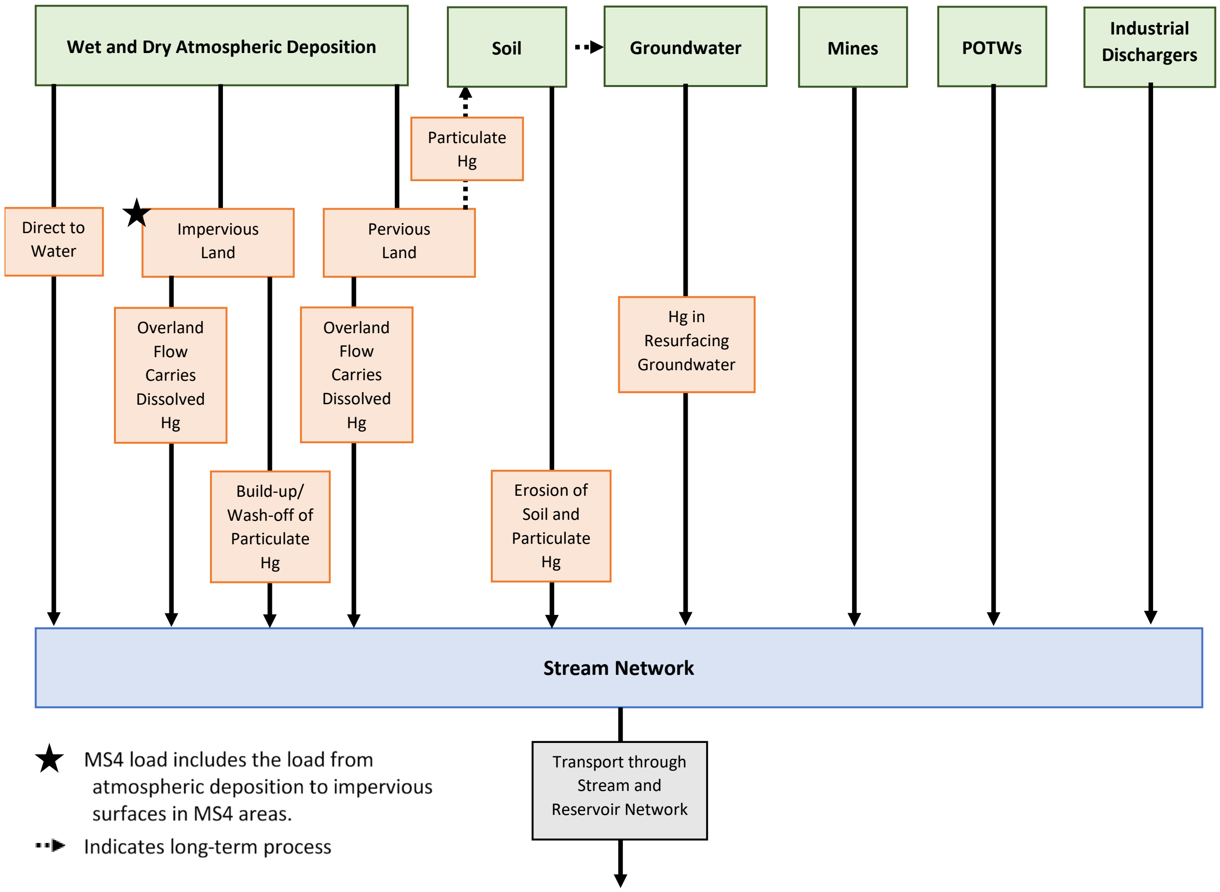

Figure 6-5. Conceptual Framework for the Total Mercury Mass Balance Model. Figure taken from Appendix: Technical Support Document.

The Willamette Basin was broken up into sub-basins in the HSPF model. This allowed for the source of mercury and the transport methods to be separated spatially in more detail than the HUC8s. The sub-basins are shown in Figure 6-6 and within each sub-basin, sources were represented using model HSPF model elements referred to as hydrologic response units. These units combine topography, soils, land use, weather and other relevant information to create homogeneous units that are simulated and combined in the HSPF model to represent movement of water and sediment within and through the Willamette Basin.

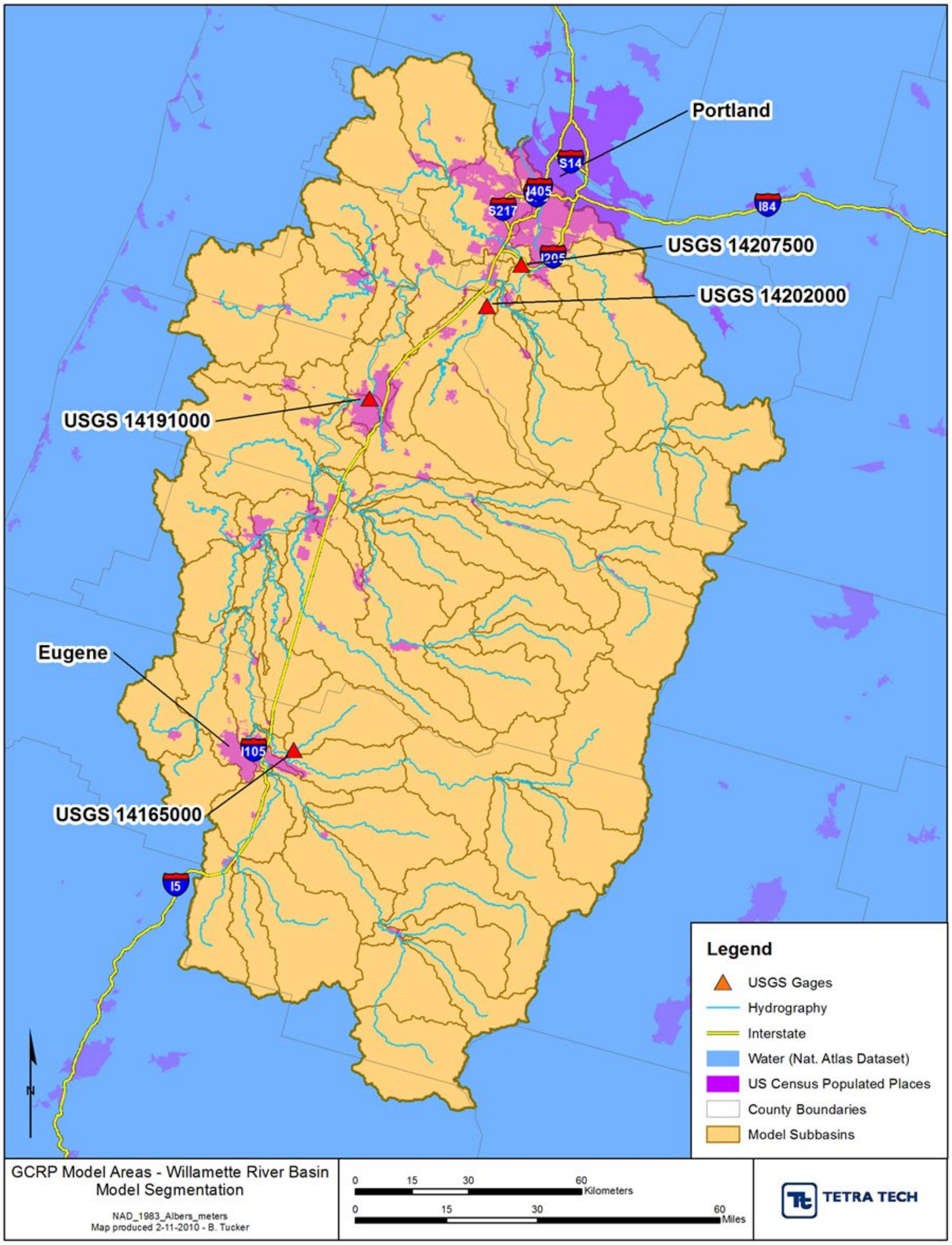

Figure 6-6. Existing HSPF Model Domain for the Willamette Basin. Taken from Appendix: Technical Support Document.

An example of the process to generate the hydrologic response units is shown in Figure 6-7. Upland processes and pathways of transport (e.g., surface runoff, groundwater resurfacing) simulated by the HSPF model were used to characterize flow and sediment export from nonpoint sources in the watershed, and paired with mercury source information to estimate nonpoint source mercury loads. Next the relationships of the different mercury sources to the pathways described in Figure 6-5 were applied using output from the HSPF model simulations and mercury source information. The development of the mercury source information for the Mass Balance Model required a comprehensive source characterization, which is summarized in the following section.

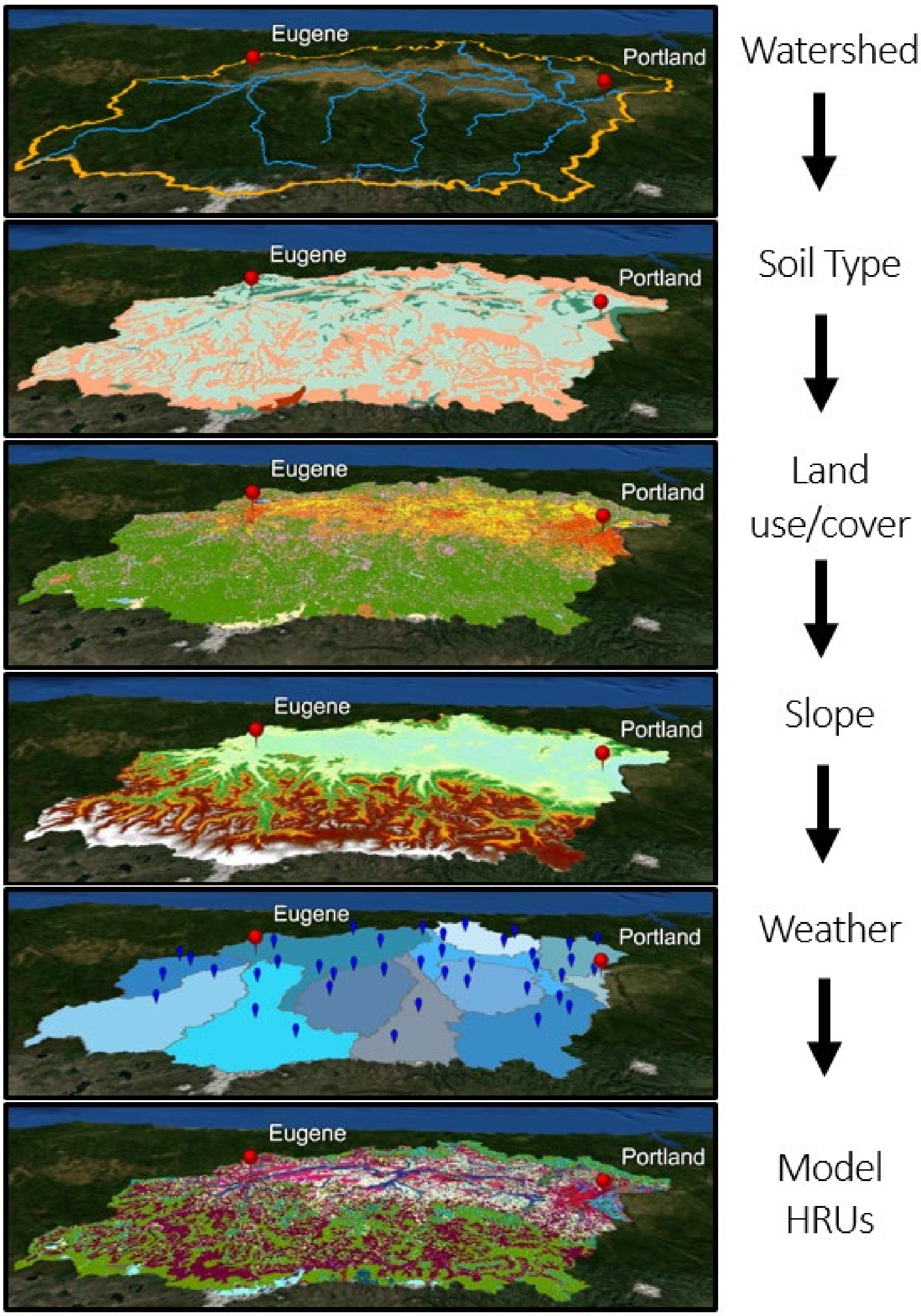

Figure 6-7. Schematic of Model Hydrologic Response Unit (HRU) Development. Taken Appendix: Technical Support Document.

6.1.4 Nonpoint source input data development

The principal sources included in the nonpoint source analysis were atmospheric deposition, soil, and groundwater. As shown in Figure 6-5 above, these sources follow various pathways to get into Willamette Basin streams. There was little information available for concentrations of mercury specific to the groundwater aquifers of the Willamette Basin. Several large scale studies were available to estimate mercury loads in the Willamette Basin from the atmosphere and in the soils. These loads are mixtures of background and anthropogenic sources.

6.1.4.1 Atmospheric deposition

Both wet and dry deposition of mercury were estimated for input to the Mass Balance Model. Wet deposition of mercury occurs in a dissolved form in precipitation. Dry deposition is associated with dust and other small particulates. Both wet and dry deposition rates of mercury were estimated for the Willamette Basin using previous studies. No significant spatial variations were found across the Willamette Basin for either form of deposition. Single values were estimated for the wet and dry deposition and are listed in Table 6-5. The wet deposition load was derived from wet deposition concentration data and surface runoff volume. The dry deposition rate was used to calculate the deposition of mercury on days without precipitation and a build-up/wash-off approach was used to estimate delivery to the stream network.

Table 6-5. Estimated Wet and Dry Atmospheric Deposition Rates in the Willamette Basin.

Deposition Type	Value
Wet deposition of total mercury concentration in precipitation	6.05 ng/L
Dry deposition of total mercury	4.24 µg/m^2/year

Modeling found that most of the atmospheric sources of mercury deposited in the Willamette Basin originate outside the basin. Air quality modeling of sources within Oregon was not undertaken in the TMDL to quantify atmospheric deposition of mercury from such sources due to their relatively small contribution to the total of atmospheric deposition.

6.1.4.2 Soil

Mercury attached to soil can be delivered to Willamette Basin streams by a number of processes. Previous studies were used to estimate the total mercury levels in the soils throughout the basin. The method used to account for the mercury level from soils was to estimate potency factors for use in the Mass Balance Model. The potency factors were multiplied by the sediment loads estimated in the Mass Balance Model to get the mercury loads from soil erosion and sediment delivered to streams. These loads can then be associated with locations in the Basin at the HUC8 level and land uses. The potency factors varied with geology, soil properties and land use type. The main effect of land use was the retention and re-emission rates related to the vegetative cover (e.g. forest, shrub, or cultivated land). Using this approach, several potency factors for soils were estimated and are listed in Table 6-6. The forest and shrub land cover potency factor varied across the HUC8s in the basin. There was not a sufficient amount of data to determine whether there was significant variation between HUCs for land cover other than forest or shrub and single values were used for each land use for the entire basin. The potency factors were multiplied by the sediment load for the land cover transported to streams. The sediment loads were taken from the watershed model of the Willamette Basin that is part of the Mass Balance Model. Although many of the sources of mercury in the soil may be from geology or other sources not directly related to human activities, the erosion and transport of soil to Willamette Basin streams are, in part, controllable. Therefore, these pathways are addressed in the TMDL and WQMP.

Table 6-6. Soil total mercury potency factor estimates for Willamette Basin

Land Cover	HUC8	THg Potency (µg/kg)
Forest and Shrub	17090001	49.7
Forest and Shrub	17090002	48.2
Forest and Shrub	17090003	85.4
Forest and Shrub	17090004	60.7
Forest and Shrub	17090005	80
Forest and Shrub	17090006	79.7
Forest and Shrub	17090007	96.8
Forest and Shrub	17090008	105.1
Forest and Shrub	17090009	90.2
Forest and Shrub	17090010	115.9
Forest and Shrub	17090011	77.3
Forest and Shrub	17090012	111
Cultivated Land	All	36.7
Herbaceous Upland	All	23.3
Other	All	30.1

6.1.4.3 Groundwater

Mercury can occur in dissolved form in groundwater. The mercury load dissolved in groundwater was estimated using simulated groundwater flow from the watershed model and estimated total mercury concentration in groundwater. Limited data are available on groundwater mercury concentrations. No studies were found that accurately characterize mercury in groundwater in the Willamette Basin, or elsewhere in the Pacific Northwest. There were some samples collected from groundwater sources near Superfund cleanup sites of the mining areas in the Coast Fork Willamette River watershed, which were low (near 1 ng/L) or below the detection limit of 0.5 ng/L. Some additional data for forested watersheds in the Coast Range of Oregon also indicated that total mercury concentrations were low in groundwater (less than 1 ng/L). A value of 1 ng/L was selected as the concentration of total mercury in groundwater for the entire Willamette Basin for the TMDL. While 1 ng/L is a low concentration, groundwater entering streams is a large component of the total flow of water in the basin. As such, this resulted in large loads of total mercury (approximately 17 percent of the total source load to the stream network) estimated from groundwater contributions.

6.1.5 Estimation of instream delivery of mercury and reservoir processes

Not all of the mercury load that enters Willamette Basin streams is delivered to the outlet of the basin (into the Columbia River). Some of the load is lost due to reservoir processes related to several impoundments located in the basin (as described in Section 9.2.2 below) and processes in the river network. The details of the methods and the results are discussed in Appendix A: Technical Support Document. Losses of mercury during transit in the stream network were represented with an exponential decay model calibrated to observed data. Reductions in loads due to reservoirs used observed data for inflow and outflow to mercury concentrations and flow from some of the reservoirs and applied to the simulated mercury loads from the HSPF model.

6.2. Current total mercury load estimation for the Willamette Basin

The Mass Balance Model was used to estimate the total load of mercury and the contributions of those loads by source categories. The way the Mass Balance Model was constructed for this TMDL allows for investigating loads from the HUC8 geographic areas and even within the HUC8s. However, the loads for the entire Willamette Basin were evaluated. The rational for focusing on the entire basin is discussed in more detail in Section 7.2 explaining the excess load and load capacity calculation. The estimated loads and the relative contribution of each source category are listed in Table 6-7. The great majority of the load (greater than 95 percent) is from nonpoint sources with the permitted point sources accounting for less than five percent. The estimated total load of 361 g/day is the value used for the current load of total mercury that needs to be reduced and is used in the calculations of the excess load and load capacity.

Table 6-7. Estimate total mercury loads for source categories from Mass Balance Model for Willamette Basin.

Source Category	Estimated Load of Total Mercury (g/day)	Relative Contribution to Total Load
Nonpoint Sources		
Surface Runoff of atmospherically deposited mercury	118.0	32.7%
Resurfacing Groundwater	60.6	16.8%
Direct deposition to open water	5.9	1.6%
Erosion of mercury containing soils	154.6	42.8%
Urban DMAs (without MS4 permits)	2.5	0.7%
Legacy mine discharges	4.0	1.1%
Point Sources		
Sewage Treatment Plant discharges	3.2	0.9%
Industrial discharges	1.2	0.3%
Permitted Stormwater (MS4) discharges	11.3	3.1%
Total Load	**361.3**	
NOTE: These are loads at the point of entry into the stream network and not loads delivered to the mouth of the Willamette.		

7. Loading capacity and excess load

7.1. Loading capacity

Summarizing OAR 340-042-0040(4)(d) and 40 Code of Federal Regulations 130.2(f), loading capacity is the amount of a pollutant or pollutants that a waterbody can receive and still meet water quality standards. Modeled estimation of the amount of total mercury in the water column that the Willamette Basin streams can receive and still meet water quality standards was developed. The TMDL Technical Support Document indicates that the loading capacity for Willamette Basin is:

- Total Mercury loading capacity: 42 g/day

7.2. Excess load

In accordance with OAR 340-042-0040(4)(e), the excess load element evaluates, to the extent existing data allow, the difference between the actual pollutant load in a waterbody and the loading capacity of that waterbody. The Willamette Basin excess load is:

- Total mercury excess load: 318 g/day

The excess load was calculated by first calculating the required reduction. The required reduction was calculated using the target total mercury concentration and observed total mercury concentrations from throughout the Willamette Basin. Excess load for the Willamette Basin, then, is the difference between the existing loads of total mercury and the loading capacities of total mercury. Required reduction can be inferred from existing total mercury water column concentrations:

$$R = 1 - \frac{TL}{EL} \times 100$$

where R is the required percent reduction, TL is the target surface water total mercury concentration (ng/L), and EL is the existing surface water total mercury concentration calculated from observed data collected during the period of 2002-2014. Boxplots of the observed total mercury data are shown in Figure 7-1.

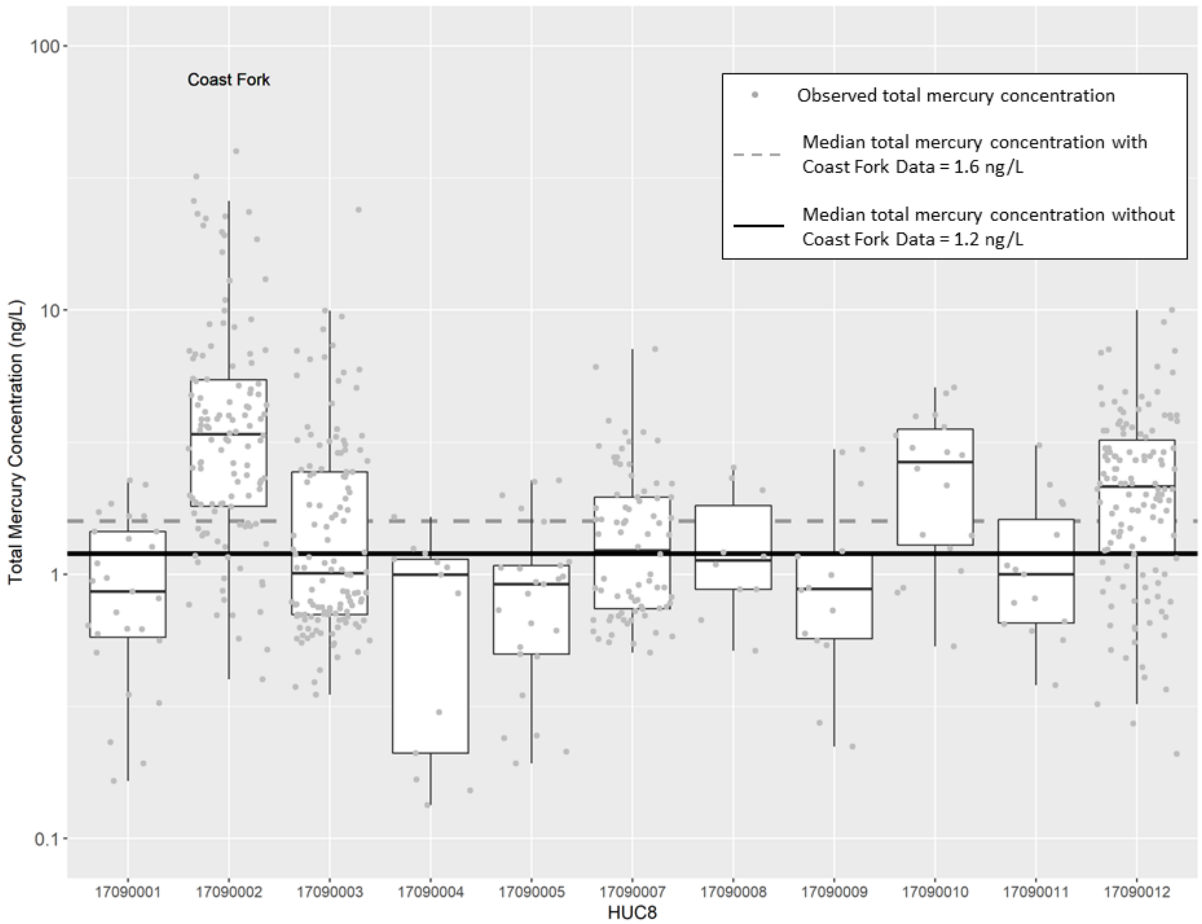

Figure 7-1. Boxplots of observed total mercury concentrations by HUC8 and medians of entire data sets with data from Coast Fork and without. The data for the Coast Fork HUC8 (17090002) is highlighed with the HUC8 name above the boxplot. No observed data was available for South Santiam (17090006).

The existing surface water total mercury concentration (EL) was calculated as the median of the observed total mercury concentrations. DEQ considered calculating the required reduction for each HUC8 and then calculating load capacity by HUC8. However, the number of observed data was not evenly distributed among the HUC8, with no data available for the South Santiam (17090006). The different number of observations for the different HUC8s can be seen in Figure 7-1 with HUC8s like the Coast Fork (17090002) and the Lower Willamette (17090012) having many more observations compared to McKenzie (17090004). The differences in the number of observations could result in more uncertainty in the estimated medians for the HUC8s with smaller number of data compared to the HUC8s with more data. DEQ decided to pool all of the HUC8 data together and calculate a single median for the existing surface water total mercury concentration for the entire Willamette Basin. Next, DEQ considered the conditions related to the mining districts in the Coast Fork HUC8 (17090002) to be a poor representation of the remaining Willamette Basin. The effects of the legacy mercury contamination is apparent in the observed data for the Coast Fork highlighted in Figure 7-1. DEQ compared the median for the entire dataset to median of the data excluding the total mercury concentration data collected in the Coast Fork HUC8. The medians are shown in Figure 7-1 and were 1.2 ng/L for the data set excluding the Coast Fork data and 1.6 ng/L for the data set including the Coast Fork data. The estimated median total mercury concentration increased by 25 percent when the Coast Fork data was included. DEQ decided to use the median of the surface water total mercury data excluding the Coast Fork HUC8 data to better represent the existing conditions for the Willamette Basin and used the median value of 1.2 ng/L to calculate the required reduction. The required reductions needed to meet to the target total mercury concentrations was calculated for each fish species and are listed in Table 7-1. The required reduction of 88 percent for the Northern Pikeminnow was the largest (see Table 7-1) and this was selected as the required reduction to be used to calculate the excess load. Rationale for selecting the required reduction for the Northern Pikeminnow is discussed further in Section 11. Margin of Safety.

Table 7-1. Required reductions of the existing median surface water total mercury concentration of 1.2 ng/L to meet fish species specific surface water total mercury target levels.

Fish Species	Surface Water Total Mercury Target Levels (ng/L) to Meet Fish Tissue Concentration	Required Reduction
Northern Pikeminnow	0.14	88%
Largemouth Bass	0.22	82%
Bluegill	0.32	73%
Smallmouth Bass	0.35	71%
Carp	0.37	69%
Largescale Sucker	0.42	65%
Rainbow Trout	0.58	52%
Cutthroat Trout	1.11	7%

The excess load was calculated next using the required reduction and the estimated daily load for the Willamette Basin calculated using the Mass Balance Model. The required percent reduction was applied directly to the current load to estimate the excess load:

$$L_{Excess} = R \times L_{Current}$$

where $L_{Excess}$is is the excess load in g/day, R is the required reduction in load (expressed as a fraction), and $L_{Current}$ is the current load in g/day estimated using the Mass Balance Model, which was estimated to be 361 g/day. The total mercury excess load for the Willamette Basin is:

$$L_{Excess} = 0.88 \times 351.42 \frac{g}{day} = 309.25 \frac{g}{day}$$

The load capacity can then be calculated as the remaining load:

$$Load\ Capacity = L_{Current} - L_{Excess} = 351.42 \frac{g}{day} - 309.25 \frac{g}{day} = 42.17 \frac{g}{day}$$

$$Load\ Capacity = 42.17 \frac{g\ of\ Total\ Mercury}{day}$$

This load capacity of 42.17 g/day corresponds to the 88 percent required reduction and was used calculate allocations and remaining parts of the TMDL equation.

8. Seasonal variation and critical condition

OAR 340-042-0040(4)(j), 40 Code of Federal Regulation 130.7(c)(2)
TMDLs must also identify seasonal variation and the critical condition. Seasonal variation of the processes and sources effecting methylmercury concentrations fish tissue was considered by using observed data collected throughout the year and through the use of models that incorporate seasonality. The Food Web Model did not explicitly address seasonality, but the data used to calibrate the model were from different times during the year. To account for seasonal variation, a single equation for the entire year better represents the many processes and conditions influencing the conversion of total mercury to methylmercury processes and total mercury loading. Observed total mercury and methylmercury data collected throughout the year were used to develop the translator equation, which adequately addresses any seasonal variation of these processes and sources.

The Mass Balance Model was used to explicitly incorporate the seasonal variation related to climate, land management, reservoir operations, and vegetation. An hourly time-step was used for watershed model simulations, which were the main component of the Mass Balance Model. This allowed for detailed simulation output to consider the seasonal generation and transport of total mercury from sources to the streams and rivers of the Willamette Basin. In addition, reservoir management was incorporated into the simulations. Regulated flows due to reservoir management is the main control over flow throughout the year for the Willamette Basin. Seasonal variation of the different inputs and processes influencing the generation and transport of total mercury were represented in the Mass Balance Model. In addition to the observed data that was collected for all of the seasons, DEQ determined that the different components of the linked models, especially the Mass Balance Model, adequately represent the seasonal variation of sources and processes that ultimately control the methylmercury concentration in fish tissue of the Willamette Basin.

Bioaccumulation of mercury in fish is a long-term process related to the intake of prey containing methylmercury and, to a lesser extent, methylmercury concentrations in the water. It takes several years for fish to accumulate enough methylmercury to exceed the fish-tissue criterion, resulting in the issuance of fish consumption advisories. Critical conditions, such as critical low flow times, are typically used for permitting pollutant discharges to achieve less acute or shorter-term impacts. Because the bioaccumulation of methylmercury is a long-term process, there were not specific conditions that could be considered critical in this TMDL.

9. Source assessment

As noted in OAR 340-042-0040(4)(f) and OAR 340-042-030(12), a source is any process, practice, activity or resulting condition that causes or may cause pollution or the introduction of pollutants to a waterbody. This section identifies the mercury sources and estimates, to the extent existing data allow, the amount of actual mercury loading from existing sources. Sources of mercury to streams include point and nonpoint sources. Specific sources are described below and are subsequently assigned allocations. By mass, nonpoint sources are the major sources of mercury in the Willamette Basin. “Nonpoint sources are diffuse or unconfined sources of pollution where wastes can either enter, or be conveyed by the movement of water, into waters of the state” OAR 340-41-0002 (42).

9.1. Air emissions

9.1.1 Oregon permitted mercury air emissions

Within the Willamette Basin there are currently 221 sources that are permitted, either by federal Title V Clean Air Act permits or Oregon Air Contaminant Discharge permits, of which 145 have reported mercury emissions. In 2016, approximately 31.8 kg/yr of measurable mercury was emitted from these permitted facilities, which are included in Appendix G. Only three of these facilities emitted more than 1 kg/yr and a single facility emitted more than 70 percent of the total permitted mercury emissions within the Willamette basin in 2016. In the remainder of the state, there are approximately 101 permitted sources of mercury emitting approximately 37.3 kg/yr.

DEQ tracks these reported permitted air emissions and is requiring controls for significant emissions under recently adopted Cleaner Air Oregon rules. However, air deposition modeling was not undertaken for the TMDL, so loads deposited due to these air emissions have not been quantified and are not assigned a specific allocation in the TMDL.

9.1.2 National and global mercury emissions trends

An existing study for global and North American mercury transport (Seigneur, 2004) was used in evaluating potential mercury air deposition sources. From these studies, 37 percent of sources of mercury from human activities deposited in the Willamette Basin from the atmosphere were from outside of North America. In 2019, the United Nations Environment Programme released a new Global Mercury Assessment 2018, which updated assessments produced at roughly five year intervals since 1990, the last being in 2013. The updated assessment found that mercury emissions continue to decline by 1 to 2 percent per year in North America and Europe, but are increasing in Asia, where approximately 49 percent of global anthropogenic mercury air emission originate (United Nations Environment Programme, 2019). The assessment asserts that legacy mining mercury sources up until the end of the 19th century continue to contribute more mercury to soils and waters than all 20th century industrial sources combined and that the potential for its remobilization complicates analysis of fate and transport (United Nations Environment Programme, 2019). In addition, the assessment confirmed a long lag time for reductions in mercury emissions to show responses because methylation of legacy mercury deposited on soils and into aquatic systems will continue (United Nations Environment Programme, 2019).

Significant reductions of atmospheric sources of mercury may not be possible by DEQ because most sources would be outside its regulatory control. However, atmospheric deposition is the primary source of mercury in surface runoff and limiting the amount of mercury from the atmosphere traveling across the land in surface runoff can be addressed in the Willamette Basin by DEQ.

9.2. Nonpoint sources

Nonpoint sources are diffuse or unconfined sources of pollution where wastes can either enter, or be conveyed by the movement of water, into waters of the state (OAR 340-41-0002 (42)). For purposes of this TMDL, nonpoint sources include activities associated with forestry, agriculture, water impoundments, water conveyances, non-permitted urban stormwater, groundwater, and atmospheric deposition to land and water.

Both nonpoint and point source loads are greatly influenced by atmospheric deposition of mercury onto the Oregon landscape. As noted in Figures 5-17 and 5-18 of the TMDL Technical Support Document, modeling indicates that the source categories of surface runoff and sediment erosion together contribute approximately 76 percent of the total mercury load to basin streams. These two source categories are implicated in nonpoint source load contributions due to land use management activities (agriculture, forestry, impoundments, water conveyances, background and non-MS4-permitted urban areas), as well as stormwater point source contributions. Figure 5-19 of the TMDL Technical Support Document indicates that 86 percent of surface runoff and 91 percent of sediment erosion may be affected by the natural and anthropogenic activities within the forestry, agriculture and urban development land use areas.

9.2.1 Agriculture, forestry, non-MS4 permitted urban areas, and water conveyances

Even though the nonpoint source categories were broken down by land use characteristics in the Mass Balance Model, loads for specific human activities and management could not be separated from natural or background processes and sources. Some examples include the difference between the forest land use category used in the TMDL analysis and forestry management. The forest land use in the TMDL covers natural undisturbed forests and some forestry management. Furthermore, harvest due to forestry are included in the shrub land use in the TMDL, but cannot be separated from shrub land that may be natural or disturbed forest not the result of harvest, such as fire. In the current TMDL analysis, there are similar limitations in separating Agricultural, Non-MS4 Permitted Urban Areas, and Water Conveyance Systems loads from natural or background sources. For these reasons, a single value is used for the load allocation of all the nonpoint sources.

9.2.2 Impoundments

Placement of dams in streams creates impoundments or reservoirs. Stream flow in the Willamette Basin is highly modified by dam and reservoir operations. DEQ searched Oregon Water Resources Department records to determine that approximately 414 impoundments of various size and function exist within the Willamette Basin. Many of these impoundments are small and some are ponds, rather than stream impoundments. As explained in the TMDL Technical Support Document, stream impoundments slow water flows, can encourage deposition of sediment and can produce low oxygen conditions that encourage bacterial transformation of mercury to methylmercury. While these processes are complex and difficult to predict, when mercury is present, impoundments can play an important role in mercury cycling (TetraTech, 2019).

In assessing impoundments in the Willamette Basin as sources of mercury, an important consideration is whether mercury is transported from reservoirs downstream. As a key component for factoring in these effects into its modeling, the DEQ, EPA and contractor team focused on large reservoirs where information was available. The TMDL Technical Support Document describes considerations around the large impoundments in the basin and how their inclusion in the modeling was determined. Modeled impoundments within the basin include: 11 of the 13 Willamette Basin reservoirs operated by the US Army Corps of Engineers (Figure 9-1) and the North Fork Reservoir, which is the largest sediment trap of the reservoirs operated by PGE in the Willamette Basin (Figure 9-2). The final set of reservoirs represented in the model is shown in Table 9-2.

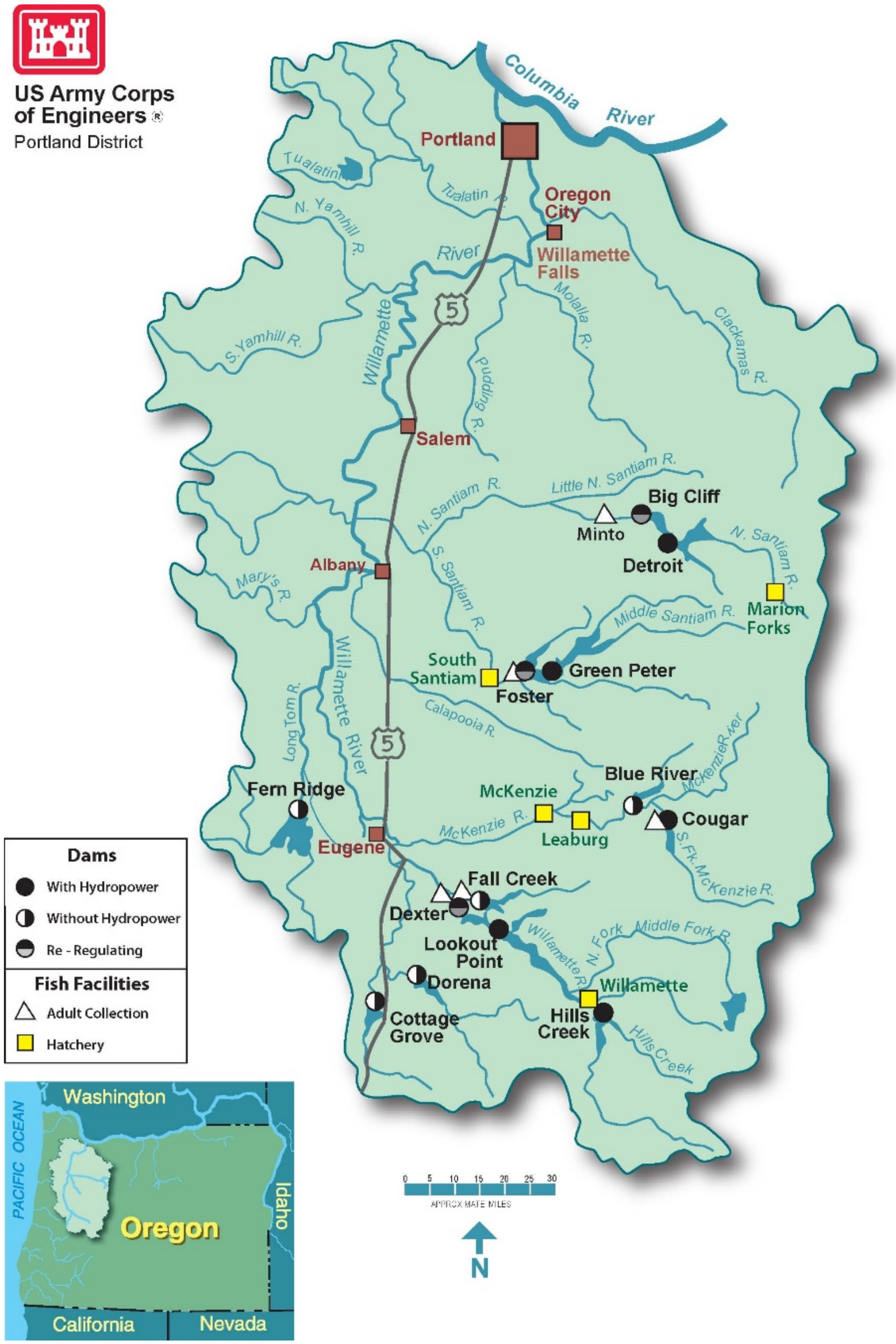

Figure 9-1. U.S. Army Corps of Engineers Dams and Reservoirs in the Willamette Basin.

Figure 9-2. PGE's North Fork Dam and Reservoir on the Clackamas River.

Table 9-1. Reservoirs Represented in the Willamette Basin HSPF Model.

Reservoir Name	River	HUC8
Blue River	Blue River-McKenzie	17090004
Cottage Grove	Coast Fork-Willamette	17090002
Cougar	South Fork-McKenzie	17090004
Detroit	North Santiam River	17090005
Dorena	Row River	17090002
Fall Creek	Fall Creek	17090001
Fern Ridge	Long Tom River	17090003
Foster	South Santiam River	17090006
Green Peter	Middle Santiam River	17090006
Hills Creek	Middle Fork-Willamette	17090001
Lookout Point	Middle Fork-Willamette	17090001
North Fork	Clackamas	17090011

9.2.3 Legacy metals mining sources

Within the Willamette Basin, there are five abandoned mercury mines, seven mercury prospects (where no extraction or production has taken place) and five districts focused on gold mining (where mercury amalgamation may have taken place). Abandoned mine lands in the basin were identified during mine land investigations conducted by DEQ, US Forest Service and Bureau of Land Management in 2000 to 2010. Table 9-2 lists the 12 mining districts and abandoned mine lands that are currently being assessed and remediated in DEQ's Cleanup Program, in collaboration with federal partners (EPA, BLM, USFS) with jurisdiction. Thirty-eight individual sites were originally presented in the TMDL Technical Support Document (Table 5-7), which are all captured in Table 9-2. Mercury mines or other mines with significant assessment and cleanup are considered as individual mercury sources, while collections of smaller and less studied sites are grouped into mining districts by subbasins.

Table 9-2. Abandoned Mine Lands and Mining Districts Within the Willamette Basin.

Mine Name	Owner	Primary Commodity	Mine District	Drainage	County
Black Butte Mercury Mine	Private	mercury	Black Butte/ Elkhead Mercury	Garroutte Creek/ Coast Fork Willamette	Lane
Champion Mine	Public	gold	Bohemia Gold	Row River/ Coast Fork Willamette	Lane
Bohemia Mines (10 unpatented)	Public	gold	Bohemia Gold	Row River/ Coast Fork Willamette	Lane
Bohemia Mines (10 patented)	Private	gold	Bohemia Gold	Row River/ Coast Fork Willamette	Lane
Blue River Mines	Public	gold	Blue River Gold	Blue River/ McKenzie	Lane
Lucky Boy (14 patented)	Private	gold	Blue River Gold	Blue River/ McKenzie	Lane
Quartzville Mines (>17 patented)	Private	gold	Quartzville Gold	South Santiam	Linn
Ruth/Amalgamated	Private	copper, zinc	North Santiam Mines	North Santiam	Marion
North Santiam Mines	Public	gold	North Santiam Mines	North Santiam	Marion
Breitenbush Mercury	Private	mercury	North Santiam Mines	North Santiam	Marion
North Fork Claims	Public	mercury	North Fork Claims	Clackamas	Clackamas
Ames-Bancroft Mine	Private	mercury	North Fork Claims	Clackamas	Clackamas

Of most relevance are the abandoned Black Butte Mine that is immediately upstream of Cottage Grove Reservoir, the Bohemia gold mining district that is tributary to Dorena Reservoir (where six abandoned sites were identified for further assessment) and the North Santiam River which is tributary to Green Peter Reservoir (where two abandoned sites were identified for further assessment).

As noted in the TMDL Technical Support Document, the Black Butte Mine is the most significant mercury source in Willamette Basin associated with mining. Furnace Creek, which was significantly impacted by Black Butte Mine activities, was determined to be contributing a substantial percentage of the mercury load to the Coast Fork of the Willamette River. Remediation of Furnace Creek took place in 2018, as part of Superfund cleanup. Because this area is a significant source of mercury to Cottage Grove Reservoir and observed water column data exists for the reservoir area, evaluation of mercury concentrations and outflows from the reservoir was possible. An example of this relationship is shown in Figure 9-3. The mercury load leaving Cottage Grove Reservoir was estimated by the modeling to be approximately 2.45 kg/yr (TetraTech, 2019).

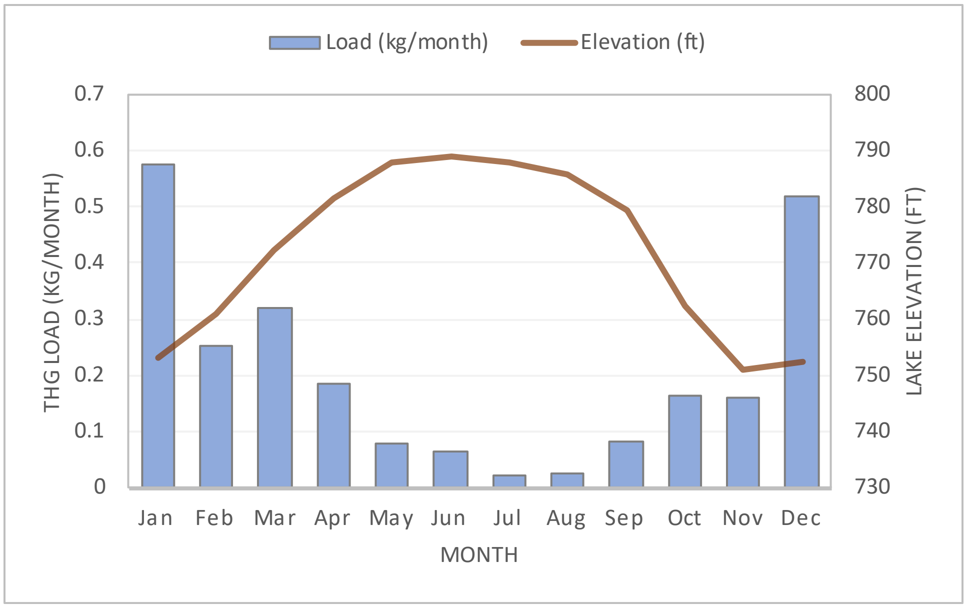

Figure 9-3. Monthly THg loads from Cottage Grove Reservoir.

The second most significant source of mercury from mining in the basin is associated with the Bohemia Mining District situated among the tributaries of the Row River upstream of Dorena Reservoir. Mercury data is limited in this area, but water samples indicate mercury concentrations flowing into the reservoir are elevated compared to elsewhere in the basin (TetraTech, 2019). Sediment samples from multiple tributaries indicate mercury contamination from mining sources is the primary cause of elevated mercury in fish tissue in Dorena Reservoir (Hygelund, Ambers, & Ambers, 2001). And mercury concentrations in macroinvertebrates were more than double those found in the Middle Fork Willamette, a nearby subbasin without known mining (Henny, Kaiser, Packard, Grove, & Taft, 2005). The mercury load leaving Dorena Reservoir was estimated by the modeling to be approximately 1.15 kg/yr (TetraTech, 2019).

Currently, the available data on other abandoned mine lands in the basin is not sufficient to indicate whether these lower priority sites are sources of mercury or at what significance. DEQ and EPA will continue to assess and remediate, as warranted, the remaining abandoned mine lands within the basin.

9.3. Background and unquantified anthropogenic sources

“Background sources include pollutants not originating from human activities and anthropogenic sources of a pollutant that the Department or another Oregon state agency does not have authority to regulate, such as pollutants emanating from another state, tribal lands or sources otherwise beyond the jurisdiction of the state” (OAR 340-042-0030(1)). Much of the atmospheric deposition falls within this definition of background sources. The same is true for groundwater sources where the mercury concentration is result of geologic properties. Also, the mercury attached to eroded soil that is delivered as sediment to the streams and rivers is from natural and anthropogenic sources. However, not all of the surface runoff or the eroded soil are background sources and human activities do elevate the rates of these processes. The increases in surface runoff and soil erosion resulting from human activities will be addressed in the WQMP and the mercury from these sources will be the focus of reduction efforts.

Unidentified or unquantified anthropogenic sources are other sources of mercury that may contribute to exceedances to the applicable criteria. Atmospheric deposition of mercury is the dominant source of mercury in the Willamette Basin. Much of the mercury coming from the atmosphere is from sources outside of Oregon, which cannot be directly identified or quantified at this time. Sources of mercury from atmospheric deposition that is delivered to streams via the surface runoff pathway remain unquantified. Mercury from surface runoff and eroded soils coming from anthropogenic activities on forest and shrub lands cannot currently be distinguished from loading from non-disturbed forest lands in the current form of this analysis. These limitations were considered when source reductions were being assigned during the load allocation of this TMDL

9.4. Point sources

Point Source means a discernible, confined, and discrete conveyance including, but not limited to, a pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, vessel or other floating craft, or leachate collection system from which pollutants are or may be discharged but does not include agricultural storm water discharges and return flows from irrigated agriculture (OAR 340-041-0002(46)). DEQ issues NPDES permits for sources that discharge to surface waters according to OAR 340-045-0015. NPDES permits fall into two categories: general and individual. Existing permit information was obtained from DEQ's databases for facilities permitted to discharge to Willamette Basin streams.

The 2006 TMDL was intended to be a phased approach to allow collection of additional data. Only very limited mercury data was available from NPDES-permitted wastewater discharges in 2006, so all NPDES-permitted wastewater discharges at the time were considered as a single point source sector with an estimated mercury load of 3.9 percent (or 5 kg/yr) of the total load to the basin. A list of individual facilities was not compiled in the 2006 TMDL. The 2006 modeling estimated a total mercury load of about 2.7 percent (or 3.5 kg/yr) from municipal sewage treatment discharges, using the average flows of 17 facilities ranging from 1.7 to 70 million gallons per day (MGD). The load from industrial discharges was estimated in 2006 at approximately 1.2 percent (or 1.5 kg/yr) from average flows of eight pulp and paper dischargers with flows ranging from 1.7 to 17 MGD. In the current analysis, the point sources still make up a small portion of only 4 percent of the total mercury load.

9.4.1 Wastewater permits and mercury loads

DEQ is delegated by EPA authority under Section 402 the Clean Water Act to issue NPDES permits for waste water discharges to waters of the state. In the Willamette Basin, DEQ issues individual and general permits for wastewater discharged from major and minor municipal sewage treatment plants, major and minor industrial operations that fall under certain Standard Industrial Classification codes and a variety of general wastewater permit categories. Information on these permit types can be found at: https://www.oregon.gov/deq/wq/wqpermits/Pages/All-Permits-Applications.aspx.

Information on permitted discharges can be found by searching facility name, waterway or permit type in DEQ's Wastewater Permits Documents Database: https://www.oregon.gov/deq/wq/wqpermits/Pages/Wastewater-Permits-Database.aspx.

9.4.1.1 Municipal sewage treatment plant permits

As described in the TMDL Technical Support Document, the 2019 modeling used mercury data and flows from 23 major sewage treatment facilities (defined as facilities with discharges >1 million gallons per day, populations greater than 10,000 or with pretreatment programs) that discharge to Willamette Basin streams (see Table 9-4) for estimating a municipal discharge mercury load of approximately 0.9 percent (or 1.17 kg/yr or 3.2 g/day) of the total load in the basin. There are also 49 minor (generally facilities with discharges < 1 million gallons per day) sewage treatment facilities that discharge to Willamette Basin streams that together may contribute up 0.07 percent to the total mercury load in the basin. Cumulatively, flow volumes from minor municipal discharges are comparable to about 9 percent of the cumulative flows from the major facilities or about the same as one major facility. Due to homogeneity of municipal effluent of any size, potential loads of mercury from all 49 minor facilities are anticipated to be similar to that from a single major facility. Therefore, DEQ determined that the cumulative discharges from minor municipal facilities represent an insignificant portion of the overall contribution of mercury to the watershed.

Table 9-3. Summary of Major NPDES-Permitted Municipal Sewage Treatment Facilities in the Willamette Basin.

Facility Name	Receiving Stream Name	EPA Permit Number	DEQ Permit Number
Clean Water Services - Rock Creek	Tualatin River	OR0029777	101144
Metropolitan Wastewater Management Commission - Eugene/Springfield	Willamette River	OR0031224	102486
City of Salem - Willow Lake	Willamette River	OR0026409	101145
Clean Water Services - Durham	Tualatin River	OR0028118	101141
Tri-City Service District - Oregon City	Willamette River	OR0031259	101168
Clackamas County Service District #1 - Kellogg Creek	Willamette River	OR0026221	100983
Clean Water Services - Hillsboro	Tualatin River	OR0023345	101143
Clean Water Services - Forest Grove	Tualatin River	OR0020168	101142
City of Portland - Tryon Creek	Willamette River	OR0026891	101614
City of McMinnville Water Reclamation Facility	Willamette River	OR0034002	101062
Albany-Millersburg Water Reclamation Facility	Willamette River	OR0028801	102024
City of Corvallis	Willamette River	OR0026361	101714
City of Canby	Willamette River	OR0020214	101063
City of Wilsonville	Willamette River	OR0022764	101888
Oak Lodge Water Services District	Willamette River	OR0026140	100986
City of Woodburn	Pudding River	OR0020001	101558
City of Dallas	Rickreall Creek	OR0020737	101518
City of Silverton	Silver Creek	OR0020656	101720
City of Lebanon	South Santiam River	OR0020818	101771
City of Newberg - Wynooski Road	Willamette River	OR0032352	100988
City of Cottage Grove	Coast Fork Willamette River	OR0020559	101300

Facility Name	Receiving Stream Name	EPA Permit Number	DEQ Permit Number
City of Stayton	North Santiam River	OR0020427	101601
City of Sweet Home	South Santiam River	OR0020346	101657

9.4.1.2 Industrial wastewater permits

For industrial discharges, Standard Industrial Classification code categories of permitted industrial activities were evaluated as to potential for mercury to be present in process wastewater discharges. As explained in the TMDL Technical Support Document, the categories of: timber products; paper products; chemical products; glass, clay, cement, concrete, gypsum products; primary metal industries; fabricated metal products; and electronic instruments were determined to have potential for mercury in discharge due to materials and processes used and the average mercury concentration derived from facility data from Oregon and other states was applied for these types of facilities in the 2019 modeling. There are 13 active minor industrial permits with identified activities in these categories, but do not discharge process wastewater (only stormwater, groundwater, non-contact cooling water, etc.), which were excluded. As described in Section 9.4.2.2 below, these stormwater loads are implicit in the municipal stormwater loads. In addition, the modeling used mercury and/or flow data from seven major industrial facilities (defined using EPA's Industrial Classification worksheet), including several pulp and paper facilities that were operating between 2006 and 2019, but have now ceased operations, and 29 minor industrial facilities discharging to Willamette Basin streams to estimate a total mercury load of approximately 0.45 kg/yr or 1.23 g/day (which makes up 0.3 percent of the total load to the basin). This estimated load represents contributions from:

- Eight major industrial facilities: five pulp and paper (three currently operating); two smelting; one electronics; and
- 56 minor industrial facilities: 15 timber; one smelting; four food and beverage; one cooling water; six dairy/hatchery/concentrated animal feeding operation; and 30 not otherwise classified

Table 9-4 lists active individual permits for seven major industrial wastewater dischargers and 15 minor facilities which fall into Standard Industrial Classification code categories with activities that have the potential to increase mercury in process wastewater discharge. The SIC Major Group column in the table indicates the main industrial category the facility reported and subcategory information can be obtained in the SIC Manual on the US Department of Labor Occupational Safety and Health website.

Table 9-4. Summary of Individual NPDES-Permitted Industrial Facilities in the Willamette Basin with Activities that could Increase Mercury in their Discharge.

Facility Name	SIC Major Group	Facility Activity	EPA Class	Receiving Water	EPA Permit Number	DEQ Permit Number
Cascade Pacific Pulp, Llc	26	Bleached Kraft Pulp Mill	Major	Willamette River	OR0001074	101114
Georgia-Pacific - Halsey Mill	26	Secondary Fiber Pulp & Paper Mill	Major	Willamette River	OR0033405	101488

Facility Name	SIC Major Group	Facility Activity	EPA Class	Receiving Water	EPA Permit Number	DEQ Permit Number
International Paper Co - Springfield Mill	26	Unbleached Kraft Pulp & Paper Mill	Major	McKenzie River	OR0000515	101081
Oregon Metallurgical, Llc - Ati Albany	33	Titanium Manufacturing & Forming	Major	Oak Creek	OR0001716	102223
Tdy Industries, Llc - Teledyne Wah Chang	33	Zirconium Production	Major	Truax Creek	OR0001112	100522
West Linn Paper Company (Not Operating)	26	Paper Manufacturing	Major	Willamette River	OR0000787	100976
Westrock, Newberg Mill (Not Operating)	26	Fiber Deink Pulp & Paper Mill	Major	Willamette River	OR0000558	101299
Ash Grove Cement - Rivergate Lime Plant	32	Lime	Minor	Willamette River	OR0001601	102465
Cascade Steel	33	Blast Furnaces & Steel Mills	Minor	South Yamhill River	OR0027260	101487
Evraz Oregon Steel	33	Blast Furnaces & Steel Mills	Minor	Willamette River	OR0000451	101007
Frank Lumber Co. Inc.	24	Sawmills And Planing Mills	Minor	North Santiam River	OR0000124	101583
Fujimi Corporation	32	Abrasive Products	Minor	Coffee Lake Creek	OR0040339	103033
Georgia-Pacific Millersburg Resin Plant	28	Plastics Materials, Synthetics	Minor	Murder Creek	OR0032107	102603
Hollingsworth & Vose Fiber Company	24	Other Wood Products	Minor	Willamette River	OR0000299	101331
Hull-Oakes Lumber Co.	24	Sawmills And Planing Mills	Minor	Oliver Creek	OR0038032	101466
Kingsford Manufacturing Company - Springfield Plant	24	Other Wood Products	Minor	Patterson Slough	OR0031330	102153
Murphy Veneer, Foster Division	24	Softwood Veneer And Plywood	Minor	Wiley Creek	OR0021741	101777
Sanders Wood Products - Rsg Forest Products - Liberal	24	Sawmills And Planing Mills	Minor	Molalla River	OR0021300	100929
Seneca Sawmill Company	24	Sawmills And Planing Mills	Minor	Unknown	OR0022985	101893

Facility Name	SIC Major Group	Facility Activity	EPA Class	Receiving Water	EPA Permit Number	DEQ Permit Number
Stimson Lumber Company - Forest Grove	24	Sawmills And Planing Mills	Minor	Scoggins Creek	OR0001295	101480
Sunstone Circuits	36	Printed Circuit Boards	Minor	Milk Creek	OR0031127	101015
Weyerhaeuser Cottage Grove Lumber	24	Softwood Veneer And Plywood	Minor	Coast Fork Willamette River	OR0000698	101449

There are also currently 158 registrants under NPDES general wastewater permits in the basin (36 cooling water, 24 filter backwash, four fish hatcheries, four boiler blowdown, nine petroleum hydrocarbon cleanup, 21 wash water, and 60 pesticide application). These activities do not involve mercury and were not identified in the TMDL Technical Support Document’s activities anticipated to increase mercury in their discharge. The lack of potential for mercury to be measured coupled with their estimated cumulative flows being very minor, makes the discharges insignificant as an overall contribution to the mercury load within the basin.

As of 2019, there are 33 registrants of the NPDES 700PM for suction dredge mining operating at 46 identified locations within the Willamette Basin. These locations are all clustered in two historical mining areas: Bohemia Mining District above Dorena Reservoir and the Bureau of Land Management’s Quartzville Recreational Mining area. There are 21 registrants with 28 mining site locations on the Row River system, which is tributary to Dorena Reservoir (eight locations on Brice Creek, two on Champion Creek, and 18 on Sharps Creek), and 12 registrants with 18 mining site locations on Quartzville Creek (tributary of Middle Fork of Santiam River). As with other general permit categories, the volume of flows in discharges from these activities are anticipated to be insignificant. However, in areas with sediment data confirming mercury contamination, disturbance by suction dredge has a high potential to mobilize and methylate mercury (Fleck, et al., 2010; Gray, Hines, Krabbenhoft, & Thoms, 2012; Humphreys, 2005; Marvin-DePasquale, et al., 2009; Marvin-DiPasquale, et al., 2011). This action adds an unquantified but direct source contribution to the loads, which are a function of concentration and flows, collected behind reservoirs.

9.4.2 Stormwater permits and mercury loads

Stormwater carries polluted runoff from streets, rooftops, parking lots, industrial facilities and construction sites into waterbodies. This runoff can contain pollutants, such as metals, pesticides, PCBs, and PAHs that can harm fish and other aquatic life. Large metropolitan areas, rapidly developing urban areas and high-traffic roadways can potentially be significant sources of these pollutants. Precipitation falling on urbanized areas within the Willamette Basin can interact with atmospherically-deposited mercury and the resulting stormwater runoff is conveyed to waterways. In the 2006 TMDL, urban stormwater loads were not broken out separately from atmospheric deposition and erosion loads, but “runoff of atmospherically-deposited mercury from urban environments was estimated at 5 percent of the total load” (Oregon Department of Environmental Quality, 2006). The lack of site-specific data and limited scientific literature available during the development of the 2006 TMDL did not allow further quantification of mercury loads in urban stormwater.

As described in the TMDL Technical Support Document (Appendix A: Technical Support Document), current urban stormwater runoff volumes and erodible soil mercury concentrations were estimated to determine that the current MS4-permitted urban and highway stormwater areas contribute approximately 3.1 percent and all other non-permitted urban areas contribute approximately 1 percent of the total mercury load to waterways in the basin. The estimated mercury loads from individual permitted MS4 jurisdictions range from 0 to 0.93 kg/yr (for a total At-source load of 5.0 kg/yr) and loads from all non-permitted urban stormwater areas combined is estimated at 0.92 kg/yr. The potential contributions of atmospherically-deposited mercury from stormwater managed through all of the general stormwater permits covering industrial and construction activities (NPDES 1200-A, 1200-Z 1200-C, 1200-CA and 1200-CN) were implicit within these modeled loads from urban stormwater runoff. Therefore, potential mercury loads from both MS4 permits and most general stormwater permits are addressed with assignment of point source waste load allocations of this report. In contrast, mercury loads from non-permitted urban stormwater areas and implicit loads from the general stormwater permits that are effective in those areas, are addressed through assignment of nonpoint source load allocations section of this report.

9.4.2.1 Municipal stormwater permits

Federal regulations require qualified municipalities, such as cities, counties and special districts, to obtain NPDES permit coverage for their stormwater discharges. These permits are referred to as municipal stormwater permits or Municipal Separate Storm Sewer System permits, referred to throughout the document as MS4 permits. The Phase I MS4 permits regulate discharges from municipal separate storm sewer systems owned or operated by Oregon's largest cities and counties, as well as the highway system managed by the Oregon Department of Transportation. The Phase II MS4 permits cover the next most populated parts of the state that have urbanized areas as defined by the US Census Bureau. In order to reduce pollutants from urban runoff entering waters, the permits establish conditions, prohibitions, and management practices applicable to discharges of urban stormwater to be protective of water quality in streams that receive permitted discharges and to meet the requirements of the Clean Water Act.

As illustrated in Table 9-5 below, to date DEQ has identified 47 entities that require coverage under Phase I and Phase II MS4 permits within the Willamette Basin. This includes the Portland metro area, the smaller metro areas of Eugene, Salem and Corvallis, as well as much smaller cities. Permit requirements include development of stormwater management programs and reports on progress over time. For more information about MS4 permits, visit: https://www.oregon.gov/deq/wq/wqpermits/Pages/MS4-Permits.aspx

Table 9-5. Summary of NPDES MS4 Phase I and Phase II Jurisdictions in the Willamette Basin.

Permit Type	Permittee	Jurisdictions Covered	EPA Class	EPA Permit Number	DEQ Permit Number
MS4 Phase I	Multnomah County	Multnomah County	Major	ORS120542	103004
MS4 Phase I	Portland and	City of Portland	Major	ORS108015	101314
	Co-Applicants	Port of Portland			
MS4 Phase I	Gresham, Fairview	City of Gresham	Major	ORS108013	101315
		City of Fairview			
MS4 Phase I	Eugene	City of Eugene	Major	ORS107989	101244

Permit Type	Permittee	Jurisdictions Covered	EPA Class	EPA Permit Number	DEQ Permit Number
MS4 Phase I	Salem	City of Salem	Major	ORS108919	101513
MS4 Phase I	Clean Water Services	Clean Water Services	Major	ORS108014	101309
		Washington County			
		City of Banks			
		City of Beaverton			
		City of Cornelius			
		City of Durham			
		City of Forest Grove			
		City of Hillsboro			
		City of King City			
		City of North Plains			
		City of Sherwood			
		City of Tigard			
		City of Tualatin			
MS4 Phase I	Clackamas County Group	Clackamas County	Major	ORS108016	101348
		City of Gladstone			
		City of Johnson City			
		City of Lake Oswego			
		City of Milwaukie			
		City of Oregon City			
		City of West Linn			
		City of Wilsonville			
		Oak Lodge Sanitary District			
		Clackamas County Service District #1			
		City of Happy Valley			
		Surface Water Management Agency of Clackamas County			
		City of Rivergrove			
MS4 Phase I	Oregon Department of Transportation	ODOT Statewide Transportation	Minor	ORS110870	101822
MS4 Phase II	Keizer	City of Keizer	Minor	ORS110870	101822

Permit Type	Permittee	Jurisdictions Covered	EPA Class	EPA Permit Number	DEQ Permit Number
MS4 Phase II	Philomath	City of Philomath	Minor	ORS112241	102914
MS4 Phase II	Wood Village	City of Wood Village	Minor	ORS098909	102911
MS4 Phase II	Benton County	Benton County	Minor	ORS113609	102912
MS4 Phase II	Lane County	Lane County	Minor	ORS113606	102895
MS4 Phase II	Marion County	Marion County	Minor	ORS113608	102905
MS4 Phase II	Polk County	Polk County	Minor	ORS116224	102906
MS4 Phase II	Springfield	City of Springfield	Minor	ORS084048	102896
MS4 Phase II	Corvallis	City of Corvallis	Minor	ORS113605	102913
MS4 Phase II	Turner	City of Turner	Minor	ORS113607	102907
MS4 Phase II	Linn County	Linn County	Minor	ORS126417	33174
MS4 Phase II	Millersburg	City of Millersburg	Minor	None	None
MS4 Phase II	Albany	City of Albany	Minor	None	None

9.4.2.2 Industrial Stormwater General Permits

There are currently no individual industrial stormwater permits active within the Willamette basin. DEQ requires certain industrial facilities that discharge stormwater either directly to waterbodies or through storm drain conveyances to obtain general industrial stormwater permit coverage, referred to as the 1200-Z permit. Examples of industrial activities that require permit coverage include manufacturing, transportation, mining, and steam electric power industries, as well as scrap yards, landfills, certain sewage treatment plants, and hazardous waste management facilities. DEQ also requires industrial facilities that discharge stormwater associated with sand and gravel mining activities to obtain industrial stormwater permit coverage, referred to as the 1200-A permit. The 1200-Z and 1200-A permits require that industrial facilities develop stormwater control plans, monitor for stormwater pollutants, and implement best management practices to reduce impacts on stormwater from industrial activities. Within the Willamette Basin, there are approximately 629 registrants under the 1200-Z and 109 registrants under the 1200-A, mostly within urbanized areas. For more information about the 1200-Z or 1200-A permit, visit: https://www.oregon.gov/deq/wq/wqpermits/Pages/Stormwater-Industrial.aspx

9.4.2.3 Construction Stormwater Permits

Federal regulations require construction sites that disturb one-acre or more to obtain NPDES permit coverage for their stormwater that discharges either directly to waterbodies or through a storm drain conveyance system. The construction stormwater general permits are commonly referred to as either the 1200-C, 1200-CN or 1200-CA permit (the 1200-CN is applicable to construction projects performed within certain qualified local municipalities and the 1200-CA is issued to public agencies). Construction activities include clearing, grading, excavation, materials or equipment staging and stockpiling. Construction sites that disturb less than one acre but are part of a common plan of development also are required to obtain permit coverage. The permits are designed to prevent the discharge of polluted stormwater from construction sites that can harm aquatic life and reduce water quality. These pollutants are commonly in the form of muddy or turbid stormwater runoff, which can transport debris and chemicals that come into contact with stormwater offsite. Within the Willamette Basin, there are approximately 1000 registrants under the 1200C/CN/CA, mostly within urbanized areas. Due to the ephemeral nature of construction activities, the number and location of 1200C/CN/CA registered projects will change over the life of the TMDL. For more information about the 1200-C, 1200-CN or 1200-CA permit, visit: https://www.oregon.gov/deq/wq/wqpermits/Pages/Stormwater-Construction.aspx

10. Allocations

To meet water quality standards, loading from all pollutant sources must not exceed the loading capacity of a waterbody, including an appropriate margin of safety. Allocations are quantified measures that assure water quality standards will be met and may distribute the pollutant loads between nonpoint and point sources. Load allocations are portions of the loading capacity that are attributed to natural or background sources, such as soils, or from nonpoint sources, such as urban, rural agriculture, forestry activities or atmospheric sources. Wasteload allocations are portions of the total load that are allotted to point sources of pollution, such as sewage treatment plants or industries. The wasteload allocations are used to establish effluent limits in discharge permits. Allocations can also be reserved for future uses.

Using the linkages of mercury sources to Willamette Basin streams described in Section 6, this section determines the allocations of mercury load among sources assessed in Section 9 needed to achieve the mercury water quality criteria within the basin. The allocations are expressed as percent reductions and are based on the best estimates of loading. However, the complex behavior of mercury in the environment and dominance of global, national and regional atmospheric deposition as an overarching source does not currently allow for distinctions between natural, other background (including long-range transport) and anthropogenic components of the sources. These source components exist in mixtures, both in modeled simulations and physically on the landscape. Therefore, the allocations that follow are as refined as possible within sectors, but are comprised of unquantified background and anthropogenic source elements, each with varying levels of potential control. DEQ's expectation is that all applicable management strategies will be applied to the controllable portions of each source in order to achieve each responsible entity's portion of the aggregated reductions needed. Nonpoint sources are the ones most affected by these mixtures of sources. These were not separated out to identify specific sources within the aggregated allocation. Rather, the broad category captures "atmospheric deposition" through the source categories described in the TMDL Technical Support Document as "sediment erosion," "surface runoff" and "atmospheric deposition direct to streams." The relative contributions of the different sources for the existing loads were estimated using the mass balance model and are listed in Table 10-1.

Table 10-1. Summary of TMDL Components.

Mercury Water Quality Criterion	0.040 mg/kg fish tissue							
Total Mercury TMDL Water Column Target	0.14 ng/L							
Total Mercury Loading Capacity	42.17 g/day or 15.40 kg/year							
SOURCE SECTORS	EXISTING LOADS			ALLOCATIONS				
	g/day	kg/year	Relative Contribution to Total Load	Percent Reduction	g/day	kg/year	Relative Allocation of Load Capacity	
General Nonpoint Source and Background[1] Captures: Forestry, Agriculture, Water Impoundments, Water Conveyance Entities, Non-Permitted Urban Stormwater, Atmospheric Deposition	341.74	124.82	94.5%	88%[2]	28.87	10.54	68.46%	
Non-Permitted Urban Stormwater				75%	0.63	0.23	1.5%	
Atmospheric Deposition				11%	5.22	1.91	12.38%	
Legacy Metals Mines	4.00	1.46	1.1%	95%	0.20	0.07	0.5%	
NPDES Wastewater Point Source Discharges	4.44	1.62	1.2%	10%	4.00	1.46	9.5%	
NPDES MS4 Stormwater Point Source Discharges	11.31	4.13	3.2%	75%	2.83	1.03	6.7%	
Reserve Capacity	NA	NA	NA	1%[3]	0.42	0.15	1.0%	
Margin of Safety	NA	NA	NA	implicit	implicit	implicit	implicit	
TOTALS	**361.49**	**132.03**	**100%**	**NA**	**42.17**	**15.39**	**100%**	

NOTES:

[1] Combines the following source categories from the TMDL Technical Support Document: Sediment Erosion, Surface Runoff, Groundwater, Atmospheric Deposition to Water

[2] There is an additional 3.5% reduction from General Nonpoint Source and Background that results from the 11% decrease in Atmospheric Deposition, which reduces the mercury in precipitation that generates surface runoff. The additional reduction is calculated from the output of the Mass Balance Model.

[3] Reserve Capacity is not allocated as a percent reduction, rather an additional 1 percent reduction is required from atmospheric deposition, which will be used for any needed reserve capacity.

The components of the TMDL equation and its relationship to the load capacity are given below

$$TMDL = \Sigma WLAs + \Sigma LAs + MOS + RC \le LC$$

$\Sigma WLAs$ is the sum of the waste load allocations, ΣLAs is the sum of the load allocations, MOS is the margin of safety, RC is the reserve capacity, and LC is the load capacity.

The TMDL equation was reorganized for clarity to incorporate the reserve capacity of 1%. The reserve capacity was set aside for future growth and is not available for the waste load allocations or load allocations. To demonstrate this we subtracted reserve capacity from both sides of the inequality of the TMDL equation, which resulted in the following form:

$$TMDL = \Sigma WLAs + \Sigma LAs + MOS + RC - RC \leq LC - RC$$

$$TMDL = \Sigma WLAs + \Sigma LAs + MOS \leq LC - RC$$

The reserve capacity is subtracted from the load capacity and the reaming load capacity is allocated among the waste load allocations and the load allocations. The remaining load capacity is:

$$LC - RC = LC - 1\% \times LC = 99\% \times LC$$

$$LC - RC = 42.17\frac{g}{day} - 1\% \times 42.17\frac{g}{day} = 42.17\frac{g}{day} - 0.42\frac{g}{day} = 41.58\frac{g}{day}$$

From the equation above, the reserve capacity is 0.42 g / day. The remaining load capacity is 41.58 g / day and is allocated to the remaining components of the TMDL equation using the third column of Table 10-1 are:

$$\Sigma WLAs = 9.5\% \times 42.17\frac{g}{day} + 6.7\% \times 42.17\frac{g}{day} = 6.83\frac{g}{day}$$

$$\Sigma LAs = 80.8\% \times 42.17\frac{g}{day} + 1.5\% \times 42.17\frac{g}{day} + 0.5\% \times 42.17\frac{g}{day} = 34.92\frac{g}{day}$$

$$TMDL = \Sigma WLAs + \Sigma LAs + MOS + RC$$

$$TMDL = 6.83\frac{\mathrm{g}}{\mathrm{day}} + 34.92\frac{g}{day} + implicit + 0.42\ \frac{g}{day} = 42.17\frac{g}{day}$$

MOS is implicit and discussed in Section 11.

In alignment with OAR 340-042-0040(6), DEQ considered several factors in distributing the allocations among the identified sources using a basin-wide approach. The factors considered include:

- Atmospheric deposition is the major source of mercury throughout Willamette Basin.
- Atmospheric deposition generally follows precipitation patterns and does not result in specific “hotspots.”
- Relative contributions of sources, including land area and discharge flow volumes
- Level of assurance that reductions needed from nonpoint and point sources are achievable with implementation of available management actions.
- Maturity of programs and existing efforts

DEQ’s allocation approach was informed by sources of mercury in the basin, sources of mercury excess loads and basin loading capacity, and the level of implementation of existing mercury control strategies. Point source discharges contribute a relatively small portion of the total load of mercury within the basin. Many of the largest municipal sewage treatment dischargers have been implementing measures that reduce mercury for many years and the technology for achieving additional reductions is very limited from those facilities. Reductions that could be achieved from the already small contribution from these sources are minimal and as a result, wastewater discharges received a relatively small reduction requirement. In contrast, nonpoint source land use activities that can mobilize mercury deposited on the landscape into waters cover a significant portion of land area within the basin. Aggregated together with background sources, this general category contributes approximately 94 percent of the mercury load in the basin. Furthermore, the mercury reduction potential from these sources is high because some activities in the category have not implemented mercury minimization measures and the large aggregated load means that even relatively small percentage reductions would achieve larger quantitative declines in loading. As a result, a large reduction requirement was applied for nonpoint sources generally. In the case of mining, specifically, the relative contribution is low, but the sources are discrete and isolated and there is a high potential for reduction upon remediation. Therefore, legacy metals mining received a very high reduction requirement. Finally, in the case of stormwater, a large reduction was assigned, despite the relative contribution being low. Reasoning included the fact that the affected jurisdictions cover large land areas within the basin, which collect relatively large portions of atmospherically deposited mercury. In addition, effective mercury minimization measures are feasible for achieving reductions. The level of maturity of stormwater control programs ranges from highly sophisticated for long-standing permitted jurisdictions to smaller communities that have not yet begun implementing control measures.

Along with relative contributions by source types, reductions needed and the resultant distribution of the load capacity among the sources are summarized above in Table 10-1 and explained in greater detail by category in the sections that follow.

Several other approaches were considered when developing the allocations. Example scenarios are provided in Appendix B: Other Allocation Scenarios Considered.

The analysis presented in this document supports DEQ's conclusion that no one source category is entirely responsible for the mercury contamination in the Willamette Basin. Collaborative efforts extending across all source categories (both point and nonpoint) will be necessary to achieve reductions in mercury loading and, ultimately, the restoration of the beneficial use of fish consumption. DEQ anticipates development and implementation of effective mercury minimization measures and other management strategies appropriate to individual facilities and land activities as the primary control mechanisms for achieving reductions in the controllable components of each sector's source load. A description of the various implementation activities and management strategies designed to achieve cross-sector reductions in the load of total mercury are presented in detail in the Water Quality Management Plan.

10.1. Load allocations for nonpoint sources

Load Allocations OAR 340-042-0040(4)(h), 40 CFR 130.2(g): This element determines the portions of the receiving water's loading capacity that are allocated to existing nonpoint sources including background sources. The mercury load allocations in the Willamette Basin is a mixture of background loads and anthropogenic nonpoint sources.

As summarized in Table 10-1 above, load allocations for Nonpoint Source Sectors are:

- General Nonpoint Source Sector: 88 percent reduction g total mercury/day and includes the following categories:
    - Forestry
    - Agriculture
    - Water Impoundments
    - Water Conveyance entities
    - Background sources (groundwater and atmospheric deposition)
- Legacy Metals Mining Sector: 95 percent reduction g total mercury/day
- Non-Permitted Urban Stormwater Sector: 75 percent reduction g total mercury/day

- Atmospheric Deposition: 11 percent reduction g total mercury/day

A single reduction percentage is being used for the General Nonpoint Source Sector load allocation, because current analysis does not enable DEQ to separate background and anthropogenic sources. The reduction of 88 percent for the load allocation will be applied to all nonpoint sources except legacy metals mining and urban stormwater jurisdictions that are not covered by an MS4 permit. Contributions from these urban areas were estimated as to the overall load of mercury using the jurisdictional boundaries of these communities. Most of the mercury load from this source is from atmospheric deposition, but controlling surface runoff and soil erosion will reduce the mercury loads from these urban areas from entering the river and streams. The same is true for all of the other nonpoint sources. The 88 percent reduction for anthropogenic sources will be addressed using runoff and erosion control approaches. The 10 percent reduction for atmospheric sources is anticipated to occur through controls on local emissions within Oregon, but to greater extent through on-going reductions being achieved nationally (United Nations Environment Programme, 2019) and in the future through enactment and implementation of international treaties. This reduction in atmospheric sources is well below the reduction used in approved mercury TMDLs throughout the US, which range from 67 percent to 90 percent (Limno Tech, 2018; North Carolina Department of the Environment and Natural Resources, 2012; Minnesota Pollution Control Agency, 2007; New England Interstate Water Pollution Control Commission, 2007). DEQ's expectation is that all relevant management strategies will be applied to the controllable portions of each source toward achieving each responsible entity's portion of the aggregated Nonpoint Source General Sector reductions needed.

10.2. Wasteload allocations for point sources

OAR 340-042-0040(4)(g), 40 CFR 130.2(h) This section describes the portions of the Willamette Basin's loading capacity that are allocated to existing point sources of pollution, including all point source discharges regulated under the Federal Water Pollution Control Act Section 402 (33 USC Section 1342).

As summarized in Table 10-1 above, wasteload allocations for NPDES permitted sources are:

- Wastewater dischargers: 10 percent reduction g total mercury/day and includes the following permit categories:
  - Major and minor domestic Sewage Treatment Plant wastewater permits
  - Major and minor Industrial wastewater permits
  - Wastewater discharges covered under General permits
- Stormwater dischargers: 75 percent reduction g total mercury/day and includes the following permit categories:
  - Municipal Separate Storm Sewer System – Phase I
  - Municipal Separate Storm Sewer System – Phase II (general and individual)
  - Industrial Stormwater (1200-A and 1200-Z general permits)
  - Construction Stormwater (1200-C/CN/CA general permits)

The 2006 Willamette Basin Mercury TMDL assigned interim waste load allocations to the existing point source discharges at the time, with the expectation that point source mercury load reductions would be achieved through implementation of mercury minimization measures. WLAs were assigned in two categories, as follows: Publicly Owned Treatment Works Discharges at 2.6 kg/yr (or about a 26 percent reduction) and Industrial Discharges at 1.1 kg/yr (or about a 27 percent reduction).

Urban stormwater discharges were not distinguished from nonpoint source runoff and erosion. While the 2006 TMDL acknowledged that MS4-permitted stormwater discharges are considered point sources, load reductions from both permitted and unpermitted stormwater were contained within the ‘runoff of atmospherically deposited mercury’ and ‘erosion of mercury containing soils’ categories and accounted for in interim nonpoint source load allocations amounting to about 27 percent reductions from both categories.

As noted in Section 9.4 on point source assessment, more data and information on both effluent flow and concentration is now available, which allowed more accurate and refined loading estimates of permitted municipal and industrial wastewater discharges and municipal stormwater discharges.

In development of this TMDL, DEQ considered whether individual waste load allocations for point sources were appropriate. DEQ completed revised evaluations under stricter and more demanding scientific standards requiring analysis of significantly more data and new information on factors affecting mercury pollution, including multiple potential sources, bioaccumulation patterns and changes in the types of mercury being released and transformed in the large and complex Willamette Basin. These revised evaluations indicate that the estimated mercury load from permitted municipal and industrial wastewater point sources is significantly lower (1.1 percent of total load) than was estimated in the 2006 evaluation (3.9 percent). As discussed in the TMDL Technical Support Document, deposition of mercury onto the Oregon landscape is the dominant source of mercury reaching Willamette Basin streams. While these deposited air emissions originate as a mix of global, national, regional and local sources, the largest portion is derived from historical deposition of global anthropogenic mercury emissions (TetraTech, 2019), or background sources outside of DEQ’s control, per Oregon’s definition in OAR 340-042-0030. Further, mercury loads from all permitted (wastewater and stormwater) point source discharges combined are conservatively estimated to be approximately four percent of the total load to Willamette Basin streams. As was found in the 2006 TMDL analysis, even total elimination of this estimated 1.1 percent wastewater and the 3 percent estimated municipal stormwater contributions would not result in measurable response in terms of lowered mercury in the streams, due to the far greater proportion of contributions from atmospheric deposition and nonpoint source delivery to streams, as well as the decades long lag time for measureable in-stream response. However, DEQ recognizes that, as an environmentally persistent bioaccumulative toxic substance, mercury should be eliminated from discharges to the extent practicable. Therefore, based on the Clean Water Act’s allowance for aggregate or individual allocations (40 CFR 130.2(i)); EPA’s Guidance for implementing the January 2001 Methylmercury WQ Criterion (2010) and EPA’s Memo on Elements of Mercury TMDLs Where Mercury Loadings are Predominantly from Air Deposition (2008); precedents of EPA approved mercury TMDLs of 21 other states (dated 2001-2018); and as indicated by a rigorous scientific evaluation, DEQ is assigning aggregate wasteload allocations for municipal and industrial wastewater and municipal stormwater point source discharges. The wasteload allocations that follow meet the intent of individual allocations by requiring site-specific permit requirements and monitoring with enforceable conditions, such that individual site reductions will be completed and will cumulatively add up to the aggregate percent reduction requirements by sector set by the TMDL.

The wasteload allocation implementation approach specific to each sector and permit category is presented in detail in the Water Quality Management Plan. A summary of DEQ’s expectation for implementation of wasteload allocations for the two NPDES-permitted sectors is as follows:

1. NPDES-permitted municipal and industrial wastewater discharges must implement mercury minimization measures, as warranted by mercury monitoring results, toward achieving a cumulative 10 percent reduction of the existing estimated wastewater point source mercury load into Willamette Basin streams.

2. NPDES-permitted MS4 stormwater jurisdictions must implement mercury and erosion minimization measures, with quantifiable objectives, toward achieving an appropriate portion of the needed cumulative 75 percent reduction of the estimated existing mercury load, from mixed atmospheric deposition and human-caused disturbance, transported in stormwater runoff to Willamette Basin streams.

For wastewater discharges, DEQ will require development and implementation of mercury minimization programs at facilities with measurable mercury, significant flows and activities that increase the potential for mercury in discharge, in order to achieve facility-specific portions of the aggregate 10 percent overall sector reduction. The facility-specific portions will reflect both current minimization programs and the potential for reductions from current conditions. Available data and information from Oregon, California, Minnesota and Michigan demonstrate achievement of mercury load reductions from municipal sewage treatment discharges using mercury minimization programs. DEQ found, during evaluation and development of potential mercury variances within the Willamette Basin, that no feasible treatment technologies have been demonstrated at the scale of major sewage treatment plants and large industrial facilities to achieve mercury effluent concentrations below 1 ng/L to 3 ng/L. Advanced wastewater treatment facilities have achieved effluent concentrations between 1 ng/L and 3 ng/L in some cases, while others have achieved levels up to 5 ng/L. Facilities with secondary treatment technologies that have implemented mercury minimization programs for a decade or more, have also been able to achieve mercury effluent concentrations of 3 ng/L to 5 ng/L. Therefore, enhancing and implementing mercury minimization programs is anticipated to be the most effective approach to achieve aggregate reductions for this sector. Please see Appendix C: Variance Justification Excerpts for supporting information.

DEQ determined that flows from minor municipal wastewater discharges and all general wastewater permit categories were insignificant with regard to mercury loading from the overall wastewater sector into Willamette Basin streams. However, as data and information warrant, some minor industrial permittees with activities that may increase the potential for mercury in their discharge may be required to implement Mercury Minimization Programs.

Also within the aggregated wastewater sector, DEQ is proposing to prohibit discharges from suction dredges under the General NPDES 700PM permit in streams with known mercury contamination from historical mercury and gold mining activities. Studies in Oregon, California, Nevada, Wisconsin and Florida have shown that mercury in stream beds is disturbed, mobilized and methylated by suction dredging (Fleck, et al., 2010; Gray, Hines, Krabbenhoft, & Thoms, 2012; Humphreys, 2005; Marvin-DePasquale, et al., 2009; Marvin-DiPasquale, et al., 2011). Soils and stream sediment sampling in the former Bohemia Mining District indicates high concentrations of mercury. Mercury concentrations found in stream-side soils range from 13 mg/kg to >50 mg/kg and stream sediments in Brice Creek, Champion Creek, Sharps Creek and the Row River upstream of Dorena Reservoir range from 0.14 mg/kg to 1.34 mg/kg (Hygelund, Ambers, & Ambers, 2001). These streams are tributary to the Dorena Reservoir, which is 303(d) listed for mercury and has fish advisories for mercury contamination in place. Therefore, upon renewal of the 700PM permit, DEQ will prohibit suction dredge mining in locations in streams that flow from the former Bohemia Mining District and are tributary to the Dorena Reservoir (including Row River, Brice Creek, Sharps Creek, and Champion Creek). While suction dredge disturbance of mercury laden sediment in these streams is currently intermittent and releases and methylation potential are not quantifiable, these prohibitions in this known historical source area will add to reductions achieved throughout the basin toward the 10 percent aggregated WLA for the wastewater sector.

Because the 10 percent overall reduction amounts to reducing the current load from aggregated wastewater discharges of 4.44 g/day to 4.00 g/day, DEQ anticipates that tracking of effectiveness of mercury minimization plan implementation will demonstrate achievement of this needed reduction. Permit requirements and timelines for implementation are described in the Water Quality Management Plan in Sections 13.3.2 and 13.4.2 of this document and the accountability framework for reasonable assurance that TMDL goals will be met is described in Section 14.1.

For municipal stormwater discharges, EPA guidance (U.S. Environmental Protection Agency, 2002; U.S. Environmental Protection Agency, 2008a; U.S. Environmental Protection Agency, 2008b; U.S. Environmental Protection Agency, 2010a; U.S. Environmental Protection Agency, 2010b; U.S. Environmental Protection Agency, 2014; U.S. Environmental Protection Agency, 2015; U.S. Environmental Protection Agency, 2016) and precedents in other states indicates that development and enhancement of measures targeted at mercury minimization and erosion control is the most effective and practical approach for achieving needed mercury reductions in stormwater discharges. As permits are renewed, DEQ will require reporting of measurable objectives for implementation of mercury and erosion controls across MS4 jurisdictions to achieve their potential portion of the 75 percent aggregate reduction. The mercury loads in MS4 discharges estimated in the modeling, which covered multiple years of collected and estimated data, were 11 g/day. As a result, the 75 percent aggregate reduction needed leaves 2.75 g/day of mercury allowable in these discharges. DEQ acknowledges that atmospheric deposition of mercury is the dominant driver of stormwater mercury loads and that MS4 controls will capture unknown quantities of both human-caused and background sources of mercury, which will not be distinguishable. Reductions in atmospheric deposition are anticipated to be reflected in reductions within MS4 jurisdictions. Because mercury loads from general stormwater permits (NPDES 1200Z, 1200A and 1200C/CN/CA) were implicit in the MS4 modeled load estimates, DEQ anticipates reductions achieved through erosion control requirements and reduced total suspended solids benchmarks for key geographic areas (for example, industrial stormwater discharges to Portland Harbor and the Columbia Slough) will also contribute to reductions needed in the overall stormwater sector wasteload allocation. DEQ also acknowledges that effective minimization measures by many MS4 jurisdictions have been ongoing for several years and reductions achieved are not reflected in the current modeling. DEQ anticipates that some portion of the needed reduction has already been achieved. As noted in the Water Quality Management Plan in Sections 13.3.2 and 13.4.2, permits will require reporting of evaluations of attainment of wasteload allocations and annual and five year intervals. DEQ will use this information in tracking and evaluating overall allocation attainment, as described in the accountability framework for reasonable assurance that TMDL goals will be met is described in Section 14.1.

10.3. Instream surrogate allocations

DEQ may use surrogate measures to estimate allocations for pollutants addressed in the TMDL (OAR340-042-0040(5)(b). DEQ may use one or more surrogate measures for a pollutant that is difficult to measure or highly variable. Typically, a surrogate measure will be closely related to the pollutant, and may be easier to monitor and track. The TMDL establishes the correlation between the surrogate measure and pollutant.

Monitoring for total mercury can be difficult and cost-prohibitive, agencies and monitoring groups often use total suspended solids, commonly referred to as TSS, as a surrogate for total mercury in stream. TSS is often used as a surrogate for pollutants, such as heavy metals and organic pollutants (Eckley & Branfireun, 2009) For example, TSS was used as a surrogate for DDT (Dichlorodiphenyltrichloroethane) to meet instream targets for the Lower Yakima TMDL in Washington (Johnson, 2005). A positive correlation between TSS and THg due to the capacity of THg to bind to particulate matter makes TSS a useful surrogate measure (Eckley & Branfireun, 2009). Therefore, provided that there is correlation between TSS and THg within the mainstem Willamette River and its tributaries, TSS could be used to predict instream THg concentrations in the Willamette River Basin (Hope & Rubin, 2004). DEQ evaluated this relationship for the Willamette Basin with the general approach and results described below and specific information in Appendix H: Willamette River Instream Surrogate TSS-THg Analysis.

All data were extracted from the WRB Hg database from 1/1/2002 to present. There were 63 paired samples used in this analysis from 9 different HUC 8 subbasins within the Willamette River Basin. All of the 63 surrogate pairs had mercury concentrations with a detection limit of 0.5 ng/L (U.S. Environmental Protection Agency, 2002) which is above the instream target of 0.14 ng/L THg set for the Willamette. All of the samples used for the analysis were above this detection limit.
The sites (sampling locations) used in the analysis were defined by the latitude and longitude coordinates where the samples were collected.

A Linear Mixed Effects model with sites (sampling locations) was used to calculate TSS concentrations that correspond to THg concentrations and was used to estimate TSS concentrations and calculate percent reductions of THg concentrations (Table 10-2). A strong relationship was found between TSS and THg for this data. Therefore, in addition to the load allocations and waste load allocations in Section 10.1 and 10.2 the data analysis of instream total mercury and TSS was used to develop instream surrogate allocations using TSS for total mercury.

Based on the strong relationship found between total suspended solids and total mercury interim surrogate allocations were set for reductions in TSS concentration to measure progress in the reduction in total mercury loads. Instream allocations were developed to set reductions in the 95-percentile for the TSS concentration over time. The initial 75 percentile of TSS concentration is based on the 2019 dataset used to develop the TSS and total mercury concentrations (Appendix H: Willamette River Instream Surrogate TSS-THg Analysis, Figure 16). The schedule is listed in Table 10-2. The empirical cumulative distribution function will be reanalyzed when new data becomes available and a Bayesian inference approach to structured decision making (Conroy & Peterson, 2013) will be used to update the statistical distribution used to assess the progress in meeting the reduction targets and to reassess past targets if any had occurred.

Table 10-2. Schedule for instream mainstem Willamette and at mouth of major tributary surrogate allocations for reducing total suspended solid concentrations.

Years from 2019	Reduction in 95th Percentile of TSS	Reduction TSS Concentration (mg/L)	Allocation for Maximum Instream TSS (mg/L)
0	0%	0	17
5	10%	1.7	15
10	25%	4.3	13
20	50%	8.5	9
30	75%	12.7	4
Note: Based on the 95th Percentile of TSS Concentrations from the Dataset of 63 Surrogate Pairs. The TSS maximum concentration at the 95th percentile is 17 mg/L.			

The TSS surrogate allocations will apply to the mainstem Willamette and subbasin tributaries and used for evaluating effectiveness. Locations will be described in the *Assessment and Monitoring Strategy to Support Implementation of Mercury Total Maximum Daily Loads for the Willamette Basin* and initial surrogate allocations could be updated as described in the Accountability Framework (Section 14). Other surrogates for THg could be evaluated from the data collected as part of the Assessment and Monitoring Strategy.

11. Margin of safety

OAR 340-042-0040(4)(1) The Clean Water Act requires that each TMDL be established with a margin of safety to account for uncertainty in available data or in the actual effect controls will have on loading reductions and receiving water quality. A margin of safety is expressed as unallocated assimilative capacity or conservative analytical assumptions used in establishing the TMDL (i.e., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions).

A margin of safety may be implicit through the use of conservative assumptions that result in more protective loading capacity, wasteload allocations, or load allocations. The margin of safety may also be explicitly stated as an added, separate quantity in the TMDL calculation. In any case, assumptions should be stated and the basis behind the margin of safety documented. The margin of safety is not meant to compensate for a failure to consider known sources.

Due to the complexity of the TMDL analysis, DEQ determined that an implicit margin of safety was appropriate. An implicit margin of safety was selected based on the following components of the TMDL analysis. First, the use of the Northern Pikeminnow provides a margin because it is the most efficient bioaccumulator of mercury among the species considered. Furthermore, the Northern Pikeminnow is not a popular commercial or recreational target. Instead, pikeminnow may be consumed on occasional basis by recreational or substance fishermen (related to the fish consumption rate of the water quality standard). The second component is the use of the median concentration calculated from the food web model as the TMDL target concentration of total mercury. The statistical distribution for the Monte Carlo simulations of the Food Web Model was right-skewed and use of the median as a measure of central tendency results in a lower value than the average concentration. The last component is the TMDL analysis used total mercury concentration in fish tissue rather than the methylmercury in the water quality criterion. The total mercury in fish is composed of 95 percent or greater methylmercury in higher trophic level piscivores (USEPA, 2000), therefore using total mercury concertation in fish tissue rather than methylmercury increases the margin of safety because the methylmercury concentration will be slightly less than the total mercury concentration. We consider the conservative nature of these three components of the TMDL analysis provide a sufficient margin of safety.

12. Reserve capacity

As described in OAR 340-042-0040(k), reserve capacity is an element of the TMDL, which is an allocation for increases in pollutant loads from future growth and new or expanded sources. DEQ used an explicit reserve capacity of 1 percent. Reserve capacity may be granted by DEQ to NPDES permitted point sources and/or nonpoint source designated management agencies and responsible parties. Prior to allocating a portion of the reserve capacity to a new or expanded point source, DEQ will require demonstration of effluent condition and implementation of DEQ approved mercury minimization measures, as described in the Water Quality Management Plan for the appropriate sector. Prior to allocating a portion of the reserve capacity to a new or expanded nonpoint source, DEQ will require implementation of DEQ approved mercury minimization measures with data collection appropriate for achieving measurable objectives, as described in the Water Quality Management Plan for the appropriate sector.

13. Water Quality Management Plan

13.1. Introduction

This draft WQMP developed by DEQ provides the framework for describing management efforts that will be put into action to attain the Willamette Basin Mercury Total Maximum Daily Load. This framework builds upon existing point and nonpoint source implementation plans to outline a management approach for reducing mercury from all land uses in the basin.

Oregon Administrative Rules (OAR 340-042-0040(4)(I)(G)) require DEQ to identify persons, including Designated Management Agencies that are responsible for implementing management strategies and sector-specific or source-specific implementation plans. A DMA is “a federal, state or local governmental agency that has legal authority of a sector or source contributing pollutants, and is identified as such by the Department of Environmental Quality in a TMDL” (OAR 340-042-0030(2)). See a complete list of DMAs and responsible persons in Appendix E: List of designated management agencies and responsible persons.

The WQMP includes a description of activities, programs, legal authorities and other measures for which DEQ and DMAs have regulatory authority. The WQMP also includes a description of how other responsible persons are expected to implement activities and programs that will help to achieve the TMDL.

13.1.1 Implementation plans

Following the issuance of a TMDL and WQMP, DEQ requires most DMAs and responsible persons to develop implementation plans that identify specific management strategies and actions that will be implemented in order to meet water quality standards over time. For DMAs and responsible persons associated with nonpoint sources of pollutants, these implementation plans may be called different names. For example, implementation plans for the Bureau of Land Management and the U.S. Forest Service are called Water Quality Restoration Plans. The Oregon Department of Agriculture uses Agricultural Water Quality Management Area Plans to meet most requirements of an implementation plan.

Per OAR 340-042-0040(4)(I)(I) the WQMP must provide a schedule for submittal of implementation plans. DEQ typically gives DMAs and responsible persons 18 months to submit new or updated implementation plans following the issuance of a TMDL and WQMP. For this WQMP, DEQ will continue using the 18-month time frame for implementation plan submittal. Implementation plans must be posted to a publicly accessible website, unless the DMA does not have a website. DEQ reviews the plans in accordance with regulations in OAR 340-042-0080(4):

(a) Prepare an implementation plan and submit the plan to the Department for review and approval according to the schedule specified in the WQMP. The implementation plan must:

A. Identify the management strategies the DMA or other responsible person will use to achieve load allocation and reduce pollutant loading;
   a. Provide a timeline for implementing management strategies and a schedule for completing measurable milestones;

b. Provide for performance monitoring with a plan for periodic review and revision of the implementation plan;
c. To the extent required by Oregon Revised Statute 197.180 and OAR chapter 340, division 18, provide evidence of compliance with applicable statewide land use requirements, and;
d. Provide any other analyses or information specified in the WQMP.

(b) Implement and revise the plan as needed.

In addition, implementation plans must provide an estimate of the technical and financial resources needed, associated costs, and the sources and authorities that will be relied upon to implement the plan.

For point sources, wasteload allocations and/or other management strategies identified in the TMDL and WQMP will be incorporated into renewed NPDES permits as enforceable provisions.

Following the issuance of the TMDL, DEQ may make a determination that nonpoint source implementation plans are not necessary for certain DMAs and responsible persons. In those cases, DEQ will provide a written determination to the DMA or responsible person of why a plan is not necessary. This determination will be based on deminimis mercury loads associated with these DMAs or responsible persons.

13.1.2 Adaptive management

The federal Clean Water Act and associated Oregon Water Quality laws and implementing regulations require water quality standards to be met over time. In some cases, responsibility may depend on practicability, but in any event DEQ typically requires that all feasible steps be taken toward achieving the highest quality water attainable. This is a long-term goal in many watersheds, particularly where nonpoint sources of pollution are the main concern and significant landscape alterations are needed.

TMDLs are numerical allocations of pollutants that are set so that instream water quality standards are met. This TMDL includes values calculated from mathematical models and other analytical techniques designed to simulate and/or predict very complex physical, chemical and biological processes of mercury release and transport in the Willamette Basin. DEQ used models and techniques that incorporate large amounts of water quality and land use data and information specific to the Willamette Basin. However, in order to evaluate these processes on this scale, the models and techniques used simplify these complex processes and inherently contain a distribution of uncertainty concerning how streams and other waterbodies will respond to various management measures. For this reason, the TMDL is required to contain a margin of safety.

WQMPs are plans designed to reduce pollutant loads to meet TMDLs. DEQ recognizes that it will take time before management practices identified in a WQMP are fully implemented and effective in reducing and controlling pollution. In addition, DEQ recognizes that technology and practices for controlling nonpoint source pollution will continue to develop and improve over time. As implementation, technology and knowledge about these approaches progress, DEQ will use adaptive management to refine implementation. Figure 13-1 provides a conceptual representation of the adaptive management concept.

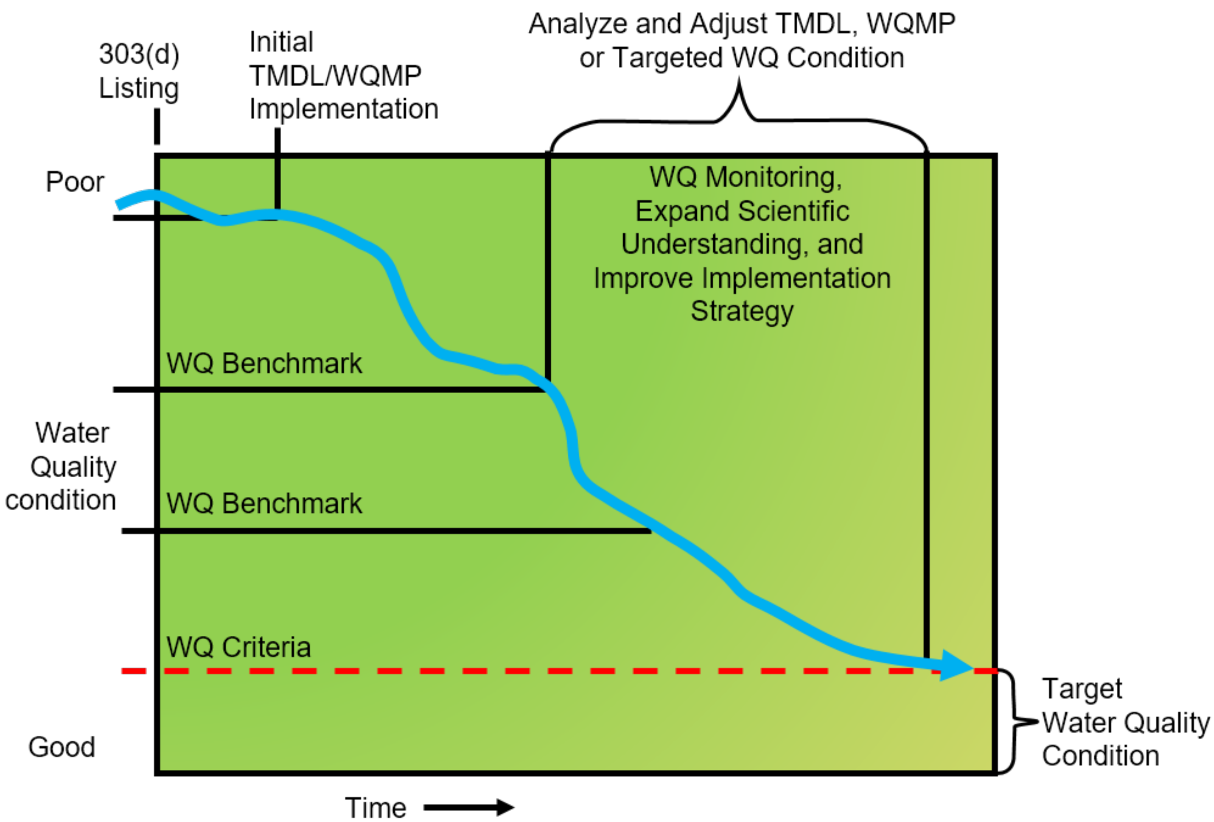

Figure 13-1. Conceptual representation of adaptive management. The estimated timeline for achieving water quality standards is multiple decades.

DEQ also recognizes that despite best efforts, natural events beyond the control of humans may interfere with or delay attainment of the TMDL. Such events include, but are not limited to, floods, fire, insect infestations, and drought.

If a source is not given an allocation, it does not necessarily mean that a source is prohibited from discharging any wastes. DEQ may permit a point source that is not covered by an allocation to discharge if the holder either can adequately demonstrate that the discharge will not impact the pollutant in question, or that the discharge is covered by reserve capacity.

If a nonpoint source DMA or responsible person complies with its implementation plan, DEQ will consider them in compliance with the TMDL. DEQ has the following general expectations and intentions for using an adaptive management approach for the TMDL and WQMP:

- Every five years, DEQ will review the progress of the TMDL and the WQMP. Where DEQ determines that implementation plans or effectiveness of management strategies are inadequate, DEQ will require DMAs and responsible persons to revise the components of their implementation plans to address these deficiencies.
- In conducting this review, DEQ will evaluate the progress towards achieving the TMDL and water quality standards and the success of implementing the WQMP.

- DEQ expects that each DMA and responsible person will also monitor and document its progress in implementing the provisions of its implementation plan. This information will be provided to DEQ for its use in reviewing the TMDL. This information is typically provided in an annual report and/ or five year review report. Please see section 13.4 for more information on annual reporting and the five year review.

If DEQ determines that all appropriate measures are being taken by DMAs and responsible persons and water quality standards will still not be met, DEQ may take one of several actions depending on the information available. For example, DEQ may conduct a use attainability analysis if the current designated beneficial use of a waterbody cannot be met. In addition, DEQ may also consider reopening and modifying the TMDL, subject to available resources, if new information showed that the TMDL or associated surrogates should be modified.

13.2. Elements of the Water Quality Management Plan

OAR 340-042-0040(4)(l) describes WQMP requirements. This section provides the framework of management strategies to attain and maintain water quality standards. The framework is designed to work in conjunction with detailed plans and analyses provided in sector-specific or source-specific implementation plans.

This section presents an overview of each element of the WQMP. Additional detail on each element is provided in the sections that follow.

13.2.1 Condition assessment and problem description

As noted in OAR 340-042-0040(4)(l)(A), WQMPs must contain an assessment of conditions and description of the problem the TMDL is developed to address. Fish tissue and water samples were collected from the Willamette Basin and analyzed for mercury. The data indicated several segments of the Willamette River and its tributaries are not meeting water quality standards. Based on Oregon's assessment methodology for the Integrated Report these waterbodies were identified as impaired and included on the state's 303(d) list. Oregon's 2012 Integrated Report contains the most recent listings relative to mercury for the Willamette Basin.

The Oregon Health Authority is responsible for evaluating contaminant concentrations in fish tissue, calculating the number of meals per month that can safely be consumed, and providing that information to the public by issuing a fish consumption advisory when data are available. DEQ helps to support this process by collecting and analyzing fish tissue samples and sharing these data with OHA. EPA and the National Parks Service also provide fish tissue data to OHA.

Advisories are designed to protect the public from contaminants sometimes found in fish, while also balancing the positive health benefits from eating fish. Information regarding fish consumption advisories can be accessed on OHA's website: https://www.oregon.gov/oha/pages/index.aspx.

There are multiple fish consumption advisories for the Willamette Basin advising people of the health risks associated with consuming fish containing elevated levels of mercury. Currently, fish consumption advisories in place for mercury include:

- Bass in all Oregon waters;
- All resident fish (except stocked, fin-clipped rainbow trout 12-inches or less) in the Dorena and Cottage Grove Reservoirs; and

- Resident fish in the mainstem Willamette River from its mouth on the Columbia River southward to Eugene, including the Coast Fork Willamette up to the Cottage Grove Reservoir.

These fish consumption advisories for mercury in the Willamette Basin and several 303(d) listings for mercury impaired waters support the need for additional mercury reductions in order to restore the beneficial use of “fishing”, and being able to safely eat fish. Table 4-1 contains the 303(d) listed waterbodies addressed in this TMDL.

The TMDL and accompanying WQMP demonstrate how Oregon will meet standards for total mercury in water and methylmercury in fish tissue, as well as the narrative water quality standard for toxic pollutants. The fish tissue methylmercury standard is 0.040 milligrams methylmercury/kilogram of fish tissue. Data indicate that the freshwater acute criterion for mercury of 2.4 micrograms/liter and the freshwater chronic criterion is 0.012 micrograms/liter of water are currently being attained.

13.2.2 Goals and objectives

Another required component of the WQMP is a section on goals and objectives, as described in OAR 340-042-0040(4)(I)(B). The overarching goal of this WQMP is to achieve the water quality standards for mercury in the Willamette Basin over time. Oregon has a mercury water standard to protect aquatic life, a methylmercury standard measured in fish tissue, and a narrative water quality standard for toxic chemicals (Section 13.2.1). The fish tissue standard, if not exceeded, protects those who consume up to approximately 23 eight ounce servings of fish or shellfish every month from Oregon lakes and streams. The primary objective of this WQMP is to lay out a framework that describes who is responsible for implementing the TMDL, management efforts that will be put into action in order to meet the TMDL, and how to measure progress towards attaining water quality standards for mercury.

The management strategies necessary to meet the TMDL load and wasteload allocations differ based upon the source of pollution and the responsibilities and resources of DMAs and responsible persons. Many DMAs and responsible persons are already implementing or planning to implement management strategies for improving and protecting water quality but may need to take additional actions to meet the mercury TMDL allocations.

13.2.3 Identification of designated management agencies and responsible persons

Identification of DMAs and responsible persons is required in the WQMP, as noted in OAR 340-042-0040(4)(I)(G). The purpose of this element is to identify responsible persons and Designated Management Agencies that are responsible for implementing the Willamette Basin Mercury TMDL. DMAs are federal, state and local governmental agencies that have legal authority over an activity or source contributing pollutants. DMAs are identified as such by the Department of Environmental Quality in a TMDL. A responsible person is an entity identified in a TMDL that has responsibility to meet assigned allocations and/or surrogate measures. DMAs and responsible persons are responsible for implementing management strategies and developing and revising sector-specific or source-specific implementation plans, unless otherwise indicated in the WQMP

Responsible persons may not have governmental (regulatory) authority to develop ordinances or other legal controls over activities. However, responsible persons identified in a WQMP may cause or contribute pollutant loading and have direct control over land or water management activities affecting mercury loading to rivers and streams.

TMDL implementation responsibilities will be carried out through existing regulatory and non-regulatory programs and activities for DMAs and responsible persons.

DMAs and responsible persons are required to develop or revise TMDL implementation plans that describe the management measures they will take to achieve their load allocations (Section 13.3). See Appendix E: List of Designated Management Agencies and Responsible Persons for a complete list of DMAs and responsible persons named in the Willamette Basin Mercury TMDL.

Appendix E: List of Designated Management Agencies and Responsible Persons is not intended to be an exhaustive list of every entity that bears responsibility for improving water quality in the Willamette Basin. All citizens that live, work and recreate in the Willamette Basin can take steps to reduce mercury and protect water quality. It will take broad participation to accelerate water quality improvements throughout the basin.

13.3. Proposed management strategies

This section of the plan describes management measures, as required in 340-042-0040(4)(l)(C), to reduce loadings of mercury to Willamette Basin waterbodies to meet TMDL load and wasteload allocations. It is organized by nonpoint and point source DMAs and responsible persons. For some of the DMAs, DEQ included a list of management measures as an implementation or “good practice” baseline. The list is not intended to be comprehensive or prescriptive and DMAs and responsible persons may propose alternative approaches or management strategies.

Following the issuance of the 2006 Willamette Basin TMDL and WQMP, DEQ required individual DMAs and responsible persons to develop implementation plans that included specific management strategies and best management practices to meet load allocations for mercury. Reporting requirements for many of these DMAs and responsible persons included an annual progress report and a comprehensive assessment of activities every five years. Summaries and reports of implementation activities since the issuance of the 2006 TMDL are summarized below (Table 13-1).

All DMAs and responsible persons named in this TMDL will be required to either update or develop mercury reduction strategies and milestones as identified in Section 13.3.1. In addition, riparian protection practices identified in the 2006 Willamette Basin **Temperature** TMDL are complementary to runoff, sediment and erosion management strategies contained in this WQMP for mercury. Together, these practices will provide a comprehensive approach to mercury pollution reduction. Existing information related to DMAs’ TMDL implementation efforts is available on DEQ’s websites below. Implementation plans and reports are also available on DMA websites.

Table 13-1. TMDL implementation reports and summaries

DMA	TMDL Report	Information available on DEQs website
Oregon Department of Agriculture	Biennial Agricultural Water Quality Management Area Plans	https://www.oregon.gov/deq/wq/programs/wqstatustrends
Oregon Department of Environmental Quality	Biennial Agricultural Water Quality Status and Trends Analysis	
Oregon Department of Environmental Quality	Willamette Basin TMDL Five Year Review: DMA Implementation 2008 - 2013	https://www.oregon.gov/deq/wq/tmdls/Pages/TMDLs-Implementation.aspx
Oregon Department of Environmental Quality	Oregon Nonpoint Source Pollution Program Annual Report	https://www.oregon.gov/deq/wq/programs/Pages/Nonpoint.aspx
Urban and Rural DMAs	TMDL annual progress report	Some DMAs provide a copy of their annual report and five year review report on their city or county website. These reports are also available from DEQ through a public records request. Public records request information: https://www.oregon.gov/deq/Requesting-Public-Records
Urban and Rural DMAs	TMDL five year review report	

13.3.1 Management strategies for nonpoint sources and water protection programs

As required in OAR 340-042-0040(4)(I)(E), the following section describes management strategies for nonpoint sources that will protect water quality. The section is arranged to include DMAs and responsible parties by state agencies, local governments, federal agencies and special districts.

13.3.1.1 Oregon Department of Environmental Quality Nonpoint Source

DEQ has the responsibility of overseeing and implementing Oregon's Nonpoint Source Management Program Plan. A nonpoint source of pollution is any pollution entering a waterbody that does not come directly from a discrete conveyance. Nonpoint sources are not normally covered by NPDES permits. The goal of DEQ's Nonpoint Source Management Program is to reduce water pollution from nonpoint sources, in order to meet water quality standards. The nonpoint source program is implemented by coordinating with many local, state and federal agencies and organizations throughout Oregon. The program uses a combination of federal and state programs for implementing statewide, programmatic, and geographic priorities, objectives, and strategies to achieve short- and long-term goals. Program requirements include tracking and reporting on implementation actions and water quality outcomes from these activities in Oregon's Nonpoint Source Annual Report submitted to EPA, which can be accessed on DEQs website https://www.oregon.gov/deq/wq/programs/Pages/Nonpoint.aspx.

Oregon's Nonpoint Source Management Program is an important part of the state's water pollution control programs because for many pollutants, nonpoint sources of pollution are the major sources of pollution to a waterbody. A summary of DEQ programs that have the potential to reduce nonpoint source mercury loading in the Willamette Basin is provided Table 13-2.

Table 13-2. Summary of DEQ programs that have the potential to reduce mercury loading in the Willamette Basin.

DEQ NPS Program	How it Protects/ Supports Water Quality
Nonpoint Source TMDL Implementation Program	Outlines and implements management goals, projects, and water quality monitoring for pollutant reductions that are needed in order meet Oregon's water quality standards, including mercury and methylmercury.
Onsite Program	Protects human health and the environment by establishing requirements for the construction, alteration, repair, operation and maintenance of onsite wastewater treatment systems.
Clean Up Program	Protects human health and the environment by identifying, investigating, and remediating sites contaminated with hazardous substances, including mercury.
Nonpoint Source 319 Grant Program	The 319-grant program funds cooperating entities for activities that address NPS emphasizing watershed protection and enhancement, watershed restoration, voluntary stewardship, and partnerships among watershed stakeholders, such as DEQ's Pesticide Stewardship Partnership. This includes alignment with significant match funding provided through the Oregon Watershed Enhancement Board (OWEB)'s parallel granting programs.
Clean Water State Revolving Fund	SRF loans finance a variety of nonpoint source water quality plans and projects. Eligible activities include integrated and stormwater management plans, establishing or restoring permanent riparian buffers and floodplains and daylighting streams from pipes.

13.3.1.2 DEQ Cleanup Program—Abandoned Mine Lands Sites

The Cleanup program includes a number of subprograms, including Site Assessment (for a complete list of subprograms visit https://www.oregon.gov/deq/Hazards-and-Cleanup/env-cleanup/Pages/default.aspx). Site Assessment is responsible for screening abandoned mine lands sites to determine which sites may be having significant impacts to the environment. Within the Willamette Basin there are 12 abandoned mine lands sites that were identified as significant sources of mercury, as shown in Table 9-3 of the Source Assessment Section above. These sites represent legacy mines that were in operation prior to Oregon's 1972 Oregon Mined Land Reclamation Act, and are now considered sources of "uncontrolled hazardous substances." These sites are subject to statutes and rules administered by the Cleanup program (ORS 465; OAR 340.122).

Between 2000 and 2004, the Cleanup program collaborated with EPA, the federal Bureau of Land Management and the US Forest Service to perform preliminary assessments of all abandoned mine lands sites in Oregon. Since that time, agency partners have completed site investigations, evaluations of potential cleanup levels and actions (feasibility studies), and the removal or treatment of contaminated materials. For up to date information visit DEQ's Environmental Cleanup Site Information database at https://www.deq.state.or.us/lq/ECSI/ecsiquery.asp.

13.3.1.3 DEQ Cleanup Program—Portland Harbor Superfund Source Control

Portland Harbor is a heavily industrialized stretch of the Lower Willamette River north of downtown Portland, from Sauvie Island south to the Broadway Bridge. EPA listed Portland Harbor on the National Priorities List, known as Superfund, in December 2000 due primarily to contaminated sediment.

EPA, DEQ and other agencies, tribal governments, community groups and companies are working to investigate and clean up contamination in Portland Harbor. EPA is the lead agency responsible for investigating and cleaning up contaminated sediments in the river, while DEQ is the lead agency for investigating and cleaning up contamination on upland sites.

Although EPA and DEQ identified mercury as a contaminant of concern in this area, additional data and investigations to date show that mercury levels alone do not warrant active cleanup of particular sediment areas. However, upland remediation and planned in-water cleanup necessary for dioxins, pesticides, metals, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons will also address some areas with mercury contamination. DEQ and EPA will be monitoring for mercury and relying on natural recovery to reduce concentrations in sediment and fish tissue. EPA established a cleanup level for mercury in fish tissue at 0.031 mg/kg. Additional information about Portland Harbor cleanup activities can be accessed on DEQs website: https://www.oregon.gov/deq/Hazards-and-Cleanup/CleanupSites/Pages/Portland-Harbor.aspx

13.3.1.4 Oregon Department of Agriculture

The responsibility of Oregon Department of Agriculture for regulating agricultural activities that impact water quality qualifies ODA as a DMA under OAR 340-042-080(3). The Agricultural Water Quality Management Act (ORS 568.900 to 933), and ORS 561.191, gives ODA the responsibility to adopt and enforce rules that protect water quality on agricultural lands. The Agricultural Water Quality Management Act directs ODA to develop Agricultural Water Quality Management Area Plans as well as rules. Together, area rules and plans represent the two main pathways through which ODA implements TMDLs on non-federal agricultural lands in Oregon. DEQ will continue to work closely with ODA's Water Quality Management Program to ensure that ODA's plans and rules are protective of water quality standards, including allocations and any surrogate measures contained in TMDLs. DEQ works with ODA as described under a 2012 Memorandum of Agreement.

Voluntary implementation through Agricultural Water Quality Management Area Plans

ODA's area plans identify local watershed conditions, water quality concerns associated with agriculture, and resources and strategies to address these concerns. There are a total of 38 Area Plans in Oregon, 10 of which specifically address watersheds within the Willamette Basin. These area plans include the Lower Willamette, Lower Columbia-Sandy, Clackamas, Middle Willamette, Molalla-Pudding-French Prairie- North Santiam, Tualatin, South Santiam, Southern Willamette, Upper Willamette- Upper Siuslaw, and Yamhill. Area plans are developed in consultation with Local Advisory Committees, which are made up of local farmers, and other watershed stakeholders.

ODA reviews each area plan on a biennial basis in consultation with local Soil and Water Conservation Districts, as well as the Local Advisory Committee. DEQ consults with ODA during the biennial review process to assess the water quality status and trends in the area in relation to allocations and any surrogate measures in an applicable TMDL. As part of the consultation process, DEQ provides a Status and Trends Report for each agricultural management area. These reports provide data and analysis of water quality status and trends in relation to water quality standards and TMDL allocations. ODA uses these reports to help identify implementation priorities at the catchment or watershed scale. Status and Trends Reports can be accessed from DEQ's website.

After the biennial review process, the Local Advisory Committee submits progress reports to the Board of Agriculture and ODA Director. These reports will continue to include statistics on landowner engagement and types of management practices being employed. These reports will continue to be available to DEQ for review in assessing implementation progress.

Soil and Water Conservation Districts also continue to be key partners in implementing area plans. During the 2013-2015 biennium all Soil and Water Conservation Districts in Oregon started working in Focus Areas. Focus Areas are geographic areas that are selected based on identified needs for agricultural water quality improvements. Soil and Water Conservation Districts contact agricultural landowners and offer voluntary assistance to improve streamside vegetation, streambank stability, and other concerns including livestock manure management and sediment reduction. These efforts are typically included in area plans and are evaluated as part the biennial review process.

Regulatory implementation through Agricultural Water Quality Management Area Rules

Implementation of the recommendations provided in area plans is voluntary, however ORS 561.191 stipulates that ODA must also adopt rules that protecting water quality in areas designated as exclusive farm use and other agricultural lands.

Between 1998 and 2014, the Agricultural Water Quality Program primarily conducted compliance investigations based on written complaints received from the public and complaint referrals from other agencies. In 2014, ODA initiated Strategic Implementation Areas, which represent a proactive approach to identifying specific agricultural activities in a specific watershed that are violating ODA rules, as well as legacy conditions that are adversely affecting water quality, and identifying conservation actions that will help achieve water quality goals.

Strategic Implementation Area watersheds are designated by ODA after conferring with watershed partners including DEQ, and reviewing available water quality and other data. After establishing a Strategic Implementation Area, properties of concern within the Strategic Implementation Area are identified. After an initial assessment, ODA contacts landowners to offer assistance and determine compliance with local rules. For more information about Strategic Implementation Areas, visit https://www.oregon.gov/ODA.

ODA is the agency responsible for compliance investigations and enforcement of program rules, however Soil and Water Conservation Districts, Oregon Watershed Enhancement Board, US Department of Agriculture Farm Service Agency, US Department of Agriculture Natural Resources Conservation Service, watershed councils, and other partners also work to provide technical assistance and other resources to help landowners implement conservation activities.

In addition to the efforts described above, ODA also registers, administers and enforces water quality permits for Confined Animal Feeding Operations. ODA and DEQ jointly issue Water

Pollution Control Facility state permits and NPDES federal permits for Confined Animal Feeding Operations. These permits do not allow discharges to waters of the state.

Measurable Objectives and WQMP Reporting Requirements

For the purpose of this TMDL, ODA has identified minimizing bare ground as the strategy most likely to have the greatest impact on sediment and erosion, especially during wet winter months. In addition to minimizing bare ground, best management practices and conservation practices that limit livestock access to the riparian area, establish stream canopy, and help stabilize channel banks should be given the highest priority. Because stream crossings, road prism failures, and hydrologically-connected roads are known sources of sediment to waterbodies across land uses, DEQ expects to work with ODA to develop measurable objectives related to roads and a schedule for implementing these strategies following the issuance of the TMDL. Examples of such strategies include: inventorying hydrologically-connected roads and potentially unstable road prisms and at-risk stream crossings.

Management strategies that minimize the impact of agricultural activities on water quality are currently identified in area plans. Management strategies that specifically impact sediment and erosion are shown in Table 13-3.

Table 13-3. Table of management strategies included in the Agricultural Water Quality Management Area Plans that address management strategies related to sediment and erosion.

Riparian Areas and Streams			
Practice	**Resource Concerns Addressed**	**Potential Benefits of Practice to Producer**	**Potential Costs of Practice to Producer**
Rotational grazing in riparian area; timed when growth is palatable to animals and when riparian area soils are not saturated.	May help establish desirable riparian vegetation and address temperature and bacteria TMDLs.	Allows limited use of riparian area for grazing, improves wildlife habitat.	Requires intense management to insure that grazing does not prevent site capable vegetation from establishing.
Livestock exclusion from riparian area; establishing off-stream watering facilities.	Helps promote desirable riparian vegetation; promotes streambank integrity; helps filter nutrients and sediment from runoff; may help narrow channel and reduce erosion in channel and address temperature, mercury and bacteria TMDLs.	May lessen streambank erosion and loss of pastures; less time involved in managing livestock grazing in riparian area, improves wildlife habitat.	May require higher weed control costs in riparian areas than seasonal riparian grazing. May require financial investment for livestock control and off-stream watering facilities.
Planting perennial vegetation in riparian area.	Helps establish perennial riparian vegetation rapidly; promotes streambank integrity; may help narrow channel and reduce erosion in	May lessen streambank erosion and loss of pastures. If livestock are excluded from riparian area, area may be eligible for federal cost-share	Costs of vegetation and weed control. May require financial investment for riparian fencing and off-stream watering facilities while vegetation establishes.

Riparian Areas and Streams			
Practice	**Resource Concerns Addressed**	**Potential Benefits of Practice to Producer**	**Potential Costs of Practice to Producer**
	channel; provides appropriate shade necessary to moderate solar heating and address temperature, mercury and bacteria TMDLs.	programs. Some alternative perennial agricultural products may be harvested from riparian areas.	

Erosion, Sediment, and Mercury Control			
Practice	**Resource Concerns Addressed**	**Benefits to Producer**	**Costs to Producer**
Grazing management: graze pasture plants to appropriate heights, rotate animals between several pastures; provide access to water in each pasture.	Helps prevent sediment, nutrient, mercury and bacteria runoff into waters of the state. Helps protect streamside areas.	May improve pasture production; easy access to water may increase livestock production as well. May improve livestock health because of better nutrition and parasite control. May improve composition of pasture plants and help prevent weed problems.	Cost of installing fencing, watering facilities for rotational grazing system; time involved in moving animals through pastures.
Farm road construction: construct fords appropriately, install water bars or rolling dips to divert runoff to roadside ditches.	Helps prevent sediment and mercury runoff to waters of the state.	May help prevent water damage on farm roads.	Cost of installation and maintenance.
Plant appropriate vegetation along drainage ditches; seed ditches following construction.	Helps prevent sediment and mercury runoff into waters of the state.	May help prevent ditch bank erosion and slumping.	Costs of establishing vegetation.
Plant cover crops on erosion-sensitive areas.	Helps prevent sediment and mercury runoff into waters of the state; helps filter nutrients and slow runoff.	May reduce weed problems; prevents loss of applied nutrients.	Costs of establishing cover crops; cover crops may compromise primary crop.
Irrigate pasture or crops according to soil moisture and plant water needs.	Helps prevent irrigation return flow and associated nutrients, sediment, and mercury to waters of the state.	May reduce costs of irrigation; may help crop or pasture production.	Installation/ maintenance cost. Monitoring time.
Install/maintain diversions or French drains to prevent	Helps prevent nutrient and mercury runoff	Decreases muddiness and shortens saturation	Cost of installation.

Riparian Areas and Streams			
Practice	**Resource Concerns Addressed**	**Potential Benefits of Practice to Producer**	**Potential Costs of Practice to Producer**
unwanted drainage into barnyards and animal heavy use areas.	into waters of the state.	period in protected areas.	

In addition to continued implementation of the strategies provided in Table 13-3, ODA will work with Local Advisory Committees, in consultation with DEQ, to identify specific measurable objectives and timelines such as percent reduction in bare ground during wet months, along with associated implementation timelines for implementing best management practices and conservation practices that address runoff, sediment and erosion. ODA will work with Local Advisory Committees to report on these metrics during the biennial review process.

DEQ is requesting that ODA and Local Advisory Committees include specific metrics for identified areas of agricultural lands that can be tracked consistently across all agricultural water quality management plan areas in the Willamette Basin. DEQ recognizes that farming practices and cropping systems vary across and within these areas; however there are relevant strategies for reducing runoff, sediment and erosion that apply universally to almost all agricultural lands, e.g. reduce bare ground. This approach does not replace developing and tracking area-specific measurable objectives.

Measurable objectives and timelines should be coordinated with biennial reviews of area plans to the extent possible, however DEQ expects measurable objectives and timelines to be incorporated into all Willamette Basin area plans within 18 months of the issuance of this TMDL. ODA will also take part in the Willamette Basin five year review. For more information about five year reviews, see section 13.4.1.

13.3.1.5 Oregon Department of Forestry

Under OAR 340-042-080(2), the Oregon Department of Forestry is the DMA for water quality protection from nonpoint source discharges or pollutants resulting from forest operations on non-federal forestlands within the state. The Forest Practices Act sets expectations for water quality outcomes and prescribes required best management practices. The Forest Practices Act has provisions for both criminal and civil penalties if forest operators do not comply with water protection regulations. ODF rules relevant to protection of water quality and erosion control are found in the Oregon Administrative Rules referenced in Table 13-4.

Table 13-4. ODF Rules Related to Water Quality and Erosion Control

Forestry Practice	Rule Reference
Treatment of Slash	OAR-629-615-0000 through 629-615-0300
Stewardship Agreements	OAR 629-021-0100 through 629-021-1100
Forest Road Construction and Maintenance	OAR-629-625-0000 through 629-625-0700
Harvesting	OAR 629-630-0000 through 629-630-0800
Water protection rules	OAR 629-635-0000 through 629-660-0060

In addition to assuring compliance with the Forest Practices Act, ODF also employs other efforts and funding, such as landowner voluntary measures conducted as part of the Oregon Plan for Salmon and Watersheds, to help support ODF's role in implementing the TMDL. ODF also delivers technical assistance and cost share funding to family forest landowners that support goals for water quality protection. See Table 13-5 for examples of management strategies that resource managers on non-federal land implement to meet Forest Practices Act regulations to control erosion and runoff.

DEQ will work with ODF to identify specific actions necessary to reduce sedimentation from non-federal forest lands, including both voluntary and regulatory actions. For example, ODF's February 2012 guide to voluntary actions to protect threatened and endangered fish is a good resource for private forest landowners who wish to implement practices that go beyond the current Forest Practices Act and rules. For additional information about ODF, visit: http://www.oregon.gov/ODF.

Table 13-5. Pollutant sources and example management strategies to address sediment and mercury.

Forestry Practice	Description
Implement Forest Practices Act	• Prescriptive rules for forest operations • Notification system (FERNS) • Forest operation inspections conducted by Stewardship Foresters • Compliance monitoring • Education and outreach on FPA topics
Protection/enhancement of riparian zone, wetlands, seeps, etc. with buffers	• Stream and water body classification • Prescriptive rules on vegetation retention, ground equipment, road building restrictions in riparian management areas • Promote implementation and reporting of Oregon Plan voluntary measures • Deliver incentive programs to restore/enhance aquatic/riparian habitat (CREP, etc.)
Conduct pre-harvest planning	• Stewardship Forester notification review, pre-operation inspections, and recommendations for any additional BMPs • Delivery of incentive programs to promote stewardship and planning
Replace/restore roads/culverts	• Prescriptive rules for road construction, maintenance and decommissioning • Identification and replacement/repair of culverts, ditches and other drainage elements of active and inactive roads that are not functioning properly or at risk of failure. • Promote implementation and reporting of Oregon Plan voluntary measures
Stabilize stream banks	• Prescriptive rules for vegetation retention in riparian management areas • Rules to minimize, avoid, restore or prohibit ground equipment, road building in or near channels or channel modification
Uplands management	• Prescriptive rules for reforestation and harvesting • Rules to minimize soil disturbance and erosion and maintain productivity

Forestry Practice	Description
	• Delivery of incentive programs to encourage forest health, minimize fire risk
Inspection/enforcement	• Civil Penalties • Forest operation inspections conducted by Stewardship Foresters
BMP monitoring and evaluation	• Adaptive management: effectiveness monitoring informs Board of Forestry who can revise prescriptive rules • Monitoring Strategy to prioritize and direct monitoring work
Instream monitoring	• Member of Water Quality Pesticide Management Team, Pesticide Stewardship Partnerships • Project-level instream water quality monitoring efforts to assess FPA effectiveness
BMP implementation monitoring	• Compliance audit study and reports
Education and outreach to operators and landowners	• Delivery of technical assistance and cost share programs to family forest landowners • Agreement with Associated Oregon Loggers • Regional Forest Practices Committee • Committee for Family Forestlands • Partnership for Forest Education • Logging Conference session(s) • Annual Tree School events • Stewardship Forester delivery of individual landowner, operator technical assistance • Ad hoc training events: Operator breakfasts, Society of American Forester meetings, Watershed Council meetings, new rule training, etc.

The Memorandum of Understanding between ODF and DEQ describes a process to evaluate the sufficiency of current Forest Practices Act best management practices in meeting water quality standards and TMDLs on state and privately owned forestlands. Forest operators conducting operations in accordance with the Forest Practices Act are generally considered to be in compliance with water quality standards. Where it is shown that existing Forest Practice Act rules and voluntary measures are not sufficient to meet water quality standards, including TMDL load allocations, DEQ will request that ODF implement additional voluntary programs, revise statewide Forest Practices Act rules and/or adopt subbasin specific rules as necessary.

Measurable objectives, milestones, and WQMP reporting requirements

In addition to continued implementation of the strategies provided in Table 13-5, and other voluntary efforts, DEQ and ODF will identify specific measurable objectives with milestones and associated implementation timelines that address runoff and erosion. Because stream crossings, road prism failures, and hydrologically-connected roads are known sources of sediment to waterbodies across land uses, DEQ expects to work with ODF to develop measurable objectives related to roads and a schedule for implementing these strategies following the issuance of the TMDL. Examples of such strategies include: inventorying hydrologically-connected roads and potentially unstable road prisms and at-risk stream crossings. Measurable objectives may also include an evaluation of hillslope erosion potential during tethered logging operations.

The measurable objectives and the metrics used for tracking measurable objectives will be submitted to DEQ in an implementation plan within 18 months of TMDL issuance.

Status of management strategies related to the Forest Practices Act erosion and runoff control requirements, progress on meeting milestones, and other ODF reporting, such as Forest Practices Compliance Audits will be included in subsequent Willamette Basin five year reviews. For more information about five year reviews, see Section 13.4. Reports or other documents used for ODF TMDL reporting should be made available on a publically accessible website.

13.3.1.6 Oregon Department of State Lands

Oregon Department of State Lands is named as a Designated Management Agency because DSL manages significant tracts of land and issues permits for earthwork below ordinary high water of waterways and in wetlands in the Willamette Basin. DSL's authorities are noted in OAR 340-042-080(4).

DSL has both a regulatory and a proprietary role with regard to the land within the Willamette Basin. DSL issues two types of permits and authorizations related to its regulatory and proprietary roles: removal-fill permits for removal or fill activity in waterways and wetlands, and proprietary waterway authorizations for use of state-owned waterways.

In its regulatory role, DSL is responsible for administering Oregon's Removal-Fill Law which was enacted in 1967 and includes the following responsibilities:

- Protect, conserve and make best use of water resources
- Protect public navigation, fishery and recreational areas
- Ensure that activities of one landowner don't adversely affect another landowner
- Minimize flooding, improve water quality, and provide fish and wildlife habitat.

For many removal-fill permits, applicants also must obtain a corresponding permit from the U.S. Army Corps of Engineers under section 404 of the federal Clean Water Act. For these permits, DEQ issues water quality certifications under section 401 of the CWA.

In its proprietary role, DSL owns certain state-owned parcels within the Willamette Basin, including:

- Approximately 2,900 acres of land which includes both the surface and underlying mineral rights
- Approximately 12,100 acres of mineral rights which occur on land on which the surface is owned by another entity (commonly termed "split estates")
- Submerged and submersible land underlying:
    - The Willamette River from its confluence with the Columbia River at River Mile (RM) 0.0 to RM 187 at the confluence of the Coast and Middle Forks of the waterway;
    - The McKenzie River from its confluence with the Willamette River at RM 0.0 to RM 37 at Dutch Henry Rock; and
    - Tidally-influenced waters.

As the manager of both upland parcels and mineral rights within the Willamette Basin, as well as submerged and submersible land underlying the Willamette River, DSL is responsible for authorizing uses placed on these holdings. Mercury may occur, or is likely or known to occur on the following types of state-owned land in the following ways:

- Upland parcels: primarily derived from local and distant sources by atmospheric deposition, and associated with possible underlying mineralization.
- Submerged and submersible land: via atmospheric deposition and from runoff from upland and industrial discharges, and prior mining operations.
- Mineral Rights: as an accessory constituent of, or used to process some mineral deposits.

Measurable Objectives, Milestones, and Water Quality Management Plan Reporting Requirements

DSL will continue to implement the management strategies identified in Table 13-6 in order to ensure that all persons applying for, and holding authorizations to use, state-owned land are implementing best management practices that reduce runoff, sediment and erosion.

In addition to the strategies identified in Table 13-6, DEQ encourages DSL to work with ODA and other watershed partners to conduct focused outreach and education that includes the water conveyance systems that are identified as responsible persons in this WQMP.

DSL is required to develop a TMDL implementation plan for the Willamette Basin for review and approval by DEQ within 18 months of the issuance of this TMDL. This plan must include specific measurable objective(s) and timelines for implementation and may include specific conditions that DSL and/or DEQ (through section 401conditions) utilize to avoid soil erosion and sedimentation. DSL will also take part in the Willamette Basin five year review. For more information about five year reviews, see section 13.4.

Table 13-6. Management Strategies that Department of State Lands implements that reduce mercury loading to the Willamette Basin.

Management Strategies
Maintain all structures, waste disposal and septic systems, and storm water runoff collection systems in good working condition.
Condition or do not allow uses of submerged and submersible land that result in streambank erosion
Encourage persons authorized to use state-owned land for grazing to prevent their animals from walking in or drinking directly from streams on state-owned property.
Not authorize any use of either upland or submerged and submersible land managed by the agency that involves the use of mercury or compounds containing mercury in amounts determined to be unacceptable based on comments received from the public review process of the application
Not allow any use to occur on, or be made of state-owned submerged and submersible land that is determined to cause the release of an unacceptable amount of mercury from the sediments to the environment based on comments received from the public review process of the application
Not allow any state-owned mineral deposit managed by DSL to be mined for mercury, or mercury to be used on state-owned land to process minerals
Wherever possible, condition authorizations to limit or prevent stormwater runoff from, and resultant erosion of soil on state-owned land
Clean up solid waste and other materials dumped illegally on state-owned land that may contain mercury, and attempt to identify the person(s) responsible for such activities for possible citation

Management Strategies
Employ interagency cross checks to confirm that a proposed use will not negatively impact a restoration site

13.3.1.7 Oregon Parks and Recreation Department

Under OAR 340-042-080(4), Oregon Parks and Recreation Department qualifies as a DMA due to responsibilities for managing several categories of lands owned by the state. Many of these areas remain undeveloped and while primarily managed for recreational uses, they also include lands managed for forestry and agriculture, such as livestock grazing. OPRD manages and operates over 130 individual parks, waysides and greenway properties, and more than 90 sites are leased to other entities for management. State Parks, State Natural Areas as well as upland areas are also managed by OPRD.

In 2017, OPRD released a 10-year Strategic Action Plan for restoration and stewardship of OPRD-managed sites in the Willamette Basin. The strategic plan, as well as a number of other programs and policies, integrate water quality implementation goals and objectives into existing management strategies, including:

- Agricultural Use of Park Lands
- Comprehensive Park Planning
- Forest Management
- Intergovernment Natural Resource Communications
- Invasive Species Management on State Park Lands
- Land Acquisition and Exchange
- Maintenance and Operation of Water and Sewerage Systems
- Natural Resource and Environmental Management Policy
- Oregon Plan
- Sewer and Water System Failures

OPRD also administers a grant program and the State Scenic Waterways program, which support activities that are protective of water quality.

Measurable objectives, milestones, and WQMP reporting requirements

OPRD's TMDL implementation plan was recently updated in 2018 and includes multiple management strategies and actions that address mercury load reductions, including but not limited to those provided in Table 13-7. OPRD will continue to implement these and other management strategies in order to ensure that OPRD as well as all persons applying for, and holding authorizations to use state-owned land managed by OPRD are implementing best management practices that reduce runoff, sediment and erosion.

In addition, OPRD will update their TMDL implementation plan to include specific measurable objectives, milestones and timelines for management strategies that address runoff and soil erosion within 18 months of the issuance of this TMDL.

OPRD will also take part in the Willamette Basin five year review. For more information about five year reviews, see section 13.4.

Table 13-7. Management Strategies that Oregon Parks and Recreation Department implements that reduce mercury loading to the Willamette Basin.

Management Strategies
Continually monitor trail systems; repair or re-route trails to reduce runoff and erosion
Continue to require permittees with Agricultural Leases to apply best management practices to prevent and reduce runoff and erosion, including retaining 50 foot no-till buffers along fish-bearing streams, and maintaining ground cover during wet, winter months
Reduce number of drain tile systems in former agriculture fields to promote infiltration of stormwater
Continue to meet or exceed all Forest Practices Act rules during forestry operations. Implement riparian restoration projects, which help to filter and reduce sediment delivery to streams
Use on-site stormwater retention in new park designs to infiltrate stormwater
Continue to provide education and outreach activities including promoting biking and walking to reduce air emissions

13.3.1.8 Oregon Department of Geology and Mineral Industries

Under OAR 340-042-080(4), responsibility for regulation of aggregate mines, many of which are located in the flood plain of rivers, qualifies Department of Geology and Mineral Industries as a DMA. As with other state agencies that have been identified as DMAs, DOGAMI is required to submit an implementation plan specific to mercury reduction in the Willamette Basin, however, because DOGAMI conducts these activities throughout the state, DOGAMI may work with DEQ to develop a state-wide implementation plan to address other TMDL implementation responsibilities. Many of the elements required in an implementation plan will be met through DOGAMI's oversite, as DEQ's Agent of implementation of the NPDES 1200A general industrial stormwater permit. The 1200A permit covers aggregate and asphalt operations. Other elements required in an implementation plan are included in DOGAMI's Best Management Practices for Reclaiming Surface Mines, which can be accessed on DOGAMI's website: https://www.oregongeology.org/mlrr/overview.htm.

13.3.1.9 Oregon Department of Fish and Wildlife

Per OAR 340-042-080(4), DEQ named Oregon Department of Fish and Wildlife DMA. ODFW manages three wildlife areas in the Willamette Basin, including EE Wilson Wildlife Area near Monmouth, Fern Ridge Wildlife Area near Eugene, and Sauvie Island Wildlife Area/ North Willamette Watershed Wildlife District near Portland. In addition to providing for wildlife habitat, these areas are also managed for recreational activities such as hunting, fishing, hiking, boating, wildlife observation, trapshooting and archery.

Measurable objectives, milestones, and WQMP reporting requirements

ODFW will develop an implementation plan that will include management strategies and actions that address mercury load reductions, including but not limited to those provided in Table 13-8. ODFW will implement these and other management strategies in order to ensure that ODFW, as well as all persons applying for, and holding authorizations to use, ODFW owned land are implementing best management practices that reduce runoff, sediment and erosion.

In addition, ODFW's implementation plan will include specific measurable objectives, milestones and timelines for management strategies that address runoff and soil erosion within 18 months of the issuance of this TMDL.

ODFW will also take part in the Willamette Basin five year review. For more information about five year reviews, see section 13.4.

Table 13-8. Management Strategies that Oregon Department of Fish and Wildlife implements that reduce mercury loading to the Willamette Basin.

Management Strategies
Continually monitor trail systems; repair or re-route trails to reduce runoff and erosion
Continue to require permittees with Agricultural Leases to apply best management practices to prevent and reduce runoff and erosion, including retaining 50 foot no-till buffers along fish-bearing streams, and maintaining ground cover during wet, winter months
Reduce number of drain tile systems in former agriculture fields to promote infiltration of stormwater
Continue to meet or exceed all Forest Practices Act rules during forestry operations. Implement riparian restoration projects, which help to filter and reduce sediment delivery to streams
Use on-site stormwater retention in new park designs to infiltrate stormwater

13.3.1.10 Oregon State Marine Board

Using authorities described in OAR 340-042-080(4), the Oregon State Marine Board administers boating safety educational programs, enforces marine law and maintains and improves boating facilities. OSMB establishes state-wide boating regulations and contracts with county sheriffs and the Oregon State Police to enforce marine laws. The board provides technical training to marine patrol officers and supplies their equipment. OSMB also provides grants and engineering services to local governments such as cities, counties, park districts and port districts, to develop and maintain accessible boating facilities and protect water quality. OSMB actively promotes safe and sustainable boating through several programs.

DEQ will coordinate with OSMB regarding implementation of the TMDL as it relates to boating practices. Boating activities potentially important to the implementation of the mercury TMDL include but are not limited to signage and education, establishment of boating regulations, practices for the removal of derelict structures that qualify under the Abandoned Vessel Program rules, and boating campaigns that encourage boaters to adopt clean and safe boating practices.

Measurable objectives, milestones, and WQMP reporting requirements

OSMB will develop an implementation plan that will include management strategies and actions that address mercury load reductions. These management strategies will likely focus on boating practices.

In addition, the OSMB implementation plan will include specific measurable objectives, milestones and timelines for management strategies that address runoff and soil erosion related to boating practices within 18 months of the issuance of this TMDL.

OSMB will also take part in the Willamette Basin five year review. For more information about five year reviews, see section 13.4.

13.3.1.11 Local Government: Cities and Counties

Oregon cities and counties have the authority to regulate land use activities through local comprehensive plans and related development regulations. The Oregon land use planning system, which is administered by local governments with oversight through the Oregon Department of Land Conservation and Development, provides a unique opportunity for local jurisdictions to address water quality protection and enhancement. Every city and county is required to have a comprehensive plan and accompanying development ordinance to be in compliance with state land use planning goals. While the comprehensive plan must serve to implement the state-wide planning goals mandated by state law, cities and counties have a wide degree of local control over how resource protection is addressed in their community.

Many of the land use planning goals in OAR 660-015-0000 have a direct connection to water quality, particularly Goal 5 (Natural Resources, scenic, and historic areas and open spaces, Goal 6 (Air, water, and land resources quality), and Goal 7 (Areas subject to natural hazards). DEQ expects that the efforts of local jurisdictions to address Goals 5, 6, and 7 requirements, when incorporated into a TMDL implementation plan, will help a DMA meet the TMDL allocations. In addition, existing city and county efforts to protect and enhance riparian vegetation along streams will help to provide natural filtering of runoff containing sediment.

Mercury in Urban Stormwater

TMDL modelling shows that in urban areas, the majority of mercury reaches waterbodies through atmospheric deposition and through runoff of mercury from soils and hard surfaces. Therefore, DEQ anticipates that city and county DMAs will largely focus on activities and strategies to reduce runoff and erosion into urban streams and into stormwater conveyance systems.

During the first implementation phase of the 2006 Willamette Basin Mercury TMDL, DEQ required some MS4 Phase I communities to collect mercury stormwater data. DEQ analyzed total mercury data from seven of these MS4 Phase I communities (see Table 13-9).

The TMDL water column target to meet a fish tissue methylmercury criterion of 0.040 mg/kg is 0.14 ng/L. The median value of total mercury in stormwater from the MS4 Phase I communities was 4.62 ng/L. Based on the analyzed data, DEQ concluded that urban stormwater has environmentally significant concentrations of mercury contributing to mercury loads in portions of the Willamette Basin, even though the sector's overall load to the basin is small. Therefore, to reduce mercury from urban runoff, DEQ developed point source wasteload allocations for NPDES MS4 permit holders, and nonpoint source load allocations for non-permitted urban DMAs.

Table 13-9. Stormwater Summary Statistics (Tetra Tech, 2019)

Analyte	Sample Size	Range (ng/L)	Median (ng/L)	25^{th} % (ng/L)	75^{th} % (ng/L)
Total Hg	655	0.25 - 120	4.62	2.94	8.31

Six Minimum Measures for Stormwater

EPA established six stormwater control measures as part of its final EPA MS4 Phase II stormwater regulations (January 9, 1998 63 FR 1536 -1643). It provides a consistent set of minimum components for a regulated small MS4 operator's stormwater management program to reduce pollution from urban runoff. The six EPA control measures generally mirror requirements in DEQ's MS4 Phase II permit that became effective in March 2019. For this TMDL, DEQ will also defer to these six stormwater control measures to control urban runoff. DEQ is requiring actions associated with these stormwater measures to achieve needed nonpoint source reductions in mercury and sediment. DEQ recognizes that implementing these requirements will also have benefits in reducing other pollutants associated with stormwater.

The six stormwater control measures described below in Table 13-10 are generally less prescriptive than the requirements contained in the Phase II general permit. Application of these measures to urban areas not previously regulated by a permit or TMDL requirements fills a gap to ensure mercury and sediment in stormwater discharges are comprehensively controlled throughout the Willamette Basin.

Table 13-10. Minimum requirements for implementing the six stormwater measures. In addition to requirements in section 13.3.2.2, these requirements apply to MS4 permittees (outside of the MS4 permit coverage area), and non-permitted urban DMAs with a population of 5,000 or greater.

Stormwater Measure	Requirements
1. Pollution Prevention and Good Housekeeping for Municipal Operations	DMAs must properly operate and maintain its facilities, using prudent pollution prevention and good housekeeping to reduce the discharge of mercury-related pollutants through the stormwater conveyance system to waters of the state. DMAs must ensure that DMA-owned or operated facilities with industrial activity identified in DEQ's 1200-Z Industrial Stormwater General Permit have coverage under this permit. The DMA must also conduct its municipal operation and maintenance activities in a manner that reduces the discharge of pollutants to protect water quality. DMAs must maintain records for activities to meet the requirements of the Pollution Prevention and Good Housekeeping for Municipal Operations program requirements and include a descriptive summary of their activities in the TMDL Annual Report.
2. Public Education and Outreach	DMAs must conduct an ongoing education and outreach program to inform the public about the impacts of stormwater discharges on waterbodies and the steps that they can take to reduce mercury-related pollutants in stormwater runoff. The education and outreach program must be designed to address stormwater issues of significance within the DMA's community. DMAs must track implementation of the public education and outreach requirements. In each corresponding TMDL Annual Report, the DMA must assess their progress toward implementation of the program, including the evaluation of at least one education and outreach activity corresponding to the reporting timeframe for the associated TMDL Annual Report. The assessment should be used to inform future stormwater education and outreach efforts to most effectively convey the educational material to the target audiences.

Stormwater Measure	Requirements
3. Public Involvement and Participation	DMAs must implement a public involvement and participation program that provides opportunities for the public to effectively participate in the development of stormwater control measures. The DMA must comply with their public notice requirements when implementing a public involvement participation process, including maintaining and promoting at least one publicly accessible website with information on the city's stormwater control implementation, contact information and educational materials.
4. Illicit Discharge Detection and Elimination	DMAs must implement and enforce a program to detect and eliminate illicit discharges into the stormwater conveyance system. An illicit discharge is any discharge to a stormwater conveyance system that is not composed entirely of stormwater. The DMA must develop and maintain a current map of their stormwater conveyance system. The stormwater conveyance system map and digital inventory must include the location of outfalls and an outfall inventory, conveyance system and stormwater control locations. The DMA must make maps and inventories available to DEQ upon request. When in digital format, the DMA must fully describe mapping standards in the TMDL Implementation plan or other city planning document. The IDDE program must prohibit non-stormwater discharges into the stormwater conveyance system through enforcement of an ordinance or other legal mechanism, including appropriate enforcement procedures and actions to ensure compliance. The ordinance or other regulatory mechanism must also define the range of illicit discharges it covers, including those discharges that are conditionally allowed, such as groundwater and lawn watering discharges. The IDDE program must also maintain a procedure or system to document all complaints or reports of illicit discharges into and from the stormwater conveyance system. The DMA must track implementation of the IDDE program requirements. In each TMDL Annual Report, the DMA must assess their progress towards implementation of the program.
5. Construction Site Runoff Control	For construction projects that disturb one or more acres (or that disturb less than one acre, if it is part of a "common plan of development or sale" disturbing one or more acres), the DMA must refer project sites to DEQ, or the appropriate DEQ agent, to obtain NPDES 1200-C Construction Stormwater Permit coverage. To further control erosion related to construction sites, the DMA must require construction site operators to complete and implement an Erosion and Sediment Control Plan for construction project sites in its jurisdictional area that result in a minimum land disturbance of 21,780 square feet (one half of an acre) or more, and are not already covered by a 1200-C permit. Through ordinance or other regulatory mechanism, to the extent allowable under state law, the DMA must require erosion controls, sediment controls, and waste materials management controls to be used and maintained at all qualifying construction projects (as described above) from initial clearing through final stabilization to reduce pollutants in stormwater discharges to the stormwater conveyance system from construction sites. The DMA must develop, implement and maintain a written escalating enforcement and response procedure for all qualifying construction sites. The procedure must address repeat violations through progressively stricter response, as needed, to achieve compliance.

Stormwater Measure	Requirements
	The DMA must track implementation of the construction site runoff program's required activities. In each TMDL Annual Report, the DMA must assess their progress toward implementing the construction site runoff program's control measures.
6. Post-Construction Site Runoff for New Development and Redevelopment	DMAs must develop, implement, and enforce a program to reduce discharges of pollutants and control post-construction stormwater runoff from new development and redevelopment project sites in its jurisdictional area. Example of such programs and program elements are provided in Appendix F: Stormwater References and Resources. Through ordinance or other regulatory mechanism, the DMA must require the following for project sites discharging stormwater to the storm water conveyance system that create or replace 10,890 square feet (one quarter of an acre) or more of new impervious surface area: (A) The use of stormwater controls at all qualifying sites. (B) A site-specific stormwater management approach that targets natural surface or predevelopment hydrological function through the installation and long-term operation and maintenance of stormwater controls. (C) Long-term operation and maintenance of stormwater controls at project sites that are under the ownership of a private entity. The DMA must target natural surface or predevelopment hydrologic function to retain rainfall on-site and minimize the offsite discharge of precipitation utilizing stormwater controls that infiltrate and evapotranspirate stormwater. For projects that are unable to fully retain rainfall/runoff from impervious surfaces on-site, the remainder of the rainfall/runoff from impervious surfaces must be treated prior to discharge with structural stormwater controls. These stormwater structural controls should be designed to remove, at a minimum, 80 percent of the total suspended solids. The DMA must maintain records for activities to meet the requirements of the post-construction site runoff program requirements and include a descriptive summary of their activities in the TMDL Annual Report.

13.3.1.11.1 Nonpoint source stormwater management requirements for MS4 Permit holders

Cities and other local governments that have Phase I or Phase II MS4 stormwater permits for stormwater discharges within the Willamette Basin are listed in Table 9-5 and already have specific requirements for meeting and reporting on associated wasteload allocations for total mercury that are applicable within the urbanized areas of their permit. For those requirements, see section 13.3.2.2.

As DMAs for nonpoint sources of mercury, MS4 permit holders must also implement the six stormwater control measures, as described in Table 13-10, in their jurisdictional areas outside of the urbanized area covered by their permit. If these city and county jurisdictional boundaries include land uses under the authority of other DMAs, such as ODA, ODF, BLM, or USFS, then those DMAs are responsible for control of any stormwater discharge from these areas. Likely areas for counties to apply the six minimum measures include areas zoned for commercial, industrial, rural residential, county parks and county road systems.

While the Table 13-10 six minimum stormwater measures are less rigorous than the section 13.3.2.2 MS4 permit requirements, for ease of implementation, MS4 permit holders may choose to implement permit requirements outside the urbanized area. This approach would meet the requirements in Table 13-10.

MS4 permit holders must also develop and submit a TMDL implementation plan that demonstrates how nonpoint source load allocations will be met. This plan must include management strategies to reduce runoff and erosion that discharge directly to waterbodies.

MS4 permits will be the mechanism by which point source wasteload allocation requirements are met. Reporting on point source and nonpoint source implementation may be streamlined into a single submission, which will be reviewed by both DEQ stormwater and TMDL program staff. See *Measurable Objectives, Milestones, and WQMP Reporting Requirements* section following Table 13-11 for more information about updating TMDL implementation plans for mercury and DEQ reporting.

13.3.1.11.2 Stormwater management requirements for non-permitted urban DMAs

The requirements for portions of cities and counties that have stormwater discharges within the Willamette Basin and are not required to have MS4 permit coverage are discussed below. If a community subject to the requirements below is later identified by DEQ as needing coverage under an MS4 permit, the MS4 permit requirements would supersede the requirements below within the permit coverage area.

The analyses that are the foundation for the draft TMDL estimate that mercury loads from all combined, non-permitted urban area stormwater discharges is approximately one percent of the overall load in the Willamette Basin. The TMDL requires a 75 percent reduction of mercury loads across this sector.

DEQ does not have direct stormwater mercury data from the stormwater discharges occurring in cities and counties that are not regulated by a MS4 Phase I permit. In the absence of data, DEQ cannot quantitatively determine the amount of mercury in stormwater discharges from these smaller cities and counties. However, analyses show that mercury contained in stormwater is primarily a function of runoff and erosion from impervious areas, rather than from specific sources in large urban areas, and could contribute to a water quality impairment. This is the reason that DEQ is requiring smaller communities to meet similar requirements for stormwater control and treatment. The percent of impervious cover in the Willamette Basin communities continues to increase in almost all jurisdictions, as seen from multiple data sources including municipal building permits, and active DEQ 1200-C permits.

Note that the 2006 Willamette Basin TMDL required cities with populations greater than 10,000 people to implement the six stormwater control measures to reduce mercury and bacteria loads from urban areas.

The stormwater requirements described in Table 13-10 will apply within the city or county boundary if not under the jurisdiction of another federal or state agency such as ODOT, Oregon Department of Agriculture, Oregon Department of Forestry, Bureau of Land Management, and

U.S. Forest Service. Additional details about implementing the six stormwater control measures based on population status are provided below.

Cities and counties with populations 5,000 people or greater (and no MS4 permit)

The following cities and counties meet a population criterion of 5,000 people or greater (according to Portland State University July 1, 2018 certified dataset):

- **Greater than 10,000**: (1) Canby, (2) Columbia County, (3) Cottage Grove, (4) Dallas, (5) Lebanon, (6) McMinnville, (7) Newberg, (8) St. Helens, (9) Woodburn, (10) Sandy, (11) Silverton, and (12) Yamhill County
- **5,000 – 10,000**: (1) Creswell, (2) Independence, (3) Junction City, (4) Molalla, (5) Monmouth, (6) Scappoose, (7) Sheridan, (8) Stayton and (9) Sweet Home.

These communities will need to either develop a new TMDL implementation plan, or update their existing TMDL implementation plan to fully incorporate the stormwater measures for mercury and sediment reduction described in Table 13-10. Cities and counties named above must implement the six stormwater control measures according to the schedule in Table 13-11.

Cities and counties with populations less than 5,000 people (and no MS4 permit)

City and county DMAs with a population less than 5,000 people and who are not required to have coverage under an MS4 permit must evaluate the six minimum stormwater control measures listed in Table 13-10 and identify the strategies and actions that they can implement to reduce mercury and sediment, including sources of runoff, sediment and erosion. The timelines in Table 13-11 do not apply to non-MS4 city and county DMAs with populations less than 5,000 people.

Under certain circumstances, such as when population growth exceeds 5,000 people or DEQ determines it is necessary to meet load allocations for mercury, DEQ may require urban DMAs with a population less than 5,000 people to implement all or a subset of the six stormwater control measures.

These communities will need to either develop a new TMDL implementation plan, or update their existing TMDL implementation plan to include strategies that address stormwater runoff and erosion.

Implementation Schedule for stormwater control measures for non-permitted urban DMAs

Since 2006, some city and county DMAs have been implementing mercury minimization plans to help reduce mercury inputs to the watershed, including, but not limited to:

- Conducting outreach and education about best management practices for the management of dental wastes and recycling of fluorescent lighting
- Requiring sediment and erosion control plans of new and re-development projects
- Requiring or encouraging the use of low impact development to reduce the volume and rate of stormwater discharged to streams
- Reducing emissions by purchasing more fuel-efficient vehicles for municipal fleets
- Enforcing and/or encouraging conservation and enhancement of riparian buffers, which trap sediment and prevent stream bank erosion

- Performing regular street sweeping and catch basin cleaning

DEQ recognizes the financial challenges that cities and counties face in implementing the Willamette Basin TMDLs. For this reason, DEQ is proposing to allow communities the following periods before they must adopt updated implementation plans, and then fully implement the stormwater control measures in those plans:

Deadlines for Submittal of New or Updated Implementation Plans

- DEQ expects DMAs with populations greater than 5,000 to either update their current TMDL implementation plan, or develop a new implementation plan, to include the six stormwater management measures, within 18 months following issuance of the TMDL.
- DEQ expects DMAs with populations less than 5,000 people and who are not MS4 permit holders to update their current TMDL implementation plan or develop a new implement plan, to include strategies and actions that address stormwater runoff, sediment and erosion within, 18 months following issuance of the TMDL. DEQ may approve an alternate deadline, such as the due date associated with a DMA's TMDL Annual Report.

DMA implementation plans must include measurable objectives for implementing the six stormwater control measures. Measurable objectives must include milestones and timelines. Timelines must reflect the deadlines in Table 13-11.

Deadlines for Fully Implementing Stormwater Control Measures

- Communities with a population of more than 10,000 people - by the end of their first five-year report.
- Communities that have 5,000 - 10,000 people - by the end of their second five-year report.
- Communities with a population under 5,000 people - no deadline unless specifically required.

Table 13-11. Stormwater Control Measures Implementation Schedule for non-permitted urban DMAs with populations of 5,000 or greater.

Stormwater Control Measures	Implementation Deadlines from TMDL Issuance Date	
	City Population	
	5,000 to 10,000	Greater than 10,000
1. Pollution Prevention and Good Housekeeping for Municipal Operations	3 years	18 months
2. Public Education and Outreach	3 years	18 months
3. Public Involvement and Participation	3 years	18 months
4. Illicit Discharge Detection and Elimination	4.5 years	3 years
5. Construction Site Runoff Control	9.5 years	4.5 years
6. Post-Construction Site Runoff for New Development and Redevelopment	9.5 years	4.5 years

Appendix F: Stormwater References and Resources contains a list of stormwater management resources to help DMAs develop TMDL implementation plans to address stormwater measures, including resources to assist DMAs in funding and developing post-construction stormwater ordinances and manuals. In addition, a number of cities and counties in the Willamette Basin have had similar stormwater management requirements based on their status as a MS4 permit holder and could be resources for communities when developing an Implementation plan.

Measurable objectives, milestones, and WQMP reporting requirements

Cities and counties identified in Appendix E: List of Designated Management Agencies and Responsible Persons as DMAs under this TMDL are responsible for either developing a new mercury TMDL implementation plan, or revising their existing mercury TMDL implementation plan to meet new load reductions required under this TMDL. These plans will describe the management strategies DMAs will take to control mercury, including developing and reporting on applicable measurable objectives and milestones. Cities and counties that have a publically accessible website must post their implementation plan to that website. Cities and counties that do not have a publically accessible website must work with DEQ to make their plans publically accessible.

Cities and counties will also take part in the Willamette Basin five-year review. For more information about five year reviews, see section 13.4.

13.3.1.12 Bureau of Land Management

The federal Bureau of Land Management is responsible for management and regulation of lands certain forest and range lands owned by the federal government. In western Oregon these are primarily forestlands. As a DMA in this TMDL, the BLM is required to develop and implement TMDL strategies and actions that address erosion and runoff.

The DEQ and BLM have a Memorandum of Understanding signed in 2017, which ensures water quality standards, TMDLs, and drinking water rules and regulations are met. The MOU also specifies that the BLM will implement site-specific best management practices as specified in management objectives, management direction, design features, and mitigation developed in Resource Management Plans and amendments, project-level plans, and Water Quality Restoration Plans to meet applicable water quality standards. Water Quality Restoration Plans are the BLM's implementation plan to meet TMDL requirements. Water Quality Restoration Plans exist for the following areas: Clackamas, Lower Willamette, Mid-Coast, Middle Willamette, Molalla, North, Santiam, Sandy, South Santiam, Tualatin, Upper Willamette, and Yamhill.

The MOU requires monitoring to ensure that practices are properly designed and applied, to determine the effectiveness of practices in meeting water quality standards, and to provide for adjustment of best management practices when it is found that water quality standards are not being protected.

Activities on BLM lands that contribute to sediment include transportation system management, recreation and forest management. Table 13-12 contains several examples of sediment, erosion and runoff control best management practices that address activities that occur on BLM lands. The BLM incorporates water quality management as part of project design. Additionally, BLM employs best management practices that are relevant to the action in order to meet water quality standards and TMDL load allocations. Best management practices are monitored for effectiveness following implementation. Appendix J of BLM's Resource Management Plan provides a list of typical best management practices that the BLM uses to manage water quality. The BLM also designs site-specific best management practices to address specific issues and conditions that have the potential to affect water quality. The BLM will evaluate the effects of their management at the scale of the Willamette Basin.

Table 13-12. Example List of BLM Management Strategies for Sediment/Mercury

Best Management Practices
Design stream crossings to minimize diversion potential in the event that the crossing is blocked by debris during storm events. This protection could include hardening crossings, armoring fills, dipping grades, oversizing culverts, hardening inlets and outlets, and lowering the fill height.
Disconnect road runoff to the stream channel by out sloping the road approach.
Suspend ground-disturbing activity if forecasted rain will saturate soils to the extent that there is potential for movement of sediment from the road to wetlands, floodplains, and waters of the State.
Road closure and decommissioning: After tilling the road surface, pull back unstable road fill and end-haul or contour to the natural slopes.
Place residual slash on severely burned areas, where there is potential for sediment delivery into waterbodies, floodplains and wetlands.
Emergency stabilization or rehabilitation BMPs related to wildfire
Water bar spacing requirements by percent gradient and erosion class
Implement erosion control measures at recreation sites to stabilize exposed soils where water flows or sediment, may reach waterbodies.
Locate new Off Highway Vehicle trails on stable locations (for example, ridge tops, benches, and gentle-to-moderate side slopes). Minimize trail construction on steep slopes where runoff could channel to a waterbody.
Use erosion-reduction practices, such as seeding, mulching, silt fences, and woody debris placement, to limit erosion and transport of sediment to streams from quarries.

Measurable objectives, milestones, and WQMP reporting requirements

BLM will continue to implement their best management practices program. In addition, BLM will also identify specific measurable objectives with milestones and associated implementation timelines for implementing best management practices that address runoff and erosion. Because stream crossings, road prism failures, and hydrologically-connected roads are known sources of sediment to waterbodies across land uses, DEQ expects to work with BLM to develop measurable objectives related to roads and a schedule for implementing these strategies following the issuance of the TMDL. Examples of such strategies include: inventorying hydrologically-connected roads and potentially unstable road prisms and at-risk stream crossings. Measurable objectives may also include an evaluation of hillslope erosion potential during tethered logging operations.

A rationale, which provides context for the measurable objectives and the metrics used for tracking measurable objectives, will be submitted to DEQ within 18 months of TMDL issuance. The measurable objectives and milestones will be included in revised Water Quality Restoration Plans based on either sixth field level watersheds (HUC12) or combined into one Water Quality Restoration Plan for the entire Willamette Basin. Water Quality Restoration Plan(s) must be made available on a publicly accessible website.

BLM will also take part in the Willamette Basin five year review. For more information about five year reviews, see section 13.4.

13.3.1.13 U.S. Forest Service

The United States Forest Service (within the US Department of Agriculture) is the federal agency tasked with the management and care of the National Forests and Grasslands. As a DMA in this TMDL, the USFS is required to develop and implement TMDL strategies and actions that address erosion and runoff.

A DEQ and USFS Memorandum of Understanding signed in 2014, identifies Water Quality Restoration Plans as the implementation planning document to meet USFS TMDL implementation plan requirements. The USFS submits these Water Quality Restoration Plans to DEQ for review and approval. The memorandum specifies that USFS will provide an annual status to DEQ on Water Quality Restoration Plans, including a five-year report on implementing each WQRP. The most recent publication date of the Willamette Basin Water Quality Restoration Plan is 2008.

The USFS relies on the following mechanisms to support TMDL implementation:

- Aquatic Conservation Strategy in the Northwest Forest Plan
- National Core BMP Technical and Monitoring guides. There is a summary of a two-year effort to demonstrate and document best management practices performance. The National BMP Program provides a nationally consistent, systematic, and objective approach to best management practices monitoring on USFS lands.
- The 2005 Travel Management Rule (36 CFR 212.5) directed all National Forests to identify the minimum road system needed for safe and efficient travel and for administration, utilization, and protection of National Forest System lands. The rule requires each National Forest to:
    - Identify the minimum road system needed for safe and efficient travel and for administration, utilization, and protection of national forest lands;
    - Identify the roads on lands under Forest Service jurisdiction that are no longer needed to meet forest resource management objectives;
    - Under separate actions, decommission or consider for other uses those roads identified as unneeded.

The Mt. Hood, Willamette and Umpqua National Forests completed Travel Analysis Plans for their respective road systems by September 30, 2015. These high-level plans provided a starting point for right sizing road systems, balancing public use, administrative use and resource protection. All subsequent planning on National Forest lands within the Willamette Basin tiers to these Travel Analysis Plans to inform and prioritize road maintenance, reconstruction, storage and decommission.

Table 13-13. Example List of USFS Management Strategies for Sediment/Mercury

Best Management Practices
Roads • Design or reconstruct stream crossings to minimize diversion potential in the event that the crossing is blocked by debris during storm events. This protection could

Best Management Practices
include hardening crossings, armoring fills, dipping grades, oversizing culverts and lowering the fill height. • Disconnect road runoff to the stream channel by either out sloping or adding additional drainage features to the road. • Road closure and decommissioning: depending on aquatic risk, treatment activities could range from water barring and berm closure, to removal of all fills/culverts to complete obliteration and re-contour.
Timber Harvest • To prevent sediment delivery to streams, prescribe adequate no-harvest buffers on both perennial and intermittent streams within treatment areas. • Suspend ground-based harvest activities during saturated soil conditions where there is potential for sediment delivery into waterbodies, floodplains and wetlands. • Dependent on road condition, suspend timber haul to prevent sediment delivery to waterbodies, floodplains and wetlands during wet weather.
Erosion Control Measures during Construction • Require a dewatering and erosion control plan for construction activities such as culvert replacement and aquatic restoration projects to prevent sedimentation to waterbodies, floodplains and wetlands to the greatest extent practicable.
Wildfire • Where there is potential for sediment delivery into waterbodies, floodplains and wetlands, obliterate (de-compact and re-contour) all direct and indirect dozer and hand lines constructed for emergency suppression after fire is controlled.

Measurable objectives, milestones, and WQMP reporting requirements

In addition to continued implementation of the strategies provided in Table 13-13, the USFS will identify specific measurable objectives with milestones and an associated implementation timeline for implementing best management practices that address runoff and erosion. Because stream crossings, road prism failures, and hydrologically-connected roads are known sources of sediment to waterbodies across land uses, DEQ expects to work with USFS to develop measurable objectives related to roads and a schedule for implementing these strategies following the issuance of the TMDL. Examples of such strategies include: inventorying hydrologically-connected roads and potentially unstable road prisms and at-risk stream crossings. Measurable objectives may also include an evaluation of hillslope erosion potential during tethered logging operations.

A rationale, which provides context for the measurable objectives and the metrics used for tracking measurable objectives, will be submitted to DEQ within 18 months of TMDL issuance. The measurable objectives and milestones will be included in revised Water Quality Restoration Plans based on either sixth field level watersheds (HUC12) or combined into one Water Quality Restoration Plan for the entire Willamette Basin. Water Quality Restoration Plans must be made available on a publicly accessible websites.

The USFS will also take part in the Willamette Basin five year review. For more information about five year reviews, see section 13.4.

13.3.1.14 U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service is an agency that manages fish, wildlife and natural habitats. In the Willamette Basin, the USFWS manages four wildlife refuges, including WL Finley National Wildlife Refuge near Corvallis, Ankeny Wildlife preserve near Ankeny Wildlife Refuge near Jefferson, Baskett Slough Wildlife Refuge near Dallas, and Tualatin River National Wildlife Refuge near Wilsonville. In addition to providing wildlife habitat, these areas are also managed for recreational activities including hunting, wildlife observation and hiking.

Measurable objectives, milestones, and WQMP reporting requirements

The USFWS will update their current implementation plan to include management strategies and actions that address mercury load reductions, including but not limited to those provided in Table 13-14. USFWS will implement these and other management strategies in order to ensure that USFWS, as well as all persons applying for, and holding authorizations to use, USFWS owned land are implementing best management practices that reduce runoff, sediment and erosion.

In addition, the USFWS implementation plan will include specific measurable objectives, milestones and timelines for management strategies that address runoff and soil erosion within 18 months of the issuance of this TMDL.

The USFWS will also take part in the Willamette Basin five year review. For more information about five year reviews, see section 13.4.

Table 13-14. Management Strategies that the U.S. Fish and Wildlife Service implements that reduce mercury loading to the Willamette Basin.

Management Strategies
Continually monitor trail systems; repair or re-route trails to reduce runoff and erosion.
Continue to require permittees with Agricultural Leases to apply best management practices to prevent and reduce runoff and erosion, including retaining 50 foot no-till buffers along fish-bearing streams, and maintaining ground cover during wet, winter months.
Reduce number of drain tile systems in former agriculture fields to promote infiltration of stormwater.
Monitor and assess how water is managed on the refuges through ditches, pumps, weirs, lakes, etc.
Continue to meet or exceed all Forest Practices Act rules during forestry operations. Implement riparian restoration projects, which help to filter and reduce sediment delivery to streams.
Use on-site stormwater retention in new park designs to infiltrate stormwater.

Special Districts

13.3.1.15 Metro (Portland Metropolitan Government)

Metro is the regional government for the Portland metropolitan area. Metro manages the solid waste program, regional parks and natural areas system, coordinates growth in the metro area, and oversees large facilities, such as the Oregon Zoo, Oregon Convention Center and the Portland Expo Center.

Metro is currently a DMA for a number of Willamette Basin TMDLs. Metro's activities include proposing bond measures to acquire natural areas. Parks and natural area levies allow for natural area restoration, such as tree and shrub planting, removal of invasive vegetation, and reconnecting rivers to their floodplains. Metro follows local MS4 permit requirements in construction and post construction for any new or redeveloped Metro projects.

Measurable objectives, milestones, and WQMP reporting requirements

As a DMA for the mercury TMDL, DEQ will work with Metro following the issuance of the TMDL to focus on stormwater control activities that will reduce erosion and runoff of stormwater from Metro properties. In addition, Metro will identify specific measurable objectives with milestones and associated implementation timeline for implementing best management practices that address runoff and erosion. An updated implementation plan will be due 18 months following the issuance of the TMDL. Metro must post their implementation plan on a publicly accessible website.

13.3.1.16 Port of Portland

The Port of Portland is a regional government with jurisdiction in Multnomah, Washington and Clackamas counties. Port of Portland property in the Lower Willamette Basin includes the Portland International and Hillsboro Airports, four marine terminals (Terminals 2, 4, 5 and 6), and the Swan Island, Rivergate, Portland International Center, and Cascade Station business and industrial parks. The Port also owns a number of undeveloped properties within the basin that include open space, mitigation areas, and industrial parcels for future development. Some of these properties are occupied by tenants, which have lease agreements with the Port.

The Port of Portland's MS4 permit can serve as the implementation plan for the mercury TMDL for the MS4 permit applicable service area. In addition, the Port of Portland will also implement, or continue to implement, management strategies to reduce runoff and erosion from Port of Portland properties that could discharge mercury in stormwater directly to waterbodies in the Willamette Basin, as well as discharges through MS4-permitted conveyances. The Port of Portland must update its TMDL implementation plan to ensure that management measures to reduce erosion and runoff directly to waterbodies are included in their suite of pollutant reduction programs. In addition, the Port of Portland must post its nonpoint source implementation plan to address areas not covered by their MS4 permit applicable service area on a publicly accessible website. Other NPDES permits held by the Port of Portland will be implemented according to requirements set forth in section 13.3.2.2.1.

13.3.1.17 Clean Water Services

Clean Water Services is a water resources management utility for residents living in the Tualatin Basin in Washington County. They manage four wastewater treatment plants and implement the MS4 stormwater permit for approximately 13 jurisdictions.

CWS's MS4 permit can serve as the implementation plan for the mercury TMDL for the MS4 permit applicable service area. In addition, CWS will also implement, or continue to implement, management strategies to reduce erosion and runoff within its stormwater service area that could discharge mercury in stormwater directly to waterbodies, in addition to discharges through MS4-permitted conveyances. CWS must update its TMDL Implementation plan to ensure that management measures to reduce erosion and runoff directly to waterbodies are included in their suite of pollutant reduction programs. In addition, CWS must post its nonpoint source

Implementation plan on a publicly accessible website. Other NPDES permits held by CWS will be implemented according to requirements set forth in section 13.3.2.2.1.

13.3.1.18 Tualatin Hills Park and Recreation District

Tualatin Hills Park and Recreation District is responsible for managing over 2,000 acres of land in Washington County. THPRD is a special park and recreation service district funded primarily by property taxes and program fees. Its service area spans the City of Beaverton and many unincorporated areas of eastern Washington County. The district has 27 miles of streams and three lakes within its boundaries.

Measurable objectives, milestones, and WQMP reporting requirements

THPRD will develop an Implementation plan that will include multiple management strategies and actions that address mercury load reductions, including but not limited to those provided in Table 13-15. THPRD will implement these and other management strategies in order to ensure that THPRD, as well as all persons applying for, and holding authorizations to use, THPRD owned land are implementing best management practices that reduce runoff, sediment and erosion.

In addition, THPRD will update their TMDL implementation plan to include specific measurable objectives, milestones and timelines for management strategies that address runoff and erosion within 18 months of the issuance of this TMDL.

Table 13-15. Management Strategies that THPRD implements that reduce mercury loading to the Willamette Basin.

Management Strategies
Continually monitor trail systems; repair or re-route trails to reduce runoff and erosion.
Continue to meet or exceed all Forest Practices Act rules during forestry operations.
Implement riparian restoration projects, which help to filter and reduce sediment delivery to streams.
Use on-site stormwater retention in new park designs to infiltrate stormwater.
Continue to provide education and outreach activities including promoting biking and walking to reduce air emissions.

13.3.1.19 Oak Lodge Water Services District

Oak Lodge Water Services District provides drinking water, wastewater, and watershed protection services in Oak Grove, Jennings Lodge, and portions of Milwaukie and Gladstone.

OLWSD's MS4 permit can serve as the implementation plan for the mercury TMDL for the MS4 permit applicable service area. In addition, OLWSD will also implement, or continue to implement, management strategies to reduce erosion and runoff from OLWSD properties that could discharge mercury in stormwater directly to waterbodies, in addition to discharges through MS4-permitted conveyances. OLWSD must update its TMDL implementation plan to ensure that management measures to reduce erosion and runoff directly to waterbodies are included in their suite of pollutant reduction programs. In addition, OLWSD must post its nonpoint source implementation plan on a publicly accessible website. Other NPDES permits held by OLWSD will be implemented according to requirements in section 13.3.2.2.1.

13.3.1.20 Responsible persons: Sector-specific Water Quality Management Plans

13.3.1.21 Water Delivery and Conveyance Systems

Irrigation districts, drainage districts, and other water delivery and conveyance systems influence the quantity and timing of sediment delivery to downstream river reaches. Return flows can enter waters of the state through ditches and pipes. Consequently, owners and operators of these systems are included as responsible persons in this WQMP because maintenance and management of these systems can impact sediment transport and erosion. Such systems are responsible only for sedimentation resulting from conveyance systems, not from upland agricultural activities.

Irrigated agriculture is the largest consumptive surface water use in the Willamette Basin, and the volume of water consumed is predicted to increase over the next 50 years. A USGS study found that more than 75 percent of water use in the Willamette Basin was derived from surface flow, and the largest single use was for irrigated agriculture. Growth in irrigation water rights leveled off in the 1990's (Jaeger, Plantinga, Langpap, Bigelow, & Moore, 2017), however the US Army Corps of Engineers recently projected irrigated acres on lands already in agricultural production to increase by more than 70,000 acres between 2020- 2070 within their study area (US Army Corps of Engineers, 2017). While irrigated agriculture continues to be an important and potentially growing demand, there remains a need to characterize the location and extent of irrigation systems in the basin, as well as the management practices used to maintain and operate these systems.

Drainage districts and systems exist primarily to manage stormwater drainage and flooding. Many of these districts were originally formed to help protect the land from flooding so that farming could occur year round. Presently, drainage districts that are registered with the state as special districts often have a tax base that comprise rural tracts of land, as well as commercial and residential properties and parks. Levees, pump stations, ditches, sloughs, streams and culverts are important components of a drainage system and must be continually maintained in order to protect the environment, property and safety.

Water conveyance systems, including those that are managed for irrigation and drainage, are currently regulated by multiple state and federal agencies, including Oregon Water Resources Department, DSL, USACE, and DEQ's 401 water quality certification program. For most waters, a DSL permit is required if a project will involve 50 cubic yards of fill and/ or removal within the ordinary high water line of a stream; this requirement also applies to some ditches. Projects that require a DSL removal-fill permit may also require a Clean Water Act Section 404 permit from the USACE. For these projects, a joint application form can be submitted to both agencies. Existing regulatory programs relevant to these activities are summarized in Table 13-16.

Implementing the requirements and conditions of these permits and Water Quality Certifications include best management practices that meet the TMDL requirements. For projects and activities that are exempt or not permitted by the agencies and programs shown in Table 13-16, owners and operators of water conveyance systems must implement similar best management practices to reduce sediment and erosion, in order to meet the TMDL requirements.

Table 13-16. Existing state and federal agencies and programs that regulate water conveyance systems

Agency	Program	Regulatory permit or certification
U.S. Army Corp of Engineers and U.S. Bureau of Reclamation	Willamette Valley Project	Water Service Contracts
DEQ	401 Program	Water Quality Certification
Department of State Lands	Waterways and Wetlands	Removal/ Fill Permit
Oregon Water Resources Department	Water Rights	Permits for withdrawal, storage, and use

Appendix E: List of Designated Management Agencies and Responsible Persons lists the water conveyance entities that DEQ has identified as responsible persons. Operation and maintenance of any hydro-modification system that discharges return flows to waters of the state has the potential to impact the timing and quantity of sediment delivery to streams, thus there remains a need to better characterize the geographic location and current operation and maintenance activities related to water conveyance entities in the Willamette Basin. This information will help DEQ and system owners and operators gain a better understanding of their potential impact on reducing sediment and erosion.

There may be additional water conveyance systems in the Willamette Basin that are not included in Appendix B due to limited availability of information about existing systems. However, all systems that have return flows or the potential to discharge to waters of the state should implement management measures to reduce sediment and erosion.

Measurable objectives, milestones, and WQMP reporting requirements

DEQ developed proposed milestones and timelines for working with owners and operators of water conveyance systems (Table 13-17). DEQ will collaborate with watershed partners including ODA and Oregon Water Resources Congress to conduct outreach and education to water conveyance entities over the next two years. DEQ will also work individually with owners and operators of water conveyance systems to gather information and better characterize their potential to discharge or have return flows to the Willamette Basin river network and determine what management and reporting strategies are relevant to their specific operations and maintenance activities.

DEQ expects Water Conveyance entities identified in Appendix E: List of Designated Management Agencies and Responsible Persons to work with DEQ as outlined in Table 13-17. Examples of the types of management strategies that responsible persons will be required to implement are shown in Table 13-18.

Table 13-17. Milestones and timelines for DEQ to work with water conveyance entities to plan and carry out implementation of the 2019 Willamette Basin Mercury TMDL

Strategy	Action	Milestone	Estimated Timeline
Conduct outreach and education to water conveyance systems in the Willamette Basin, specifically those identified in Appendix E of the 2019 Willamette Basin Mercury TMDL WQMP.	DEQ will work with Oregon Department of Agriculture, Oregon Department of State Lands, Oregon Water Resources Congress and other watershed partners to provide informational and educational opportunities relevant to the Willamette Basin Hg TMDL.	Individually contact Water Conveyance Entities identified in Appendix E of the Willamette Basin Hg TMDL WQMP using available contact information.	Initial contact completed by June 30, 2019.
		Provide at least one in-person informational meeting during the public comment period	Informational meeting will occur in 2019
Work directly with Water Conveyance Entities to better identify and characterize water conveyance systems identified in Appendix E of the 2019 Willamette Basin Mercury TMDL WQMP.	DEQ will work with water conveyance entities to characterize and document water conveyance systems for purpose of identifying relevant management strategies, and implementation tracking and reporting requirements.	Complete at least one in-person meeting after the public comment period.	Meeting to occur between December 1, 2019 and April 30, 2020.
Work directly with Water Conveyance Entities to develop implementation strategies, objectives, and timelines, and reporting requirements.	Finalize implementation strategies, objectives, timelines and reporting requirements.	Schedule implementation planning and development meetings.	Implementation planning and development meetings to occur between May 1, 2020 and September 30, 2021.
		Water Conveyance Entities will submit DEQ- requested information that is necessary to develop implementation, tracking and reporting strategies and requirements.	All information to be submitted according to schedule identified during one-on-one and/ or aggregate implementation planning and development meetings (see above).
		DEQ will finalize implementation, tracking and reporting requirements.	DEQ will finalize implementation, tracking and reporting requirements by December 31, 2021.

Table 13-18. Examples of Management Strategies that will be required of water conveyance entities named as responsible persons in the 2019 Willamette Basin Mercury TMDL WQMP

Water Quality Protection Management Strategies for Water Conveyance Entities
List of turbidity/sediment control best management practices for watercourse maintenance activities.
Maintain a list of construction or ditch maintenance activities that require state and/ or federal permits or ODFW approval.
Use streambank and/ or canal stabilization practices, including structural and non-structural best management practices.
Manage upland conveyance system infrastructure, for example, roads, pumps, etc. to prevent soil erosion, and sediment delivery to waterbodies.
Conduct education and outreach to water users and upland agricultural and urban land owners that discharge to system.
Monitor and evaluate best management practices and strategies.
Flow and drainage management to reduce erosion, and sediment delivery to streams.
Maintain a schedule for operation and maintenance activities.
Maintain a current map of system, including canals, ditches, pumps, weirs, etc.

13.3.1.22 Reservoir management

Impoundments create conditions where mercury methylation rates are higher than flowing stream segments. Higher methylation rates produce more bioavailable mercury for uptake by the reservoirs' biota resulting in higher fish tissue methylmercury concentrations. There is also potential for release of methylmercury from impoundments to lower stream segments.

According to the Oregon Department of Water Resources dam inventory, there are 414 dams in the Willamette Basin that can store at least 9.2 acre-ft. Included in the inventory are dams defined by OAR 690-020-0022(8):

> "Dam" means hydraulic structure built above the natural ground line that is used to impound water. Dams include all appurtenant structures, and together are sometimes referred to as "the works". Dams include wastewater lagoons and other hydraulic structures that store water, attenuate floods, and divert water into canals.

Collectively, Willamette Basin dams can store over 2.7 million acre-ft. Many of the dams are located in areas under the authority of various DMAs. Appendix E: List of Designated Management Agencies and Responsible Persons shows dams, owners and DMAs for the 124 dams storing at least 100 acre-ft, which is the smallest capacity of the dams owned by the four largest owners. All DMAs and responsible persons operating reservoir must be aware of factors contributing to increased reservoir methylation rates, which include water level fluctuations, thermal stratification and upland activities that may contribute elemental mercury to reservoirs. DMAs and responsible persons must also be familiar with the operations or conditions resulting in dam releases or discharges to surface water.

The U.S. Army Corps of Engineers, Portland General Electric, U.S. Bureau of Reclamation and Eugene Water and Electric Board are the four largest owners and operators of reservoirs in the

Willamette Basin, based on maximum storage volumes. Reservoir implementation requirements pertaining to for these four DMAs are specified below.

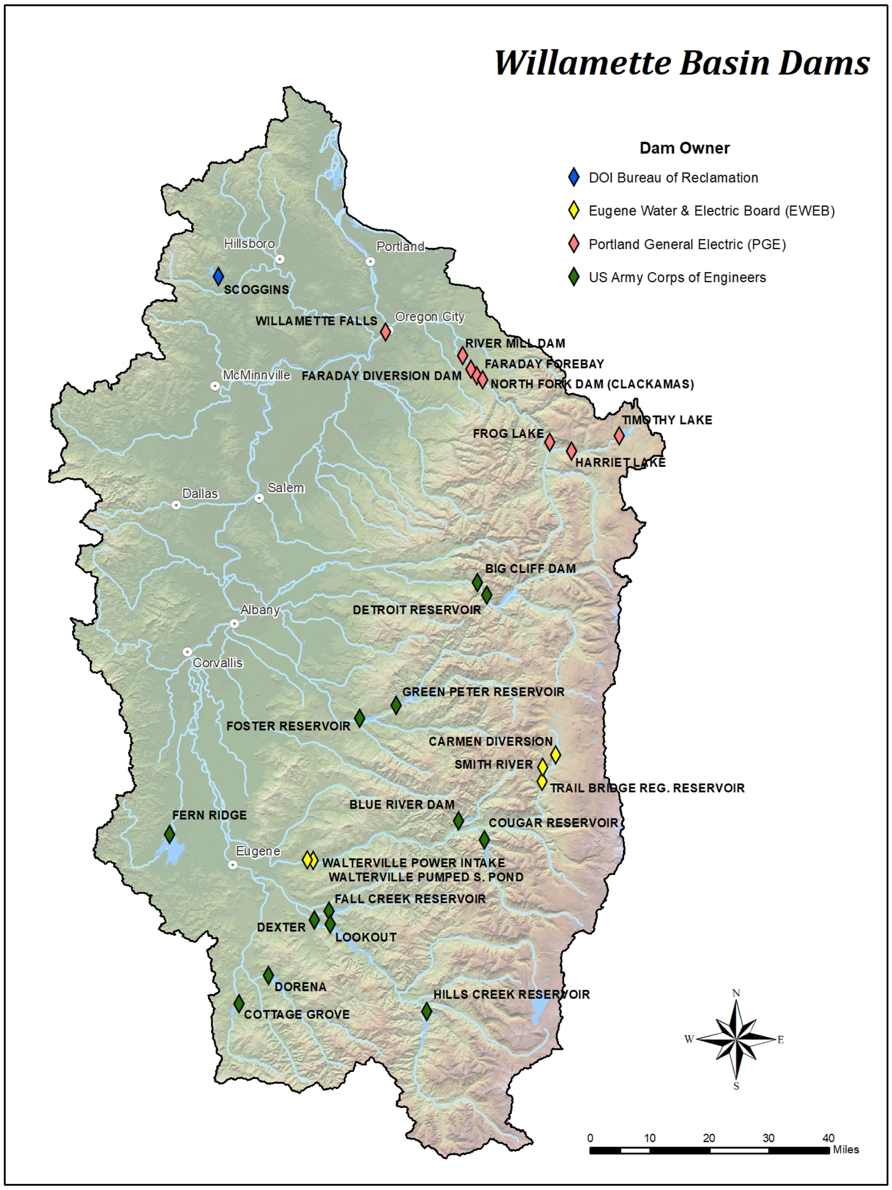

Figure 13-2. Map of Reservoirs Belonging to the Four Largest Owners in the Willamette Basin

Table 13-19. Example of Best Management Practices for Reservoirs

Best Management Practices
Oxidant addition to reservoir bottom waters
Hypolimnetic oxygenation systems
In-reservoir sediment removal or encapsulation
Artificial circulation
Reduction of average water level fluctuations
Vegetation management
Sediment amendment

Measurable objectives, milestones, and WQMP reporting requirements

USACE, PGE, USBOR and EWEB will assess factors affecting methylation rates in their reservoirs by evaluating DEQ specified metrics. These metrics include (1) a reservoir specific-mercury translator, which relates water column total mercury to dissolved methylmercury, like the translator used in the TMDL model, (2) nutrient status, (3) dissolved oxygen profile, (4) water level fluctuations and (5) area of reservoir-adjacent wetlands affected by water level fluctuations. This assessment step will establish baseline conditions for use in adaptive management and inform evaluations of site-specific approaches to reduce methylmercury production. The DMAs will also identify specific measurable objectives with milestones and associated implementation timeline for implementing best management practices that address methylation rates in their reservoirs.

A TMDL implementation plan must be submitted to DEQ within 18 months of TMDL issuance. The plan will describe the timeline for completing the assessment of factors affecting methylation rates, evaluation of site-specific best management practices for reducing methylation, and implementing best management practices to address methylation rates in their reservoirs. The plan will also include a rationale for identifying specific measurable objectives and any additional DMA determined metrics used for tracking measurable objectives. Development of implementation plan elements for the Cottage Grove Reservoir must be coordinated with EPA's Black Butte Mine Superfund Remedial Investigation and Feasibility Study.

The USACE, PGE, USBOR and EWEB will also take part in the Willamette Basin five year review. For more information about five year reviews, see section 13.4.

13.3.1.22.1 U.S. Army Corps of Engineers

Stream flow in the Willamette Basin is highly modified by dam and reservoir operations. The U.S. Congress passed 15 flood control acts between 1938 and 1974 that affect the Willamette Basin and are implemented by USACE. The 13 USACE dams comprise 91 percent of the total dam storage capacity in the basin. These dams provide flood control, navigation, hydroelectric power, and water in summer for irrigation, recreation, and downstream water quality. Dam operations have dramatically changed the natural flow patterns of the Willamette River by reducing peak flows in winter and artificially augmenting summer low flows.

13.3.1.22.2 U.S. Bureau of Reclamation

USBOR operates Scoggins Dam, which impounds Scoggins Creek forming Hagg Lake in the Tualatin sub-basin. Hagg Lake comprises approximately 2 percent of the total dam storage capacity in the Willamette Basin.

13.3.1.22.3 Eugene Water and Electric Board

EWEB is Oregon's largest customer-owned public utility providing electricity and water to Eugene and portions of East Springfield and the McKenzie River Valley. EWEB owns and operates Carmen Diversion, Smith River, Trail Bridge Reservoir, Leaburg Dam and Waterville in the Upper McKenzie sub-basin. These five dams comprise approximately 0.6 percent of the total dam storage capacity in the Willamette Basin.

The Leaburg-Walterville Hydroelectric Project is comprised of two run-of-the-river dams on the McKenzie River. The Leaburg Dam impounds and diverts the McKenzie River through the Leaburg Canal to the Leaburg power plant. Flow from the Leaburg power plant returns to the McKenzie River. The impoundment forms the Leaburg Reservoir.

13.3.1.22.4 Portland General Electric

PGE provides electricity to Portland, Salem and the surrounding areas. PGE owns and operates Timothy Lake, North Fork Dam, River Mill Dam, Faraday Forebay, Faraday Diversion Dam, Frog Lake and Harriet Lake. These seven dams comprise approximately 5 percent of the total dam storage capacity in the Willamette Basin.

13.3.2 Management strategies for point sources

As required in OAR 340-042-0040(4)(I)(E), the following section describes management strategies for point sources. As noted in this TMDL, point source wasteload allocations are applied as percent reductions aggregated across two sectors – permitted wastewater discharges and permitted stormwater discharges. Wasteload allocations are assigned to the permitted source sectors, not to specific dischargers. DEQ determined that the most effective way to optimize mercury reductions is to apply mercury and erosion minimization and control measures that are appropriate for each sector, facility, land use, or activity. Reasonable assurance that point source wasteload allocations will be met is addressed through the issuance or revision of National Pollutant Discharge Elimination System permits.

13.3.2.1 NPDES Wastewater Permits

As described in Section 10, the wastewater sector wasteload allocation is a 10 percent reduction from estimated existing mercury loads discharged under all wastewater permits. Permit categories under the aggregate 10 percent reduction wasteload allocation include: major and minor domestic sewage treatment plant permits; major and minor industrial wastewater permits; and wastewater discharges covered under non-stormwater general permits.

13.3.2.1.1 Domestic Sewage Treatment Plant Wastewater Permits

Major sewage treatment plant facilities

Major sewage treatment plant facilities are facilities with discharges greater than 1 million gallons per day, populations greater than 10,000 or with pretreatment programs classified as "major" and are listed in Table 9-4 in Section 9 on source assessment. For these major STP facilities, consideration of permit renewal will include enforceable conditions for monitoring and reporting of total mercury and development and implementation of mercury minimization programs, in accordance with the most recent version of DEQ's Internal Management Directive on Implementation of Methylmercury Criterion in NPDES Permits, 2013. Required elements include:

- Identification of potential sources of mercury in discharge;
- Implementation and tracking of source reduction activities;
- Monitoring to document effectiveness; and
- Reporting.

As part of the Accountability Framework described in Section 14.1, reporting from major STPs will be tracked and evaluated for progress toward the 10 percent overall wastewater sector reduction of approximately 0.44 g/day or 0.16 kg/yr.

Minor sewage treatment plant facilities

Within the Willamette Basin, estimated total discharge flows from all minor STPs are less than 10 percent of the total discharge flows from all major STPs. In the TMDL Technical Support Document (TetraTech, 2019), the total mercury load from all minor STPs was estimated at 0.095 kilograms/year, or essentially 0 percent of the total mercury load in the basin. DEQ determined that the potential mercury load from minor STP discharges is an insignificant contribution to the estimated 0.8 percent of total mercury load from all STPs within the basin. Therefore, no additional controls or monitoring will be required from minor STPs toward achieving the 10 percent overall wastewater sector reduction of 0.44 g/day or 0.16 kg/yr. As minors qualify to become majors, permit requirements will reflect those described above for major STPs.

13.3.2.1.2 Industrial and General Wastewater Permits

As described in the TMDL Technical Support Document (TetraTech, 2019), the following NPDES permitted industrial activity categories have the potential to include mercury in their process operations:

- timber products;
- paper products;
- chemical products;
- glass/clay/cement/concrete/gypsum products;
- primary metal industries;
- fabricated metal products;
- electronics and instruments.

Permits for facilities that do not include process wastewater discharges of any of the categories of activities in the list above will not include requirements specific to achieving a portion of the aggregated sector-specific 10 percent reduction wasteload allocation.

Major and minor industrial

DEQ evaluated whether the existing eight major (as determined using EPA Industrial Classification worksheet) and 57 minor industrial wastewater permits in the Willamette Basin discharge process wastewater from any of the above categories of activities. DEQ determined that there are seven major industrial discharges with active permits, and 15 minor facilities that fall into SIC code categories with activities that have the potential to increase mercury in process wastewater discharge (see Table 9-5. below). DEQ will confirm these determinations during renewal of each permit. For confirmed facilities, DEQ will evaluate existing data to determine the significance of mercury loads in discharges. DEQ will also consider the potential for measurable reductions toward the 10 percent sector aggregate wasteload allocation in making a determination as to whether development and implementation of a mercury minimization plan is warranted for the facility. Depending on mercury and flow data availability and quality, permits will include, either:

1. If sufficient mercury and flow data exists, enforceable conditions for monitoring and reporting of influent and effluent total mercury and, if determined to be warranted, development and implementation of a mercury minimization plan, in accordance with the most recent version of DEQ's Internal Management Directive on Implementation of Methylmercury Criterion in NPDES Permits, 2013. Required elements include:
    - Identification of potential sources of mercury in discharge;
    - Implementation and tracking of source reduction activities;
    - Monitoring to document effectiveness; and
    - Reporting.
2. If there is insufficient mercury and flow data, enforceable conditions on influent and effluent monitoring and reporting of total mercury and discharge flows. After two years of data collection, effluent mercury and total suspended solids concentrations and discharge flows will be evaluated to determine estimated mercury load discharged, to determine whether development and implementation of a mercury minimization plan is warranted for the facility.

Mercury influent data will also be evaluated in comparison to effluent to inform decisions regarding the need for mercury minimization plans and the potential for intake credits (described in section 13.3.2.1.3).

As part of the Accountability Framework described in Section 14.1, reporting from these industrial facilities will be tracked and evaluated for progress toward the 10 percent overall wastewater sector reduction of approximately 0.44 g/day or 0.16 kg/yr.

General wastewater

With the exception of the 700PM general permit for suction dredge mining, DEQ determined that all categories of the 158 entities currently issued general wastewater permits (36 cooling water, 24 filter backwash, 4 fish hatcheries, 4 boiler blowdown, 9 petroleum hydrocarbon cleanup, 21 wash water, 60 pesticide application) have little to no potential for mercury to be increased in permitted discharges. In addition, flow volumes are insignificant as contributors to the estimated 0.3 percent total load of mercury from industrial discharges into Willamette basin streams. Therefore, no permit requirements are necessary specific to achieving a portion of the aggregated sector-specific 10 percent reduction wasteload allocation.

Discharge flows from suction dredges permitted under the 700PM generally are also insignificant. However, as noted in Section 9.4.1, when operated in areas of historical mercury contamination, studies in Oregon, California, Nevada, Wisconsin and Florida have shown that significant levels of mercury can be disturbed, mobilized and methylated by suction dredging.

The high potential for high concentrations of mercury to be released and converted in this specific subbasin constitutes a significant mercury load. Therefore, upon renewal of the 700PM permit, DEQ will prohibit dredging locations in streams that flow from the former Bohemia Mining District and are tributary to the Dorena Reservoir (including Row River, Brice Creek, Sharps Creek and Champion Creek).

Reductions from ceasing these discharges are expected to contribute to the 10 percent overall wastewater wasteload allocation of approximately 0.44 g/day or 0.16 kg/yr, but will be locally effective in Dorena Reservoir and its tributaries. This small portion of the wasteload allocation will be evaluated as part of the Monitoring Framework, being developed by DEQ and EPA.

13.3.2.1.3 Additional NPDES wastewater permit implementation tools

Variances

If the wasteload allocation results in an unattainable effluent limit for a facility, and treatment options to achieve the effluent limit are not technically, economically or otherwise feasible, the facility has the option of applying to DEQ for a variance in accordance with the variance rule (OAR 340-041-0059). In addition, the Environmental Quality Commission is considering a proposed multiple discharger variance for mercury in the Willamette Basin. If a variance is authorized and applied for, DEQ will incorporate conditions of the variance in the facility's permit consistent with federal and state requirements.

Mercury in intake water

OAR 340-045-0105 specifies the process for intake credits. For some facilities, the only source of mercury in a discharge may be mercury in the intake water drawn directly from the same body of water to which the facility discharges. When intake credits are allowed under the rule, DEQ may reasonably conclude that there is no contribution to an exceedance of the water quality standard. In those instances, DEQ may conclude compliance with the aggregate sector waste load allocation is achieved.

13.3.2.2 NPDES Stormwater Permits

The permitted stormwater sector wasteload allocation is a 75 percent reduction from estimated existing mercury loads discharged under all stormwater permits. As noted in the TMDL and TMDL Technical Support Document (TetraTech, 2019), atmospheric deposition is the major source of mercury. Once mercury is deposited on the landscape it can be eroded and/or transported in stormwater to rivers, streams and other waterbodies.

Permittees will be responsible for applying controls to prevent mercury discharges from within their jurisdictions in light of these mixed sources and delivery mechanisms of mercury. Controls cannot accurately distinguish or specifically target sources, thus DEQ acknowledges that some portion of background sources will be captured by permittee implemented controls and that some portion of sources will remain uncontrolled. The goal is to show achievement of measureable objectives within each jurisdiction toward a 75 percent reduction as an overall sector. Permit categories under the 75 percent reduction wasteload allocation include: MS4 Phase I; MS4 Phase II; 1200-A; 1200-Z; and1200-C/CN/CA.

13.3.2.2.1 Municipal Separate Stormwater Sewer System

As noted in Section 9.4.2, coverage is required for 47 entities under Phase I and Phase II MS4 permits within the Willamette Basin, as listed in Table 9-6.

MS4 Phase I

Upon permit renewal, each MS4 Phase I permit will include the following requirements:

- Develop and submit a mercury minimization section within the Stormwater Management strategy with the second annual report of the renewed permit term, that includes:
    - Evaluation of current actions and their relative effectiveness of reducing the amount of solids discharged into the MS4 system (similar to the actions currently required in Schedule A of the permits); and
    - An effectiveness monitoring strategy to inform implementation of future control measures.
- Continued implementation of the actions described in the stormwater management plan that are effective for mercury reduction, along with documentation in each subsequent annual report (beginning with the third year annual report) of implementation progress.
- An analysis of the effectiveness of the actions taken and qualitative pollutant load reductions achieved in the fourth annual report. Due to data limitations, mercury benchmarks are not applicable in the first permit cycle after the TMDL is finalized.
- Collection of paired total mercury and total suspended solids samples.
- Submittal of monitoring data in the appropriate DEQ data submission template, pollutant load reduction evaluation and wasteload allocation attainment analysis.

MS4 Phase II

DEQ's MS4 Phase II general permit became effective in March 2019. The permit includes requirements for controlling erosion and other pollutants associated with solids entrained in stormwater. Therefore, the jurisdictions covered under the Phase II general permit will not be required to implement any additional control measures toward achieving the 75 percent reduction sector wasteload allocation during the permit term.

For Phase II jurisdictions covered under an individual permit, upon renewal each permit will include, at minimum, the conditions in the MS4 Phase II general permit effective at the time regarding construction and post-construction requirements or requirement to develop, submit and implement a mercury minimization plan with the goal of demonstrating achievement of objectives toward attaining the 75 percent overall sector reduction. The plan must include:

- A description of both structural and non-structural control measures the permittee intends to implement;
- An evaluation of current structural and non-structural control measures and their relative effectiveness;

A control measure effectiveness monitoring strategy to inform implementation of future control measures.

As part of the Accountability Framework described in Section 14.1, reporting from these MS4 Phase I and II jurisdictions will be tracked and evaluated for progress toward the 75 percent overall stormwater sector reduction of approximately 8.48 g/day or 3.10 kg/yr. DEQ will use information from the first permit cycle following issuance of the TMDL to determine future permit requirements needed, if any, to adaptively manage mercury reduction achievement.

13.3.2.2.2 Stormwater General Permits (1200-A, 1200-Z and 1200-C/CN/CA)

Most of the general stormwater permitted sites are located within MS4-permitted and non-permitted urban areas. In the Willamette Basin, these include approximately: 109 registrants under the 1200-A for non-metallic mining and asphalt and concrete plants; 629 registrants under the 1200-Z for industrial facilities; and approximately 1,000 short term registrants under the 1200-C/CN/CA for stormwater control during construction activities.

As noted in the TMDL and Technical Support Document (TetraTech, 2019), mercury loads from general stormwater permits (1200-A, 1200-Z, and 1200-C/CN/CA) were implicit in the modeled MS4-permitted mercury load estimates. There are several existing requirements and planned revisions for these permits that DEQ expects will result in reduction of mercury loads contributing toward the achievement of the overall stormwater sector wasteload allocation of 75 percent reduction.

The NPDES 1200-Z Industrial General Stormwater Permit was re-issued in 2017 and updated in 2018. The 1200-Z permit includes a reduced benchmark for total suspended solids for discharges into the geographic regions of the Portland Harbor (approximately the lowest 10 miles of the Willamette River) and the Columbia Slough. These are the most densely industrialized areas of the Willamette Basin and, according to the TMDL modeling, represent key areas for mercury load reductions from stormwater (TetraTech, 2019). The total suspended solids benchmark for discharges to these areas was set at 30 mg/L, reduced from 100 mg/L for discharges into Portland Harbor and from 50 mg/L in the Columbia Slough. In part, the reduced benchmark targets reduction of toxic substances (including mercury) that are associated with solids in stormwater and wastewater discharges. Upon renewal, it is expected that the 1200-A permit will also include the 30 mg/L total suspended solids benchmark in these two key geographic areas. Implementation of the lowered total suspended solids benchmark in these permits, as well as prohibitions on turbid discharge in the widespread, but temporary 1200-C/CN/CA permits, is anticipated to enhance reduction of mercury loads toward achievement of the overall stormwater sector wasteload allocation of 75 percent reduction. As a result, mercury reductions achieved through current and future general stormwater permit requirements for permitted activities conducted within the MS4-permitted jurisdictions will contribute to the aggregate stormwater sector reductions needed to achieve the wasteload allocation.

13.3.3 Other DEQ Mercury Reduction Programs

13.3.3.1 Regulatory Programs

Air Emissions Mercury Reductions

DEQ achieves mercury reductions from air emissions through implementation of federal Title V permits, state Air Contaminant Discharge permits and the newly adopted state Cleaner Air Oregon program.

Environmental Cleanup Program

DEQ requires responsible parties to remediate contaminated land, groundwater and stream sediment as authorized by OAR 340-122-0070. DEQ Cleanup Program activities related to mercury are focused on abandoned mines in the state and responding with EPA to mercury spills. The Black Butte Mine site, which is a significant source of mercury to the Cottage Grove

Reservoir, is an EPA Superfund site where cleanup actions were implemented in 2018 to address this source.

State Legislation on Mercury in Products

With regard to preventing mercury pollution, the Oregon Legislature adopted several bans, restrictions or management requirements for mercury in products since the 1990s. Those products include:

- Lighting fixtures
- Novelty items
- Thermostats, and
- Vehicle switches

In addition, the 2007 Legislature required dental offices to install dental amalgam separators and related maintenance best management practices to ensure mercury-containing amalgam waste does not end up in wastewater systems.

13.3.3.2 Voluntary programs

Household and small business mercury waste collection activities

DEQ's Solid and Hazardous Waste programs have initiated and implemented multiple specialized collection and exchange projects for mercury-containing products, including collecting mercury wastes at numerous one-day household hazardous waste collection events throughout Oregon. For more information about household hazardous waste events visit DEQ's website: https://www.oregon.gov/deq/Hazards-and-Cleanup/hw/Pages/hhw.aspx.

- **Thermometers** – A thermometer exchange program was initiated to reduce the amount of mercury in homes and ensure proper disposal of mercury thermometers. DEQ provides free digital thermometers at collection events to citizens turning in a mercury containing thermometer. DEQ also supplies local governments with free digital thermometers to encourage them to implement their own exchange programs. Currently, DEQ averages approximately one digital thermometer exchange for every 50 participants.
- **Thermostats** – The Thermostat Recycling Incentive project was initiated by DEQ, Portland General Electric, the Thermostat Recycling Corporation and the Product Stewardship Institute to encourage recycling of mercury containing thermostats. Between 2006 and 2007, contactors participating in the program received $4 rebate coupons for each mercury-containing thermostat they returned to a participating wholesaler for recycling. The coupons could be used toward the purchase of mercury-free Energy Star ® qualified thermostats. From 2010 to 2013, DEQ covered the $25 registration cost for contractors and local governments to receive a Thermostat Recycling Corporation collection bin.
- **Dairy Manometers** – DEQ worked with dairy and agricultural organizations in 2005 and 2006 to replace mercury manometers (pressure-measuring devices) used in dairy farm milking operations with mercury-free digital vacuum gauges. The mercury-containing manometers were managed and disposed of properly by DEQ's hazardous waste contractor. An EPA grant provided $300 to each participant to cover most of the costs associated with supplying and installing the mercury-free replacement pressure-measuring device.

- **Dental Mercury Wastes** – DEQ has been working with the Oregon Dental Association and the Oregon Association of Clean Water Agencies since 2003 to improve the management of mercury-containing wastes, such as dental amalgam. The partners sponsor an annual mercury waste collection event held in conjunction with the annual dental association conference. DEQ's Solid Waste program funded the collection and disposal of the waste in collaboration with local household hazardous waste programs.
- **Mercury Auto Switches** – The Northwest Auto Trades Association, the Oregon Environmental Council, local governments, and DEQ began a program in 2001 to replace mercury-containing automotive light switches in consumer automobiles with mercury-free ball-bearing switches free of charge. Eligible cars were 2002 and older. DEQ's Hazardous Waste program also developed and distributed a fact sheet on mercury switch removal for automobile dismantlers in Oregon.
- **Suction Dredge Mining Waste Mercury** – DEQ worked with a hobby mining association in 2002 and 2003 on various activities including sponsoring two mercury waste collection events in Myrtle Creek.
- **Fluorescent Lamps** – Fluorescent light tubes and compact fluorescent bulbs can be taken to a household hazardous waste collection event or facility. For more information about collection events visit DEQ's website: https://www.oregon.gov/deq/Hazards-and-Cleanup/hw/Pages/Mercury-Disposal.aspx

Household and small business mercury education and reporting activities

DEQ's Solid and Hazardous Waste programs continue to partner with various organizations, local governments and non-profits to educate households and businesses about proper management of mercury-containing products and alternatives. DEQ also initiated an effort to collect better data on mercury waste generated by businesses. Specific activities implemented between 2002 and 2006 include the following:

- **Educational materials** – DEQ developed educational fact sheets on the proper management of mercury-containing products and wastes, including cleaning up mercury spills.
- **Dental offices** – At the Oregon Dental Association's annual conference DEQ staff assist with educational outreach to participating dentists. In addition, DEQ developed a simplified tax credit application and fact sheet for dentists installing amalgam separators.
- **Fluorescent lamps** – The Hazardous Waste program participated in several lighting fairs sponsored by electric utilities to provide educational information on proper disposal of mercury-containing fluorescent lamps. In addition, DEQ worked with the Oregon Environmental Council to develop a lamp fact sheet for property management companies.
- **Suction dredge miners** – DEQ developed printed educational information for miners on proper mercury management
- **Reporting on mercury containing hazardous waste** –DEQ's hazardous waste generation annual reporting form was modified to request specific information on the generation and management of mercury containing wastes from businesses and other entities required to submit these reporting forms.

13.4. Timeline for implementing management strategies

The purpose of this element of the WQMP, required by OAR 340-042-0040(4)(l)(D), is to demonstrate a strategy for implementing and maintaining the implementation plan, and to evaluate water quality improvements over time. Included in this section are timelines for TMDL implementation activities for nonpoint sources and point sources.

13.4.1 Nonpoint Source DMAs and responsible persons

Each nonpoint source DMA and responsible person will submit a TMDL implementation plan that includes timelines for implementation of the measurable objectives and milestones described in section 13.3.1. Timelines will be specific wherever possible and will include a schedule for implementation and evaluation of strategies, and reporting dates and milestones for evaluating progress. TMDL implementation plans must be submitted to DEQ for approval within 18 months of the issuance of the TMDL, or earlier if desired (for example, DMA's may wish to have their plans coincide with already established deadlines for annual reports). DMAs should work with DEQ basin coordinators on specific submission requirements.

Adaptive management is a central element of individual implementation plans, this WQMP, and the TMDL. As part of adaptive management, DEQ intends to regularly review the progress of implementation plans. Through ongoing monitoring and evaluation, DEQ, DMAs and responsible persons can learn from experience and modify policy and implementation approaches in order to achieve better environmental outcomes.

Annual reports

Cities and counties that have been named DMAs in this WQMP will have annual reporting requirements. DMAs will report on progress in implementing nonpoint source strategies identified in the TMDL implementation plans, including any delays or challenges DMAs had in implementing strategies. DMAs may combine reporting for mercury along with other Willamette Basin TMDL pollutants. Annual reports must be posted on a publicly accessible website unless a DMA does not have a website.

Responsible persons and DMAs (which include special districts, and local, state and federal agencies) will report on implementation progress of nonpoint source strategies, which may include annual reports. Implementation strategies will be identified in TMDL implementation plans, as described in an existing Memorandum of Understanding or Memorandum of Agreement, or as directed by DEQ.

Willamette Basin TMDL Five Year Review

The 2006 Willamette Basin TMDL required the development and submission of TMDL implementation plans with annual reporting to DEQ. The 2006 TMDL also required DMAs and responsible persons to submit a report every five years to assess effectiveness of the management strategies identified in implementation plans and emplaced during the preceding four years. As part of the five year review, DEQ evaluates the number of implementation plans and annual reports submitted by DMAs and responsible persons, and the adequacy of the strategies contained in those plans to reduce pollutant inputs and restore water quality. These reviews have provided valuable feedback to the agency on successes and challenges DMAs experience in implementing their nonpoint source program. For this reason, DEQ will continue to require all nonpoint source DMAs and responsible persons, unless otherwise notified by DEQ, to include progress in implementation of mercury reduction strategies with their five year report as described in this WQMP.

Willamette Basin five year reviews occurred in 2013 and 2018, and the Molalla-Pudding five year review occurred in 2015. The next five-year reviews for the Molalla-Pudding and the Willamette Basin TMDLs are planned to occur in 2021 and 2023, respectively. DEQ expects that management strategies related to mercury will be included in the Willamette Basin 2023 five year review, even though four complete years of mercury implementation based on the updated WQMP will not have occurred by then. The objective of this timeline is to retain a consistent five-year reporting cycle for current and future Willamette Basin TMDLs. DEQ will post five year review reports to its website.

In the five year reviews, DMAs and responsible persons must address progress in implementing mercury reduction strategies, in addition to other nonpoint source pollutants established under previous Willamette TMDLs for which they were named as DMAs or responsible persons. Details of this submittal will be provided by DEQ to DMAs and responsible persons in advance of the deadline for these reports. Entities such as state and federal agencies with a Memorandum of Understanding or Memorandum of Agreement with DEQ may have different or additional reporting requirements.

During the five year review, DMAs must review their implementation plans in collaboration with DEQ staff to evaluate whether strategies, timelines, milestones, or other components of the plan should be updated for the next five years. DMAs and responsible persons may also update implementation plans more often than every five years due to significant changes in TMDL pollutant reduction strategies or program priorities.

13.4.2 Point sources

Provisions to address the appropriate point source wasteload allocations will be incorporated into National Pollutant Discharge Elimination System permits when permits are renewed by DEQ. A schedule for meeting the requirements associated with this TMDL will be incorporated into the permit. Like other permit conditions, compliance with the terms and conditions of the permit is required by state and federal law. NPDES permittees will implement the permit renewal requirements described in Section 13.3.2.

Table 13-20. The timeline for activities related to this WQMP and associated DMA and responsible person Implementation plans, and NPDES permits.

Activity	Year of Activity				
	2019	2020	2021	2022	2023
DEQ modification of affected NPDES Wastewater and Stormwater Permits	Upon permit renewal				
Ongoing implementation of DEQ- approved plans that DMAs and responsible persons already have in place	X	X			
Designated Management Agencies and responsible persons (see Appendix E of WQMP) develop and/ or update, and submit implementation plans within 18 months of TMDL issuance		X	X		

Activity	Year of Activity				
	2019	2020	2021	2022	2023
Implementation of new, updated or revised DMA and responsible person implementation plans			X	X	X
DMA and responsible person submittal of annual reports	X	X	X	X	X
DEQ, DMA and responsible person five year review of implementation					X

13.5. Timeline for attainment of water quality standards

This WQMP component is required by OAR 340-042-0040(4)(l)(F). The timeline for attainment of water quality standards for this TMDL is expected to take multiple decades. The primary source of mercury in the basin is air deposition, and while efforts to reduce emissions in North America are ongoing, continued air emissions from global sources may offset these efforts. Other sources of mercury are varied and include buffering and re-release of mercury from the ocean, re-suspension of sediment-bound mercury in waterbodies, and changes in total mercury in groundwater. These legacy mercury deposits will take years to diminish.

Nonpoint sources of mercury contribute more mercury to the basin relative to point sources. Therefore, it is especially important for this TMDL for nonpoint sources to make timely progress toward meeting the TMDL load allocations. DEQ expects nonpoint source DMAs and responsible persons to meet the interim milestones for percent reductions (Table 13-21). If interim milestones are not met, DEQ may require DMAs and responsible persons to revise their implementation plans and implementation timelines accordingly (OAR 340-042-0080(4)(b)).

If DEQ determines that private forest operations regulated under the Forest Practices Act are not making satisfactory progress toward meeting milestones or achieving load allocations, or if DEQ determines that the general Forest Practices Act rules are not sufficient for meeting allocations, site specific rules under the Forest Practices Act rules will need to be created or revised. If the site specific rules are not implemented, DEQ will request the Environmental Quality Commission to petition the Board of Forestry to make necessary changes (OAR 340-042-0080(2)).

If DEQ determines that agricultural practices subject to the Agricultural Water Quality Management Act are not making satisfactory progress toward meeting milestones or achieving load allocations, or if the area plan and rules are not adequate to ensure implementation of the load allocation, the department will provide Oregon Department of Agriculture with comments on what would be sufficient to meet TMDL load allocations during each biennial review process. Should that effort not be sufficient DEQ will request the Environmental Quality Commission to petition ODA to make the necessary changes (OAR 340-042-0080(3)).

Table 13-21. Timeline for reaching interim milestones for the general nonpoint source 88 percent reduction in instream mercury levels. Assessment of progress will be supported by water quality monitoring conducted by DEQ and watershed partners.

Assessment Year	Cumulative Percent Reduction Milestones for Instream Mercury
2028	30
2038	60
2048	88

13.6. Monitoring and evaluation

As required in OAR 340-042-0040(4)(l)(K), this section describes DEQ's plan to monitor and evaluate progress toward achieving TMDL allocations and water quality standards.

Accountability and evaluation has two basic components: 1) tracking the implementation of DMA-specific water quality implementation plans identified in this document and 2) monitoring the physical, chemical and biological parameters for water quality. Monitoring will provide a check on the progress being made toward achieving the TMDL allocations and meeting water quality standards, and will be used as part of the Adaptive Management process (Figure 13-1) The estimated timeline for achieving water quality standards is multiple decades.

The objectives of this monitoring effort are to demonstrate long-term recovery, better understand natural variability, and track implementation of projects and best management practices, and track effectiveness of TMDL implementation. This monitoring and feedback mechanism is a major component of the "reasonable assurance of implementation" for the Willamette Basin WQMP.

DMA-specific implementation plans will be tracked by accounting for the numbers, types and locations of projects, best management practices, education activities, or other actions taken to improve or protect water quality. The mechanism for tracking DMA and responsible person implementation efforts will be annual reports to be submitted to DEQ.

The information generated by each of the agencies or entities gathering data in the Willamette Basin will be pooled and used to determine whether management actions are having the desired effects or if changes in management actions and/ or TMDLs are needed. This detailed evaluation will typically occur on a five year cycle. If progress is not occurring, then the appropriate DMA or responsible person will be contacted with a request for action.

DEQ and EPA are currently developing an *Assessment and Monitoring Strategy to Support Implementation of Mercury Total Maximum Daily Loads for the Willamette Basin*. This monitoring strategy will be used to evaluate effectiveness of DMA and responsible person implementation strategies at meeting allocations and may require certain DMAs to collect data. The monitoring strategy will also be used to determine progress in the Willamette River and its tributaries toward meeting the total mercury loading capacity of 0.14 ng/L, methylmercury fish tissue criteria of 0.04 mg/kg, and instream total suspended solid surrogate allocations. DEQ will finalize this monitoring strategy after the issuance of the TMDL.

13.7. Costs and funding

This section provides a general discussion of costs and funding for implementing management strategies as required by Oregon Administrative Rule 340-042-0040(4)(l)(N). Please note that sector-specific or source-specific implementation plans may provide more detailed analyses of costs and funding for specific management strategies.

Designated Management Agencies will be expected to provide a fiscal analysis of the resources needed to develop, execute and maintain the programs described in their Implementation plans. The purpose of this element is to describe estimated costs and demonstrate there is sufficient funding available to begin implementation of the WQMP. Another purpose is to identify potential future funding sources for project implementation.

Funding is essential to implementing projects associated with this WQMP. There are many sources of local, state, and federal funds. Table 13-22 provides a partial list of funding and assistance programs available in the Willamette Basin.

Table 13-22. Partial list of funding programs available in the Willamette Basin that may be used to support planning and implementation activities that benefit water quality

Program	General Description	Contact
Clean Water State Revolving Fund	Loan program for below-market rate loans for planning, design, and construction of various water pollution control activities.	DEQ
Conservation Reserve Enhancement Program (CREP)	Provides annual rent to landowners who enroll agricultural lands along streams. Also cost-shares conservation practices such as riparian tree planting, livestock watering facilities, and riparian fencing.	NRCS, SWCDs, ODF
Conservation Reserve Program (CRP)	Competitive CRP provides annual rent to landowners who enroll highly erodible lands. Continuous CRP provides annual rent to landowners who enroll agricultural lands along seasonal or perennial streams. Also cost-shares conservation practices such as riparian plantings.	NRCS, SWCDs
Conservation Stewardship Program (CSP)	Provides cost-share and incentive payments to landowners who have attained a certain level of stewardship and are willing to implement additional conservation practices.	NRCS, SWCDs
Drinking Water Source Protection Fund	These funds allow states to provide loans for certain source water assessment implementation activities, including source water protection land acquisition and other types of incentive-based source water quality protection measures.	Oregon Health Authority
Emergency Watershed Protection Program (EWP)	Available through the USDA-Natural Resources Conservation Service. Provides federal funds for emergency protection measures to safeguard lives and property from floods and the products of erosion created by natural disasters that cause a sudden impairment to a watershed.	NRCS, SWCDs
Environmental Protection Agency Section 319 Grants	Fund projects that improve watershed functions and protect the quality of surface and groundwater, including restoration and education projects.	DEQ, SWCDs, Watershed Councils
Environmental Quality Incentives Program (EQIP).	Cost-shares water quality and wildlife habitat improvement activities, including conservation tillage, nutrient and manure management, fish habitat improvements, and riparian plantings.	NRCS, SWCDs
Farm and Ranchland Protection Program (FRPP)	Cost-shares purchases of agricultural conservation easements to protect agricultural land from development.	NRCS, SWCDs
Federal Reforestation Tax Credit	Provides federal tax credit as incentive to plant trees.	Internal Revenue Service

Program	General Description	Contact
Grassland Reserve Program (GRP)	Provides incentives to landowners to protect and restore pastureland, rangeland, and certain other grasslands.	NRCS, Farm Service Agency, SWCDs
Landowner Incentive Program (LIP)	Provides funds to enhance existing incentive programs for fish and wildlife habitat improvements.	U.S. Fish and Wildlife Service, ODFW
Oregon Watershed Enhancement Board (OWEB)	Provides grants for a variety of restoration, assessment, monitoring, and education projects, as well as watershed council staff support. 25 percent local match requirement on all grants.	SWCDs, Watershed Councils, OWEB
Oregon Watershed Enhancement Board Small Grant Program	Provides grants up to $10,000 for priority watershed enhancement projects identified by local focus group.	SWCDs, Watershed Councils, OWEB
Partners for Wildlife Program	Provides financial and technical assistance to private and non-federal landowners to restore and improve wetlands, riparian areas, and upland habitats in partnership with the U.S. Fish and Wildlife Service and other cooperating groups.	U.S. Fish and Wildlife Service, NRCS, SWCDs
Public Law 566 Watershed Program	Program available to state agencies and other eligible organizations for planning and implementing watershed improvement and management projects. Projects should reduce erosion, siltation, and flooding; provide for agricultural water management; or improve fish and wildlife resources.	NRCS, SWCDs
Resource Conservation & Development (RC & D) Grants	Provides assistance to organizations within RC & D areas in accessing and managing grants.	Resource Conservation and Development
State Forestation Tax Credit	Provides for reforestation of under-productive forestland not covered under the Oregon Forest Practices Act. Situations include brush and pasture conversions, fire damage areas, and insect and disease areas.	ODF
Stewardship Program	Provides cost share dollars through USFS funds to family forest landowners to have management plans developed.	ODF
State Tax Credit for Fish Habitat Improvements	Provides tax credit for part of the costs of voluntary fish habitat improvements and required fish screening devices.	ODFW
Stewardship Incentive Program (SIP)	Cost-sharing program for landowners to protect and enhance forest resources. Eligible practices include tree planting, site preparation, pre-commercial thinning, and wildlife habitat improvements.	NRCS, SWCDs, ODF
Wetlands Reserve Program (WRP)	Provides cost-sharing to landowners who restore wetlands on agricultural lands.	NRCS, SWCDs
Wildlife Habitat Incentives Program	Provides cost-share for wildlife habitat enhancement activities.	NRCS, SWCDs
Wildlife Habitat Tax Deferral Program	Maintains farm or forestry deferral for landowners who develop a wildlife management plan with the approval of the Oregon Department of Fish and Wildlife.	ODFW, SWCDs, NRCS

13.8. Citation legal authorities

As required in Oregon Administrative Rule 340-042-0040(4)(l)(O), this section cites legal authorities relating to implementation of management strategies.

Clean Water Act, Section 303(d)

The DEQ is the Oregon state agency responsible for implementing the Clean Water Act in Oregon. The EPA delegates many Clean Water Act authorities to the State of Oregon which is administered by the Oregon Environmental Quality Commission through Oregon Revised Statute. Section 303(d) of the 1972 Federal Clean Water Act as amended requires states to develop a list of rivers, streams and lakes that cannot meet water quality standards without application of additional pollution controls beyond the existing requirements on industrial sources and sewage treatment plants. These waters are referred to as “water quality limited.” Water quality limited waterbodies must be identified by the EPA or by a state agency which has been delegated this responsibility by EPA. In Oregon, the responsibility to delegate water quality limited waterbodies rests with DEQ and DEQ’s list of water quality limited waters is updated every two years. The list is referred to as the 303(d) list. Section 303 of the Clean Water Act further requires that TMDLs be developed for all waters on the 303(d) list. The Oregon Environmental Quality Commission granted the DEQ Director authority to develop TMDLs and issue them as orders (OAR 340-042-0060). DEQ was granted authority by the commission to implement TMDLs through OAR 340-042 with special provisions for agricultural lands and nonfederal forestland as governed by the Agriculture Water Quality Management Act and the Forest Practices Act, respectively. The EPA has the authority under the Clean Water Act to approve or disapprove TMDLs that states submit. When a TMDL is officially submitted by a state to EPA, EPA has 30 days to take action on the TMDL. In the case where EPA disapproves a TMDL, EPA must issue a TMDL within 30 days. A TMDL defines the amount of pollution that can be present in the waterbody without causing water quality standards to be violated. A WQMP is developed to describe a strategy for reducing water pollution to the level of the load allocations and waste load allocations prescribed in the TMDL, which is designed to restore the water quality and result in compliance with the water quality standards. In this way, the designated beneficial uses of the water will be protected for all citizens.

Endangered Species Act, Section 6

Section 6 of the 1973 federal Endangered Species Act, as amended, encourages states to develop and maintain conservation programs for federally listed threatened and endangered species. In addition, Section 4(d) of the ESA requires the National Marine Fisheries Service to list the activities that could result in a “take” of species they are charged with protecting. With regard to this TMDL, NMFS’ protected species are salmonid fish. NMFS also described certain precautions that, if followed, would preclude prosecution for take even if a listed species were harmed inadvertently. Such a provision is called a limit on the take prohibition. The intent is to provide local governments and other entities greater certainty regarding their liability for take.

NMFS published their rule in response to Section 4(d) in July of 2000 (see 65 FR 42421, July 10, 2000). The NMFS 4(d) rule lists 12 criteria that will be used to determine whether a local program incorporates sufficient precautionary measures to adequately conserve fish. The rule provides for local jurisdictions to submit development ordinances for review by NMFS under one, several or all of the criteria. The criteria for the Municipal, Residential, Commercial and Industrial Development and Redevelopment limit are listed below:

1. Avoid inappropriate areas such as unstable slopes, wetlands, and areas of high habitat value;
2. Prevent stormwater discharge impacts on water quality;
3. Protect riparian areas;

4. Avoid stream crossings – whether by roads, utilities, or other linear development;
5. Protect historic stream meander patterns;
6. Protect wetlands, wetland buffers, and wetland function;
7. Preserve the ability of permanent and intermittent streams to pass peak flows (hydrologic capacity);
8. Stress landscaping with native vegetation;
9. Prevent erosion and sediment run-off during and after construction;
10. Ensure water supply demand can be met without affecting salmon needs;
11. Provide mechanisms for monitoring, enforcing, funding and implementing; and
12. Comply with all other state and federal environmental laws and permits.

Oregon Revised Statute Chapter 468B

DEQ is authorized by law to prevent and abate water pollution within the State of Oregon. Particularly relevant provisions of this chapter include:

ORS 468B.020 Prevention of pollution

(A) Pollution of any of the waters of the state is declared to be not a reasonable or natural use of such waters and to be contrary to the public policy of the State or Oregon, as set forth in ORS 468B.015.

(B) In order to carry out the public policy set forth in ORS 468B.015, the Department of Environmental Quality shall take such action as is necessary for the prevention of new pollution and the abatement of existing pollution by:

a) Fostering and encouraging the cooperation of the people, industry, cities and counties, in order to prevent, control and reduce pollution of the waters of the state; and

b) Requiring the use of all available and reasonable methods necessary to achieve the purposes of ORS 468B.015 and to conform to the standards of water quality and purity established under ORS 468B.048.

ORS 468B.110 provides DEQ and the EQC with authority to take actions necessary to achieve and maintain water quality standards, including issuing TMDLs and establishing wasteload allocations and load allocations.

NPDES and WPCF Permits

DEQ administers two different types of wastewater permits in implementing Oregon Revised Statute (ORS) 468B.050. These are: the NPDES permits for waste discharge into waters of the United States; and Water Pollution Control Facilities permits for waste disposal on land. The NPDES permit is also a federal permit and is required under the Clean Water Act. The WPCF permit is a state program.

401 Water Quality Certification

Section 401 of the CWA requires that any applicant for a federal license or permit to conduct any activity that may result in a discharge to waters of the state must provide the licensing or permitting agency a certificate from DEQ that the activity complies with water quality requirements and standards. These include certifications for hydroelectric projects and for ‘dredge and fill’ projects. The legal citations are: 33 U.S.C. 1341; ORS 468B.035 – 468B.047; and OAR 340-048-0005 – 340-048-0040.

USACE Dam Operation and Management

In association with other federal statues, including House Document No. 531 Volume V, the River and Harbor Act, the Flood Control Act, and the Water Resources Development Act, the USACE is charged with operating its projects in compliance with the federal Clean Water Act, and in accordance with all federal, State, interstate and local requirements, administrative authority, and process and sanctions respecting the control and abatement of water quality pollution as per Title 1 Section 313 (33 U.S.C. 1323).

Oregon Forest Practices Act

The Oregon Department of Forestry is the designated management agency for regulating land management actions on non-federal forestry lands that impact water quality (ORS 527.610 to 527.992, and OAR 629 Divisions 600 through 665). The Board of Forestry has adopted water protection rules, including but not limited to OAR Chapter 629, Divisions 625, 630, and 635-660, which describe best management practices for forest operations. The Oregon Environmental Quality Commission, Board of Forestry, DEQ, and ODF have agreed that these pollution control measures will primarily be relied upon to result in achievement of state water quality standards. Statutes and rules also include provisions for adaptive management that provide for revisions to FPA practices where necessary to meet water quality standards. These provisions are described in ORS 527.710, ORS 527.765, OAR 629-035-0100, and OAR 340-042-0080.

Agricultural Water Quality Management Act

The Oregon Department of Agriculture has primary responsibility for control of pollution from agricultural sources (ORS 561.191). This is accomplished through the Agriculture Water Quality Management program authorities granted ODA under Senate Bill 1010 adopted by the Oregon State Legislature in 1993 (ORS 568.900 to ORS 568.933 and OAR 603-090-000 to 603-090-0120) The Agricultural Water Quality Management Plan Act directs the ODA to work with local communities to develop water quality management plans for specific watersheds that have been identified as violating water quality standards and have agriculture water pollution contributions. The agriculture water quality management plans are expected to identify problems in the watershed that need to be addressed and outline ways to correct the problems. Water Quality area rules for areas within the Willamette Basin include OAR 603-095-2100 to 1160, OAR 603-095-2300 to 2360, OAR 603-095-2600 to 2660, and OAR 603-095-3700 to 3760.

Local Ordinances

Local governments are expected to describe in their Implementation plans their specific legal authorities to carry out the management strategies chosen to meet the TMDL allocations. Legal authority to enforce the provisions of a city’s NPDES permit would be a specific example of legal authority to carry out management strategies.

14. Reasonable Assurance

OAR 340-042-0030(9) defines Reasonable Assurance as “a demonstration that a TMDL will be implemented by federal, state or local governments or individuals through regulatory or voluntary actions including management strategies or other controls.” OAR 340-042-0040(4)(l)(J) requires a description of reasonable assurance that management strategies and sector-specific or source-specific implementation plans will be carried out through regulatory or voluntary actions.

The Clean Water Act section 303(d) requires that a TMDL be “established at a level necessary to implement the applicable water quality standard.” Federal regulations define a TMDL as “the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background” [40 CFR 130.2(i)].

When a TMDL is developed for waters impaired by point sources only, the existence of the NPDES regulatory program and the issuance of NPDES permits provide the reasonable assurance that the wasteload allocations in the TMDL will be achieved. That is because federal regulations implementing the Clean Water Act require that water quality-based effluent limits in permits be consistent with “the assumptions and requirements of any available [wasteload allocation]” in an approved TMDL [40 CFR 122.44(d)(1)(vii)(B)].

Where a TMDL is developed for waters impaired by both point and nonpoint sources, it is the state’s and EPA’s best professional judgment as to reasonable assurance that the TMDL’s load allocations will be achieved. EPA past practice directs that these determinations include consideration of whether practices capable of reducing the specified pollutant load: (1) exist; (2) are technically feasible at a level required to meet allocations; and (3) have a high likelihood of implementation.

Where there is a demonstration that nonpoint source load reductions can and will be achieved; a determination that reasonable assurance exists and, on the basis of that reasonable assurance, allocation of greater loads to point sources is appropriate. Without a demonstration of reasonable assurance that relied-upon nonpoint source reductions will occur, reductions to point sources wasteload allocations are needed.

Because of the well-documented lag time for instream responses to effective mercury reductions from controls on point and nonpoint sources (United Nations Environment Programme, 2019), DEQ anticipates that attainment of instream target mercury concentrations and reduced fish tissue methylmercury concentrations will take decades.

The Willamette Basin Mercury TMDL was developed to address both point and nonpoint sources with load reduction allocations proportional to estimated source contributions and in consideration of opportunities for effective measures to reduce those contributions. There are several elements that combine to provide the reasonable assurance to meet federal and state requirements. Education, outreach, technical and financial assistance, permit administration, permit enforcement, DMA or responsible person’s implementation and DEQ enforcement of TMDL implementation plans will all be used to ensure that the goals of this TMDL are met. Details of these elements are provided in the WQMP (Section 13) and are summarized in the sections that follow.

14.1. Accountability framework

Reasonable assurance that needed load reductions will be achieved for nonpoint sources is based primarily on an accountability framework incorporated into the WQMP, together with the implementation plans of DMAs and responsible persons. This approach is similar to the accountability framework adopted by EPA for the Chesapeake Bay TMDL, which was adopted in 2010 and can be accessed from EPA's website: https://www.epa.gov/chesapeake-bay-tmdl/chesapeake-bay-tmdl-document. The reasonable assurance and accountability framework for this draft TMDL include the following elements:

Figure 14-1. A Representation of the Reasonable Assurance Accountability Framework Led by DEQ.

14.1.1 Pollutant reduction strategies

Section 13.3 identifies management strategies and specific implementation actions needed to achieve the identified pollutant reductions. These strategies and actions are comprehensively implemented through a variety of regulatory and non-regulatory programs. Many of these are existing strategies and actions that are already being implemented within the basin or elsewhere in the state and demonstrate reduced mercury loading. These strategies are technically feasible at an appropriate scale in order to meet the load allocations that are proposed for DMAs and responsible persons. A high likelihood of implementation is demonstrated because DEQ reviews the individual implementation plans and proposed actions for adequacy, establishes a monitoring and reporting system to track implementation and is establishing surrogate outcome measures that also will be monitored. Where implementation is not occurring, or where surrogate measures are not being met, DEQ will take action to require DMAs and responsible persons to take corrective action. Key reduction strategies include: control of all air emissions sources greater than 1 kg/year of mercury within Oregon; implementation of Oregon-wide dental amalgam treatment since 2007; Oregon bans on products containing mercury; remediation of legacy mining mercury sources; point source permit requirements; and nonpoint source implementation plans from 12 state and federal agencies and dozens of local governments, special districts and other responsible parties.

14.1.2 Identify relevant DMAs

Section 13.2.3 and Appendix E: List of Designated Management Agencies and responsible persons identify approximately 171 DMAs and responsible persons that will implement the WQMP management strategies and develop or revise their own implementation plan. This category captures additional entities identified since the 2006 TMDL was issued. In this 2019 revision, DEQ is including explicit allocations and requirements for control of mercury in stormwater and direct discharges from urban areas that do not yet meet the population thresholds requiring municipal stormwater permits and also for water conveyance maintenance practices. This significantly expands the numbers of DMAs and responsible persons actively applying mercury controls in the Willamette Basin. DEQ Willamette Basin coordinators work individually with these DMAs and responsible persons on developing and implementing the required management strategies to reduce mercury. All of these factors increases robustness of TMDL implementation throughout the basin.

14.1.3 Develop timeline, targets, measurable objectives

Section 13.4 provides comprehensive timelines for implementing management strategies. This includes schedules for revising permits, submittal of reports, achieving appropriate incremental and measurable water quality targets, and completion of other measurable milestones. These timelines support the accountability framework by requiring timely action by both DEQ and DMAs and responsible persons so that enforcement and adaptive management actions can be triggered and evaluation of attainment of TMDL goals occurs.

14.1.4 Evaluate implementation plans and progress

As provided in Section 13.4, DEQ will evaluate new or revised implementation plans from DMAs and responsible persons. This will ensure that the actions and measures included in the plans are feasible and have a high likelihood of being implemented and achieving load allocations. In addition, DEQ is proposing TSS as a surrogate measure for evaluating implementation of the allocations for the mainstem Willamette River and its tributaries. TSS will be used for evaluating the effectiveness of implementation plans. Monitoring locations will be described in the *Assessment and Monitoring Strategy to Support Implementation of Mercury Total Maximum Daily Loads for the Willamette Basin*. DEQ will use the monitoring data to determine trends in both the TSS surrogate measure and available data for mercury in the water column and in fish tissue.

As noted in Sections 13.5 and 13.6, DEQ will track the management strategies being implemented and evaluate achievements against established timelines and milestones. At a minimum, this will occur in the Willamette Basin through DEQ's Five Year Reviews.

In making determinations about the effectiveness and implementability of mercury reduction measures, DEQ relies heavily on DMA and responsible person experience with measures specific to reducing erosion and runoff from their specific activities. The wide variety of potential actions that will be applied by 171 DMAs and responsible persons across dozens of point source sectors and land use activities prevent unilateral mandating of preferred practices and conclusions about their specific success. However, examples of where proven techniques are applied to reduce mercury give confidence that DEQ's approach is reasonable and will effective for reducing mercury. Some examples of effective controls since implementation of the 2006 Willamette Basin Mercury TMDL began include:

- Oregon's two most significant air emissions mercury sources in 2006 were a coal-fired electric generation plant in Boardman and a cement plant in Durkee. In 2007, DEQ put strict control requirements in place on these facilities. Reductions in mercury emissions of 94 and 97 percent, respectively, have since been achieved and the coal plant is closing in 2020.
- The 2019 Cleaner Air Oregon regulations will address the largest air source of mercury in the Willamette Basin. This source currently comprises 70 percent of the total mercury air emissions within the Willamette Basin. Controls under this program are expected to achieve significant reductions.
- Clean Water Services operates four municipal sewage treatment plants serving more than a half a million residents in Washington County, Oregon. Advanced treatment technologies are employed at its facilities and mercury minimization measures have been implemented since at least 2004. While the systems are not designed specifically to address mercury, the facilities consistently achieve 97 to 99 percent mercury removal efficiencies. Effectiveness of mercury minimization measures, particularly reduced dental amalgam contributions, is also demonstrated by declining levels of mercury in biosolids between 2006 to 2018.
- ODA and DEQ have worked together to complete biennial reviews of Agricultural Water Quality Management Plans in the Upper, Middle and Lower Willamette Basin areas. These reviews report on water quality at a number of stations, including the status and trends in TSS levels. Although data are limited, these reports illustrate how DEQ will continue to work with ODA to focus work on agricultural lands to reduce sedimentation and mercury loading. DEQ will take a similar approach with both federal and non-federal forest lands.

Among both point and nonpoint sources, there is variation as to maturity of programs focused on mercury minimization measures. DEQ anticipates that entities with longer experience in implementing measures targeting mercury, particularly erosion and runoff controls, will continue to achieve modest reductions using strategies and techniques that have evolved over time. DEQ expects that entities that have not yet begun implementing mercury minimization measures can learn from practices employed by entities with more mature programs. In addition, DEQ expects that entities employing these techniques and strategies for the first time have greater reduction potential. Together, optimized mercury reduction actions applied broadly across all sources is anticipated to achieve the aggregated sector-specific allocations over time.

14.1.5 Take action on failure to implement

Following up on reviews to track progress of implementation plans, DEQ will take appropriate action if the DMAs or responsible persons fail to develop or effectively implement their implementation plan or fulfill milestones. DEQ's actions can take two tracks, enforcement or engagement in voluntary initiatives. DEQ uses both, as appropriate within the process, to achieve optimal pollutant reductions. In some cases DEQ can assist in facilitating the availability of incentives for meeting voluntary initiatives or providing education. DEQ will also take enforcement actions where necessary based on authorities listed in Section 13.8, or raise the issue to the EQC as provided in OAR 340-042-0080.

14.1.6 Track water quality status and trends

As noted above in Section 13.6, DEQ is tracking water quality status and trends concurrently as management strategies are implemented. DEQ is relying on a system of interconnected evaluations, which include DMAs meeting measurable objectives, effectiveness demonstration of mercury management strategies, accountability of implementation, discharge monitoring and instream monitoring. Together, these data and evaluations will allow refinement of focus on specific geographic areas or discharges and appropriate implementation of adaptive management actions to attain, over time, the objectives of the TMDL. In partnership with EPA, DEQ is currently developing an *Assessment and Monitoring Strategy to Support Implementation of Mercury Total Maximum Daily Loads for the Willamette Basin.* Intended to be a living document, this plan will serve as the overarching structure to tie together the information gained from the other evaluations during implementation of the TMDL by the 171 DMAs and responsible persons.

Tracking of water quality status and trends will include DEQ tracking and reporting on:

- TMDL implementation plan submittals, reviews, and approvals
- DMA, responsible person and permittee implementation of management actions
- Instream compliance points for allocations, in conjunction with revisiting the watershed modeling
- Annual and other increment reporting from DMAs, responsible persons and permittees
- Five year reviews of implementation and evaluation of the TMDL and WQMP

14.2. Dominance of atmospheric deposition of mercury

As discussed in the TMDL Technical Support Document and preceding sections of this draft TMDL, atmospheric deposition of mercury onto the Oregon landscape is the dominant source of mercury reaching Willamette Basin streams. While these deposited air emissions originate as a mix of global, national, regional and local sources, the largest portion is derived from historical deposition of global anthropogenic mercury emissions (TetraTech, 2019). Further, the current air emissions sources originating within Oregon are small relative to the total mercury budget of the basin. Air emissions from local sources are being addressed by existing programs and mercury loads from all permitted point source discharges combined are conservatively estimated to be less than five percent of the total mercury load or approximately 18 g/day or 6.61 kg/yr. As such there is limited overall potential for reducing mercury loads within Willamette Basin streams through further reductions of air emissions and wastewater discharge point sources. Despite distant origins of the dominant sources of mercury, once on the landscape in the Willamette Basin, the greatest potential for reductions of mercury delivered to streams is through enhancing controls on nonpoint source land use activities that have the potential to result in erosion and surface runoff. DEQ's approach prioritizes focus on controls for erosion and surface runoff from both point and nonpoint sources to optimize mercury reductions into waterways.

In alignment with EPA guidance relevant to the Willamette Basin situation where mercury loadings are predominantly from air deposition (EPA 2008, 2010), DEQ opted to allocate aggregated nonpoint source loads and point source wasteloads using the proportionality approach. These approaches also follow precedents affirmed in EPA-approved mercury TMDLs in 21 other states. These allocations include portions of natural and anthropogenic background sources that are outside of the reasonable control of designated management agencies and responsible parties.

14.3. Conclusions

DEQ's implementation approach is multi-faceted and requires many targeted management practices across the entire basin to reduce anthropogenic mercury, regardless of source origination. This is a reasonable approach that recognizes the inherent uncertainty in global atmospheric deposition reduction trends, on-going inputs from historical sources of mercury still available to be delivered to streams and long lag times until positive responses occur in streams and fish.

Because the depositional sources are mixed and the management practices that can be employed are distributed over a wide area and among many DMAs and responsible persons, there is uncertainty about reductions in mercury loading. DEQ's draft WQMP addresses this uncertainty by including an extensive monitoring, reporting, and adaptive component that is designed to match the accountability framework used by EPA in its Chesapeake Bay TMDL (2010).

The examples of effective actions employed since issuance of the 2006 TMDL (presented in Section 14.1.4 above), demonstrate that effective mercury management practices exist that can and will be employed, for both nonpoint and point source activities, to achieve the load and wasteload allocations contained in this draft TMDL.

The rationale described in this document stems from a more robust evaluation using significantly more data, captures additional urban areas not previously regulated, implements an accountability framework (including the *Assessment and Monitoring Strategy to Support Implementation of Mercury Total Maximum Daily Loads for the Willamette Basin*) and provides opportunities for adaptive management to maximize mercury reductions. Together this approach provides reasonable assurance to meet state and federal requirements and attain the goals of the TMDL.

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Appendix A: Technical Support Document

The Technical Support Document is available at:
https://www.oregon.gov/deq/FilterDocs/wbmtmdl042019mm.pdf

Appendix B: Calculation of allocations

The allocations for the TMDL were calculated as percent reductions and compared to the load capacity. These calculations and comparisons were automated and done in a spreadsheet. The existing loads for the mercury sources obtained from the Mass Balance Model were entered into the spreadsheet and then criteria were set for the optimization routines. The criteria pertained to the size of the reductions in a source that were being tested. The source categories used in the spreadsheet are listed in Table B-1. The percent reductions listed in the second column of Table B-2 were multiplied by the loads for each of the source categories. The third column is the result that the reduction of atmospheric deposition load will result in a reduction in the load in surface runoff in addition to a reduction in loads directly from surface runoff. The fourth and fifth columns of Table B-2 are the limits in the reductions set for the optimization. The optimization was setup so the smallest reduction within the range would be used in the load calculation. The optimization was run until the calculated TMDL load was less than or equal to the load capacity as shown in Table B-3.

Table B-1. Source category names and descriptions used in spreadsheet for calculating the allocations.

Source Category	Description
Runoff of atmospheric deposition	THg in surface runoff from wet and dry atmospheric deposition to pervious and impervious surfaces.
Atmospheric deposition direct to water	THg from wet and dry atmospheric deposition direct to water surfaces.
Groundwater	Dissolved THg associated with subsurface flows (shallow interflow and resurfacing groundwater).
Sediment	Particulate-associated THg from sediment erosion and transport.
MS4	THg associated with stormwater in permitted Phase I & II MS4 areas (cities, counties, & ODOT). Includes THg from runoff of atmospheric deposition, dissolved THg in shallow subsurface interflow, and particulate-associated THg from sediment erosion. Limited to developed low, medium, and high density land in MS4 areas.
Urban DMAs	THg associated with stormwater from urban Designated Management Areas (DMAs). Includes THg from runoff of atmospheric deposition, dissolved THg in shallow subsurface interflow, and particulate-associated THg from sediment erosion. Limited to developed low, medium, and high density land in urban DMA areas.
Mines	Legacy THg from contaminated mine tailings and furnace areas at the Black Butte Mine and the Bohemia Mining District.
POTWs	THg associated with discharges from major POTWs and minor domestic WWTPs that hold NPDES permits.
Industrial dischargers	THg associated with discharges from industrial facilities that hold NPDES permits.

Table B-2. Allocation spreadsheet table.

Category	Opt Reduction	Combined with Atmospheric Deposition Reduction	Lower Limit	Upper Limit
Runoff of atmospheric deposition (agriculture)	**88%**	98%	80%	88%
Runoff of atmospheric deposition (forest)	**88%**	98%	80%	88%
Runoff of atmospheric deposition (shrub)	**88%**	98%	80%	88%
Runoff of atmospheric deposition (developed)	**88%**	98%	80%	88%
Runoff of atmospheric deposition (other)	**88%**	98%	80%	88%
Atmospheric deposition direct to water	**11%**		0%	11%
Groundwater (agriculture)	**32%**		0%	88%
Groundwater (forest)	**88%**		0%	88%
Groundwater (shrub)	**77%**		0%	88%
Groundwater (developed)	**0%**		0%	88%
Groundwater (other)	**88%**		0%	88%
Sediment (agriculture)	**88%**		75%	88%
Sediment (forest)	**88%**		0%	88%
Sediment (shrub)	**88%**		80%	88%
Sediment (developed)	**88%**		75%	88%
Sediment (other)	**88%**		75%	88%
MS4	**75%**		50%	75%
Urban DMAs	**75%**		50%	75%
Mines	**95%**		90%	95%
POTWs	**10%**		10%	75%
Industrial dischargers	**10%**		10%	75%

Table B-3. Comparison of Load Capacity to TMDL Loads Calculated for the Reductions.

Category	Load
Load Capacity (g/day)	42.17
TMDL for reductions (g/day)	42.17

Appendix C: Variance justification excerpts

Water Quality Based Effluent Limits for mercury are not achievable

There are no technology-based effluent limits or effluent guidelines for mercury. Therefore, NPDES permits limits for mercury are evaluated based on the water quality criterion. Because total mercury levels in the Willamette Basin exceed the water concentration needed to meet the methyl mercury criterion, dischargers would be required to achieve an effluent concentration equal to the water concentration target of 0.14 ng/L, before the effluent is discharged to the receiving water. As demonstrated below, DEQ has determined that there are currently no feasible treatment technologies that could reduce mercury levels to those necessary to achieve 0.14 ng/L.

Mercury Removal Achieved by Municipal Treatment Technologies (3.2.1)

This section presents data on mercury levels achieved by municipal treatment systems in California and Oregon. In 2005, California performed a study looking at methyl mercury removal from NPDES permitted dischargers in the Sacramento River Delta[2]. California required dischargers to collect and report on methyl mercury influent and effluent data over twelve months in 2004 and 2005. A subset of these facilities also reported total mercury effluent data. A summary of annual average total mercury effluent concentrations is shown in Figure C-1. The facilities were categorized as either secondary or tertiary treatment plants. The median of the average annual total mercury effluent concentrations was 8.4 ng/l in secondary treatment plants (n=27) and ranged from 3.1-21.5 ng/l. In tertiary treatment plants (n=22), the median average annual concentration was 4.2 ng/l and ranged from 0.8 – 11.6 ng/l.

DEQ also compiled and analyzed mercury levels from 2016 data provided by municipal dischargers in Oregon (Figure C-2). In this case, DEQ categorized each system as secondary or advanced. Advanced systems included any in which additional filtration or treatment was installed after secondary treatment. The median average annual total mercury effluent concentration was 2.8 ng/l in secondary treatment plants (n=11) and ranged from 1.2-8.3 ng/l in advanced treatment plants (i.e., those employing nutrient removal, tertiary or other post-secondary treatment filtration, or both) (n=8), the median annual average concentration was 1.7 ng/l and ranged from 1.1 – 3.0 ng/l. The Oregon data comes from larger facilities that have a pre-treatment program and have implemented source control programs for several to many years. The California data comes from both large and small systems, is 12 years older and comes from the Sacramento River Delta, which has high mercury levels resulting from historical gold mining. These facts may explain why Oregon effluent data has considerably lower concentrations than that from California.

[2] California EPA, Regional Water Quality Control Board, Central Valley Region. 2010. Staff Report: A Review of Methylmercury and Inorganic Mercury Discharges from NPDES Facilities in California's Central Valley.

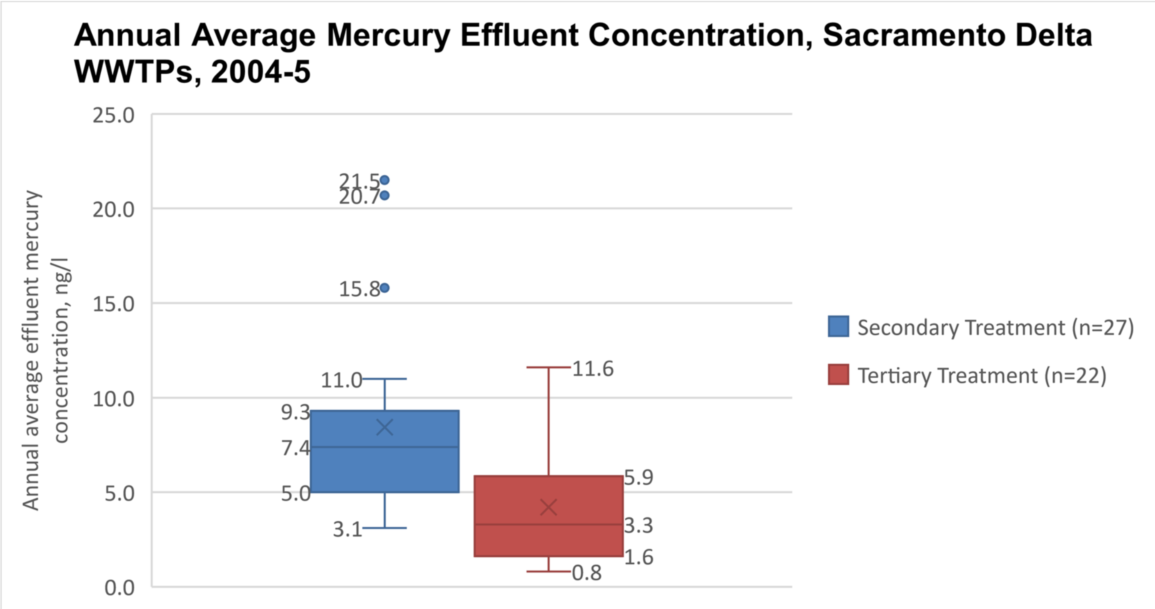
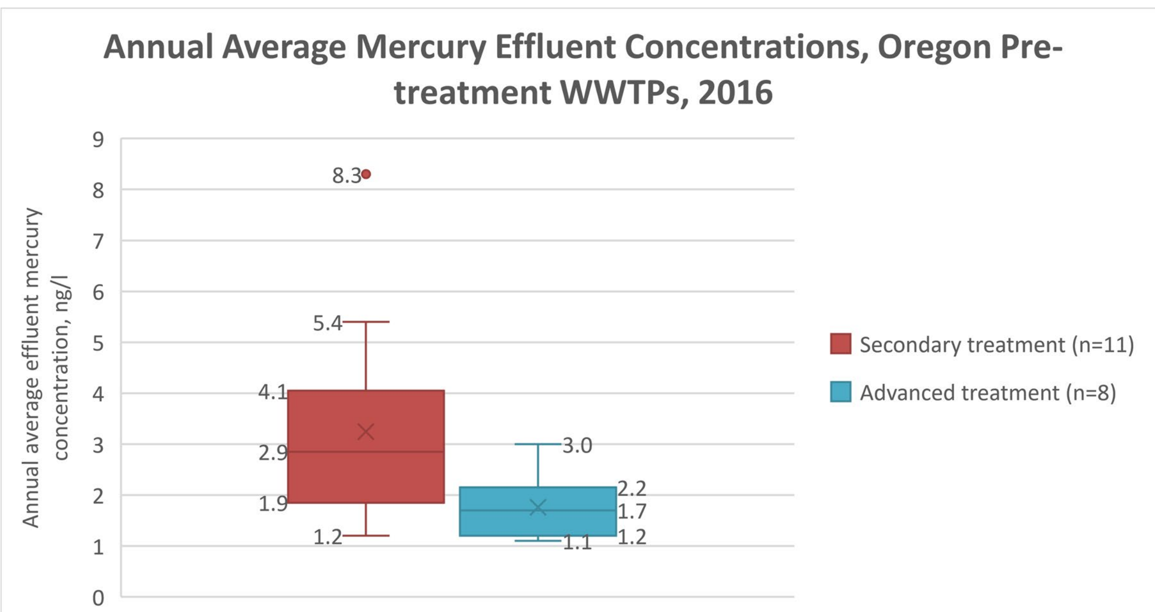


Figure C-1. Average Total Mercury Effluent Concentration, Sacramento Delta WWTPs, 2004-5. Source: California EPA, Regional Water Quality Control Board, Central Valley Region. 2010. Staff Report: A Review of Methylmercury and Inorganic Mercury Discharges from NPDES Facilities in California's Central Valley.



Note:

Figure C-2. Average Total Mercury Effluent Concentrations, Oregon pre-treatment WWTPs, 2016

The Oregon wastewater treatment facilities include in the advance treatment group (n=8) for this graphic include: Rock Creek and Durham operated by Clean Water Services, McMinnville, Wilsonville, Albany, Kellogg Creek, Newberg and Tri-cities. Only a portion of the Tri-cities WWTP flow is filtered after secondary treatment; however, the average mercury concentration in effluent in 2016 was 1.6 ng/l, comparable to other advanced systems.

Review of Available Treatment Technologies

In variance applications for individual variances, Clean Water Services, which operates four wastewater treatment plants in the Willamette Basin, provided the results of a literature review on the ability of available treatment technologies to remove mercury. CWS noted that their literature review did not identify pilot or full-scale treatment systems that would be able to achieve the 2006 TMDL target of 0.92 ng/L, nor the lower water concentration target from the updated TMDL modelling of 0.14 ng/L.

Because there is a lack of full-scale installations consistently producing effluent mercury concentrations in the low ng/L range, it is difficult to predict whether it is possible to consistently achieve mercury concentrations in the low ng/L range on a long-term, large-scale basis. An Ohio EPA study[3] concluded that end-of-pipe controls to meet the mercury water quality standards of 1.3 ng/L would cause substantial and widespread economic impact *and the ability of the added controls to meet the standard was not known* (emphasis added). Michigan relied on the Ohio study to support their state's multiple discharge variance as well. In EPA's 2015 approval of Michigan's Multiple Discharge Variance, EPA concluded that the installation and operation of filtration technology short of reverse osmosis *cannot ensure compliance with a monthly average water quality based effluent limit of 1.3 ng/L* (emphasis added).

In Oregon, the WQBEL needed to meet the human health criterion is estimated to be 0.14 ng/L, an order of magnitude lower than the Ohio and Michigan standards. If the ability of the controls to meet 1.3 ng/L is not known, it is reasonable to conclude that the ability of the controls to meet 0.14 ng/L has not been demonstrated.

This information is consistent with a review conducted by HDR for the Association of Washington Businesses.[4] The HDR study examined the potential performance of adding reverse osmosis or granular activated carbon to the back end of a tertiary microfiltration process and hypothesized that such a treatment system *might* be able to remove mercury to a concentration of 0.12 to 1.2 ng/l. However, the study provided no data from any test or operational system. Such treatment systems had not at that time been employed on a bench or pilot scale, or at a wastewater treatment plant scale to DEQ's knowledge.

In addition, membrane filtration technologies have high energy costs, creating a substantial carbon footprint, and would need to dispose of the removed waste sludge[5] According to a life cycle assessment performed for the Berlin-Ruhleben secondary wastewater treatment plant (63 MGD), the operational energy use of polymer ultrafiltration or ceramic microfiltration membranes would be 0.33 watt×hour/gal. This would represent approximately a 9 percent increase in that plant's existing global warming potential and does not include the additional global warming potential that would be contributed by infrastructure, chemicals for maintenance and any necessary coagulant (from CWS Variance Application, Attachment 1, p. 13). Of the different types of membrane filtration, reverse osmosis also has the large disadvantage of necessitating disposal of the concentrate stream, which can amount to approximately 5 to 20 percent of the influent.

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[3] Ohio Environmental Protection Agency. 1997. Assessing the Economic Impacts of the Proposed Ohio EPA Water Rules on the Economy. Prepared for the Division of Surface Water by Foster Wheeler Environmental Corporation and DRI/McGraw Hill.

[4] Treatment Technology Review and Assessment, Association of Washington Businesses, HDR, Dec. 2013.

[5] Michigan Department of Environmental Quality. 2015. Mercury Multiple Discharge Variance Document

EPA contracted with Battelle to complete a review of current wastewater treatment technologies for mercury and to update the 1997 Ohio EPA study. Battelle's 2013 draft report found that bench scale and pilot tests resulted in a concentration of 1.3 ng/L. However, little information is available for facilities actually implementing a technology to remove mercury from their effluent. Of the five facilities actively using the technology referenced in the report, only two had been in operation for over two years and these facilities have small discharges (0.035 MGD and 1.4 MGD). Although technology is advancing, it has not yet been demonstrated that the newer technologies can be successful at the scale needed for a large WWTF, with varying influent concentrations and design flows.[6]

A 2007 EPA report regarding mercury treatment notes that there are technologies, such as precipitation, filtration or other physical/chemical treatments (see Table C-1) that might treat mercury in addition to those typically employed by wastewater treatment plants. However, these have been employed in industrial settings where influent concentrations were an order of magnitude higher than influent concentrations at municipal wastewater treatment facilities[7]. The effluent concentrations at many of these industrial applications were similar to the influent concentrations at municipal treatment facilities. Moreover, the information provided in the EPA report did not indicate flow volumes, so it is difficult to translate these studies to typically larger municipal wastewater treatment plant volumes.

In another study, an oil refinery evaluated various treatment technologies for wastewater with low (10 ng/l) mercury levels to determine the extent to which mercury concentrations could be lowered following conventional treatment. Bench scale tests of various adsorbent techniques showed that they could remove mercury to as low as less than 0.08 ng/l of total mercury[8]. Ultra- and micro-filtration tests also reduced mercury to less than 1 ng/l, although not as much as adsorption. However, such techniques have not been shown to work at the higher volume or the higher influent concentrations in municipal treatment. Moreover, they would be have to supplement existing treatment and would be energy intensive, generate additional waste and cost millions of dollars to install and operate[9].

Table C-1 summarizes results from treatment technologies that have been tested at a small scale for municipal wastewater or used for water treatment or industrial wastewater treatment. None of these technologies have been demonstrated to be feasible for use at large municipal WWTFs and it is not known what effluent concentrations would be achievable if they were used for this purpose. Table C-1 summarizes results from various technologies.

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[6] Michigan Department of Environmental Quality. 2015. Mercury Multiple Discharge Variance Document.

[7] U.S. EPA. 2007. Treatment Technologies for Mercury in Soil, Waste, and Water. Office of Superfund Remediation and Technology Innovation. Washington, DC. 133 pp.

[8] Urgun-Demirtas, M, P. Gillenwater, M. C. Negri, Y. Lin, S. Snyder, R. Doctor, L. Pierece and J. Alvarado. 2013. Achieving the Great Lakes Initiative Mercury Limits in Oil Refinery Effluent. Water Environment Research 85(1): 77-86.

[9] Treatment Technology Review and Assessment, Association of Washington Businesses, HDR, Dec. 2013.

Table C-1. Potential treatment technologies considered for mercury treatment

Study	Type of treatment technology	Influent total mercury concentration (ng/l)	Average effluent total mercury concentration (ng/l)	Percent removal	
EPA (2007)[10]	Precipitation (Chelator)	400-9,600,000	25-21,400	42-99.9%	Full scale
EPA (2007)[6]	Adsorption/ Granular Activated Carbon	3,300-2,500,000	300-1,000	99-99.8%%	Full scale
HDR Study (2013)[11]	Tertiary Microfiltration/ Reverse Osmosis		0.12-1.2 hypothetically	>99%	Not demonstrated at WWTP scale
HDR Study (2013)	Tertiary Microfiltration/ Granular Activated Carbon		0.12-1.2 hypothetically	>99%	Not demonstrated at WWTP scale
Urgun-Demirtas, et al. (2013)[12]	Precipitation	10 ng/l	3.1 ng/l (before filtration) 0.17 ng/l (after filtration)	56.5% before filtration	Bench scale testing
Urgun-Demirtas, et al. (2013)	Adsorption	10 ng/l	<0.08 ng/l – 0.72 ng/l (lowest achieved)	92.8% - 99.2%	Bench scale testing
Urgun-Demirtas, et al. (2013)	Filtration	10 ng/l	0.26 – 0.34 ng/l (lowest achieved)	65 – 97% depending on pressure	Bench scale testing
Hollerman, et al. (1999)[13]	Adsorption	739-1447 ng/l	~25-340 ng/l	n/a	Low volume
Rock Creek AWWTF	Activated sludge with nutrient removal + filtration	78 (long term geometric mean)	1.6 (long term geometric mean)		Full scale municipal treatment facility

[10] U.S. Environmental Protection Agency. 2007. Treatment Technologies for Mercury in Soil, Waste, and Water. Office of Superfund Remediation and Technology Innovation. Washington, DC. 133 pp.

[11] HDR. 2013. Treatment Technology Review and Assessment. Prepared for the Association of Washington Businesses.

[12] Urgun-Demirtas, M, P. Gillenwater, M. C. Negri, Y. Lin, S. Snyder, R. Doctor, L. Pierece and J. Alvarado. 2013. Achieving the Great Lakes Initiative Mercury Limits in Oil Refinery Effluent. Water Environment Research 85(1): 77-86.

[13] Hollerman, W., L. Holland, D. Ila, J. Hensley, G. Southworth, T. Klasson, P. Taylor, J. Johnston, and R. Turner. 1999. Results form the low level mercury sorbent test at the Oak Ridge Y-12 Plant in Tennessee. Journal of Hazardous Materials B68:193-203.

Table C-2. Treatment capability of mercury technologies

Treatment Technology	Volume Range of Known Uses	Treatment Ability
Activated sludge	Up to 25 MGD	3-50 ng/L
Activated sludge w/ Nutrient Removal or Filtration	Up to 25 MGD	1-10 ng/L
Membrane Filtration	Low volume	Bench scale to 0.26 ng/L
Ion Exchange	0.015 MGD (5-50 GPM)	1 ng/L
Precipitation and filtration	Low volume	Bench scale to 0.17 ng/l; full scale to 25 ng/l
Adsorption	Low volume	Bench scale to 0.08 ng/l; full scale to 25 ng/l

Demonstration that MMP implementation will achieve similar effluent concentrations as advanced wastewater treatment plants

As described in section 3.2.2, municipalities using advanced wastewater treatment (either tertiary filtration or nutrient removal) have mercury effluent concentrations ranging from 1-3.5 ng/L as an annual average. DEQ has concluded that there are no current feasible technologies that have been demonstrated to achieve lower mercury effluent concentrations.

Some secondary treatment plants have higher mercury concentrations in their effluent. Data indicates that over the 20-year proposed term of the variance, appropriate implementation of an MMP at facilities without advanced treatment will result in similar mercury concentrations as that achieved at advanced treatment plants. In fact, many secondary treatment plants are already achieving such levels.

The Wisconsin Department of Natural Resources has tracked mercury effluent data from NPDES permittees over the past fifteen years, during which NPDES permitted facilities have been implementing MMPs under the Great Lakes Initiative. The data show that both municipal and industrial point sources have reduced mercury effluent concentrations through MMP implementation to be similar to that found at advanced wastewater treatment plants in Oregon.

WDNR tracks mercury concentrations using both 1-day and 4-day, 99th percentile (1-day and 4-day P99) metrics. For our analysis, we focused on the 4-day metric as evidence of a longer term trend. Among 52 municipal dischargers, the average 4-day P99 decreased from 11.2 ng/L in the initial 5-year period that was tracked[14] to 3.2 ng/L in the most recent 5-year period (2014-2018). The median 4-day P99 during this time also decreased from 5.2 to 2.8 ng/L. All but three municipal systems experienced decreasing trends in effluent concentrations and all but eight experienced decreasing 4-day P99 concentrations (Figure C-3). Moreover, whereas 13 facilities had 4-day P99s greater than 8 ng/L in their initial permit term, only one facility had a 4-day P99 greater than 8 ng/L based on the most recent data (Figure C-4), highlighting how effluent levels have decreased over time. The mercury concentrations seen in most of these facilities are within the range that are seen in advanced municipal wastewater treatment plants. According to WDNR staff, none of these facilities employ advanced treatment, but have achieved these levels through minimization.[15]

[14] The initial 5 year period varied from permit to permit.

[15] *Personal communication*, Laura Dietrich, Wisconsin Department of Natural Resources, 2/28/19.

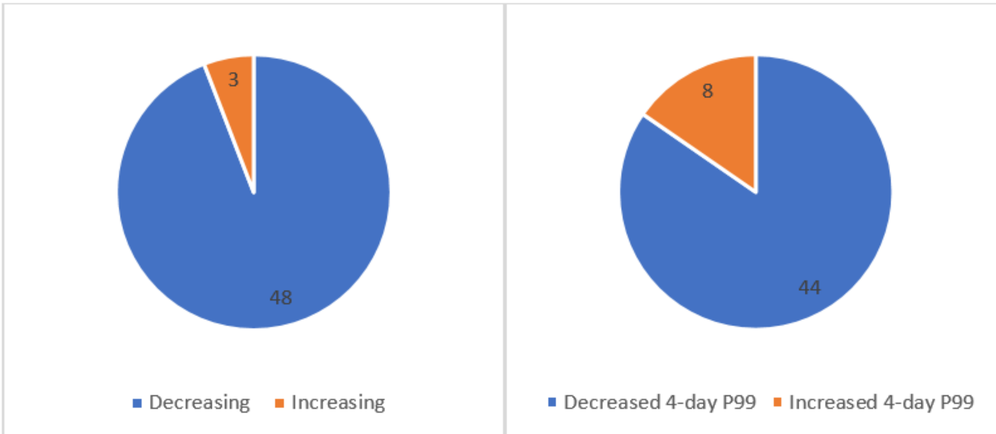

Figure C-3. Number of Wisconsin municipal wastewater treatment systems with increasing and decreasing trends in average (left) and 4-day P99 (right) concentrations. Source: Wisconsin Department of Natural Resources.

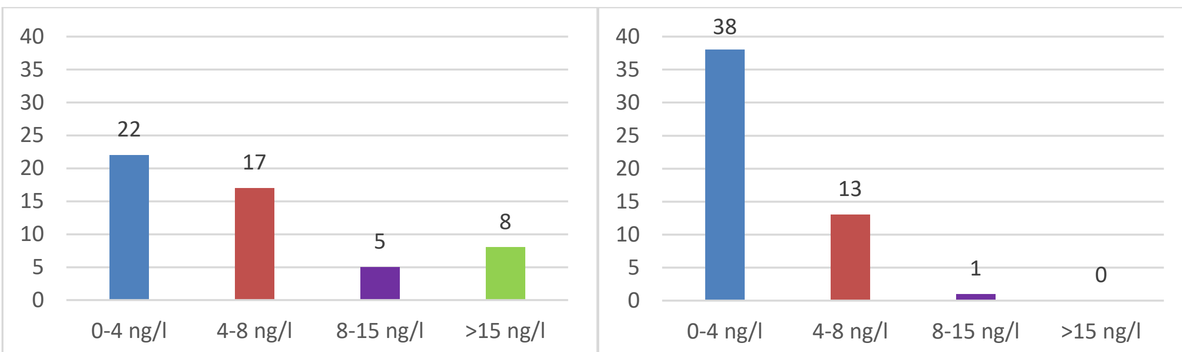

Figure C-4. Number of Wisconsin municipal WWTPs by 4-day P99 mercury concentrations from initial five-year period (left) to most recent five-year period (right). Source: Wisconsin Department of Natural Resources.

Available data in Wisconsin also indicates an overall decreasing trend in mercury concentrations at industrial facilities. Among 24 industrial NPDES permit holders, the mean 4-day P99 decreased from 25.4 to 13.7 ng/L and the median 4-day P99 decreased from 14.1 to 7.2 ng/L. Eighteen of the 24 facilities had lower 4-day P99 concentrations in the most recent five-year period as compared to the initial period, and sixteen had decreasing average mercury concentrations (Figure C-5). Finally, while only one additional facility had a 4-day P99 less than 8 ng/L from the initial five-year period to the most recent, five fewer facilities had concentrations greater than 15 ng/L (Figure C-6). Industrial facilities in the Willamette Basin contribute approximately 0.3% of the total load of mercury to the Willamette. Moreover, these facilities have effluent levels of mercury that average less than 15 ng/L. Given the high environmental costs of treatment (as demonstrated in the section below), the effectiveness of source reduction and the small contribution to the overall load, DEQ has concluded that it is preferential for such facilities to focus on MMP implementation, rather than trying to upgrade treatment.

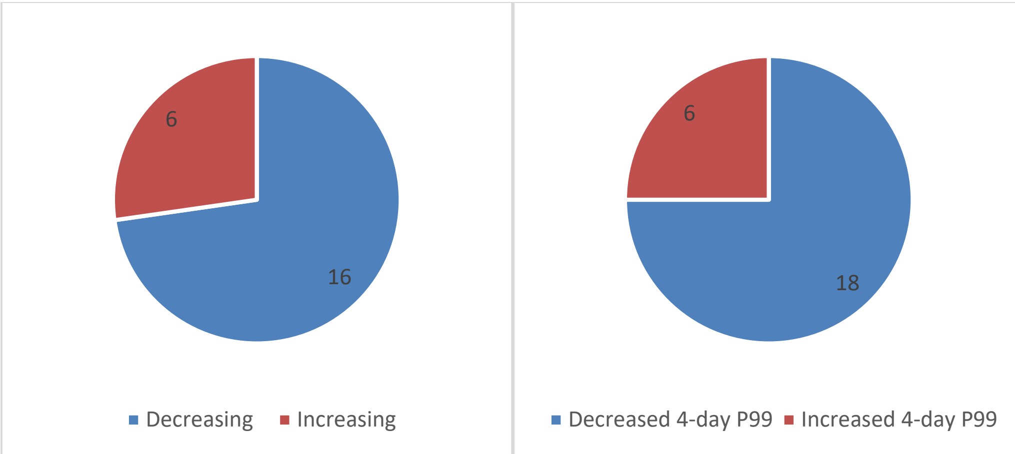

Figure C-5. Number of Wisconsin industrial wastewater treatment systems with increasing and decreasing trends in average (left) and 4-day P99 (right) concentrations. Source: Wisconsin Department of Natural Resources.

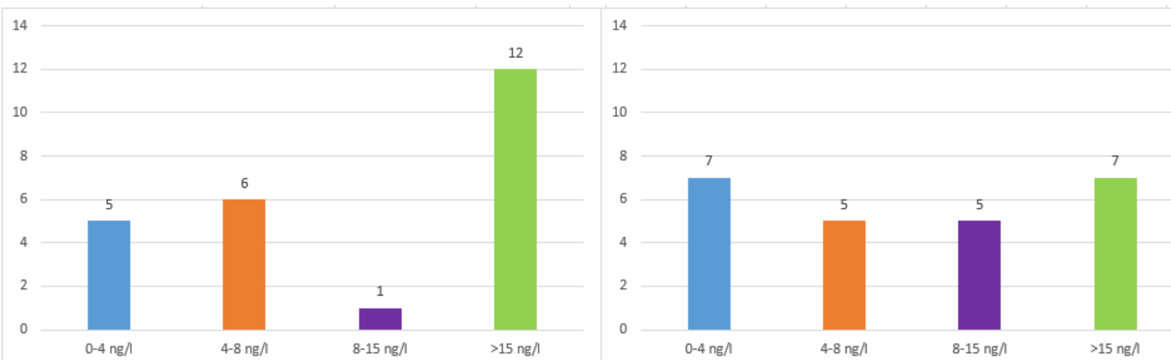

Figure C-6. Number of Wisconsin industrial NPDES facilities by 4-day P99 mercury concentrations from initial five-year period (left) to most recent five-year period (right). Source: Wisconsin Department of Natural Resources.

Evidence from influent and biosolids data also indicates the effectiveness of MMPs in reducing mercury, even when effluent levels are variable. A decade of mercury influent data from 72 major NPDES wastewater treatment plants in Minnesota indicate that MMPs have resulted in significant and continued reductions in mercury concentrations entering treatment systems. Between 2008 and 2017, influent total mercury concentrations decreased from an average of 180 ng/l to 70 ng/l (Figure C-7). Finally, data from the Rock Creek Advanced Wastewater Treatment Plant operated by Clean Water Services indicates decreasing mercury levels in biosolids, showing the effectiveness of their mercury reduction efforts over the last 20 years (Figure C-8).

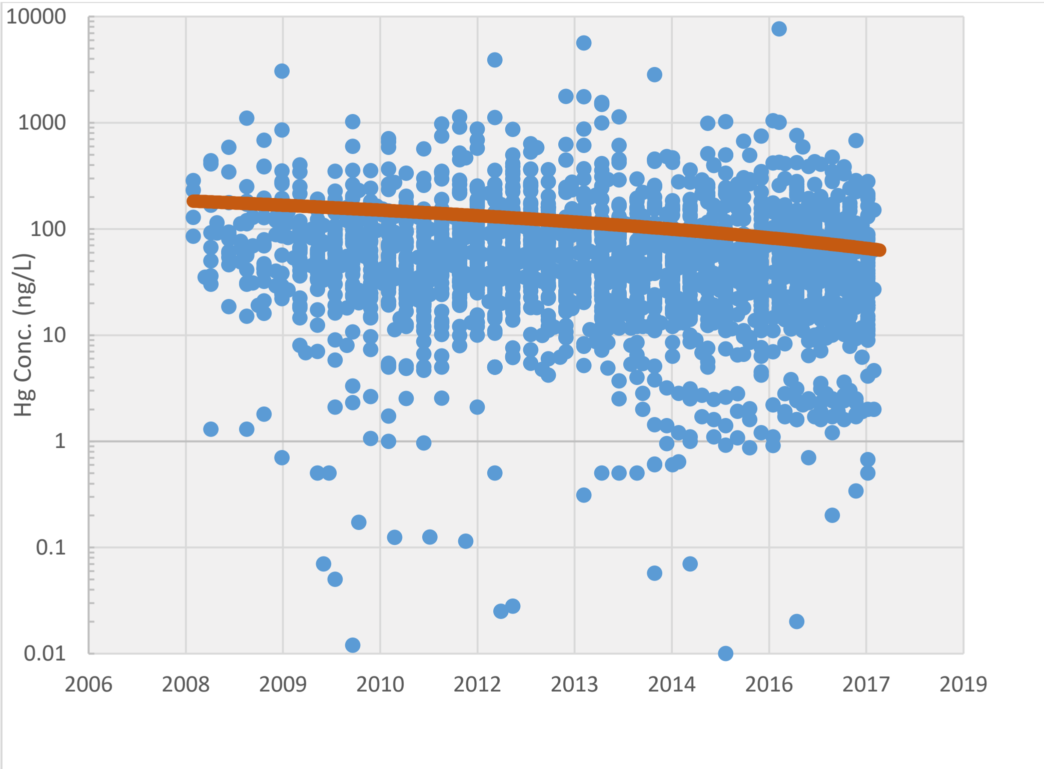

Figure C-7. Influent Data from Major Wastewater Treatment Plants in Minnesota. Source: Minnesota Pollution Control Agency

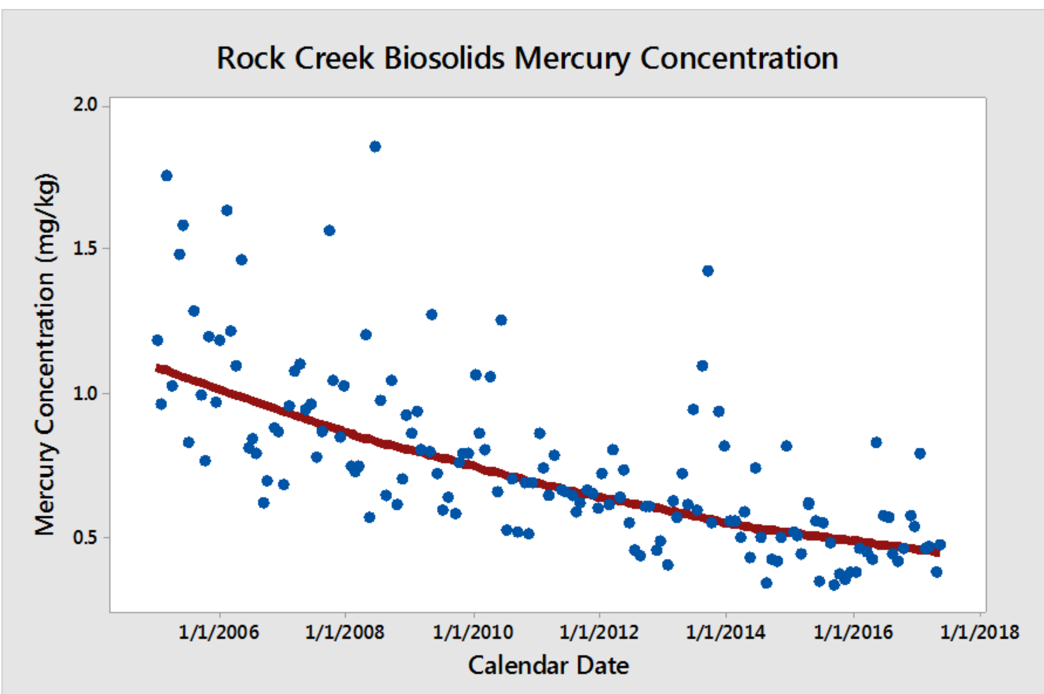

Figure C-8. Mercury Concentrations in Biosolids, Rock Creek Wastewater Treatment Plan. Source: Clean Water Services.

MMP implementation will result in less environmental damage than treatment

While source reduction can attain similar levels as treatment, it also has less environmental costs than treatment. Environmental costs associated with treatment include greater energy use and additions to greenhouse gas emissions, as well as the need for additional waste disposal outweigh any benefit that might come from treatment to reduce mercury.[16]

According to a report from the Water Research Foundation and Electric Power Research Institute, daily energy consumption at advanced treatment plants is about 500-600 kwh per million gallons per day higher than that of secondary activated sludge plants.[17] Thus, for the smallest facility likely to need a variance (those with approximately 1 MGD design flow), the additional annual energy consumption to upgrade to advanced treatment is 219 megawatt-hours per year. This equates to an annual carbon footprint increase of approximately 125 metric tons carbon dioxide equivalent per year.[18] According to U.S. EPA's analysis of the social costs of one metric ton of greenhouse gas emissions in 2020 dollars ranges from $12 to $123[19]. The increased energy consumption at a smaller plant covered by the variance would have a social cost ranging from $1,500 to $15,375 per year, while having a similar outcome to source reduction. For larger facilities that may receive coverage under the variance, additional treatment could equate to as much as 5000 metric tons CO_2 equivalent per year released into the environment. Additional waste disposal required by wastewater treatment would add additional carbon footprint due to the need to haul additional material. Moreover, waste disposal would result in land application of material with concentrated mercury, which would potentially be re-released to the environment.

The total mercury load from all point sources to rivers in the Willamette Basin is 1.6 kg/year, or about 1% of the total annual load of mercury to the basin. Treatment upgrades at the estimated number of facilities with higher mercury concentrations would only reduce a portion of this load, which would also likely be achieved eventually through source reduction without the associated environmental cost. Therefore, DEQ has concluded that the additional energy costs associated with treatment would cause more environmental harm than removing similar amounts of mercury load through source reduction, even though the source reduction may take more time.

[16] DEQ acknowledges that treatment upgrades are sometimes necessary for reasons other than mercury removal. This possibility is incorporated into the procedure for Highest Attainable Condition described in Chapter 6.

[17] Electric Power Research Institute and Water Research Foundation. 2013. Electricity Use and Management in the Municipal Water Supply and Wastewater Industries. 194 pp.

[18] To calculate the annual carbon footprint, DEQ utilized carbon footprint information utilized in the 2019 Triple Bottom Line analysis to support the chloride and mercury variance for the city of Madison, Wisconsin.

[19] https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

Appendix D: Spreadsheet for calculating wasteload and load allocations

This spreadsheet calculates wasteload and load allocations for the Willamette Basin Mercury TMDL.

https://www.oregon.gov/deq/wq/Documents/WillHgAllocations.xlsx

Appendix E: List of designated management agencies and responsible persons

No.	DMA NAME	DMA Category	Land Use	2018 Population	Municipal Stormwater/ Pop Status	New Mercury DMA?	DEQ Region
1	Adair Village	City	Urban	860	<1K	no	WR
2	Albany	City	Urban	53,145	MS4 Phase 2	no	WR
3	Amity	City	Urban	1,655	>1K	yes	WR
4	Aumsville	City	Urban	3,975	>1K	no	WR
5	Aurora	City	Urban	985	<1K	no	WR
6	Banks	City	Urban	1,785	MS4 Phase 1	no	NWR
7	Barlow	City	Urban	135	<1K	no	NWR
8	Beaverton	City	Urban	97,000	MS4 Phase 1	no	NWR
9	Brownsville	City	Urban	1,705	>1K	no	WR
10	Canby	City	Urban	16,800	>10	no	NWR
11	Carlton	City	Urban	2,270	>1K	yes	WR
12	Coburg	City	Urban	1,195	>1K	no	WR
13	Cornelius	City	Urban	11,935	MS4 Phase 1	no	NWR
14	Corvallis	City	Urban	59,280	MS4 Phase 2	no	WR
15	Cottage Grove	City	Urban	10,005	>10K	no	WR
16	Creswell	City	Urban	5,455	>5K	no	WR
17	Dallas	City	Urban	15,830	>10K	no	WR
19	Dayton	City	Urban	2,720	>1K	yes	WR
20	Detroit	City	Urban	210	<1K	no	WR
21	Donald	City	Urban	985	<1K	no	WR
22	Dundee	City	Urban	3,230	>1K	no	WR
23	Durham	City	Urban	1,880	MS4 Phase 1	no	NWR
24	Estacada	City	Urban	3,400	>1K	no	NWR
25	Eugene	City	Urban	169,695	MS4 Phase 1	no	WR
26	Fairview	City	Urban	8,990	MS4 Phase 1	no	NWR
27	Falls City	City	Urban	955	<1K	no	WR
28	Forest Grove	City	Urban	24,125	MS4 Phase 1	no	NWR
29	Gaston	City	Urban	655	MS4 Phase 1	no	NWR
30	Gates	City	Urban	485	<1K	no	WR
31	Gervais	City	Urban	2,585	>1K	no	WR
32	Gladstone	City	Urban	11,880	MS4 Phase 1	no	NWR

No.	DMA NAME	DMA Category	Land Use	2018 Population	Municipal Stormwater/ Pop Status	New Mercury DMA?	DEQ Region
33	Gresham	City	Urban	110,505	MS4 Phase 1	no	NWR
34	Halsey	City	Urban	935	<1K	no	WR
35	Happy Valley	City	Urban	20,945	MS4 Phase 1	no	NWR
36	Harrisburg	City	Urban	3,660	>1K	no	WR
37	Hillsboro	City	Urban	101,920	MS4 Phase 1	no	NWR
38	Hubbard	City	Urban	3,305	>1K	no	WR
39	Idanha	City	Urban	140	<1K	no	WR
40	Independence	City	Urban	9,370	>5K	no	WR
41	Jefferson	City	Urban	3,245	>1K	no	WR
42	Johnson City	City	Urban	560	MS4 Phase 1	no	NWR
43	Junction City	City	Urban	6,125	>5K	no	WR
44	Keizer	City	Urban	38,505	MS4 Phase 2	no	WR
45	King City	City	Urban	3,700	MS4 Phase 1	no	NWR
46	Lafayette	City	Urban	4,105	>1K	yes	WR
47	Lake Oswego	City	Urban	38,215	MS4 Phase 1	no	NWR
48	Lebanon	City	Urban	16,920	>10K	no	WR
49	Lowell	City	Urban	1,075	>1K	no	WR
50	Lyons	City	Urban	1,195	>1K	no	WR
52	McMinnville	City	Urban	33,810	>10K	yes	WR
53	Mill City	City	Urban	1,865	>1K	no	WR
54	Millersburg	City	Urban	2,315	MS4 Phase 2	no	WR
55	Milwaukie	City	Urban	20,525	MS4 Phase 1	no	NWR
56	Molalla	City	Urban	9,625	>5K	no	NWR
57	Monmouth	City	Urban	9,890	>5K	no	WR
58	Monroe	City	Urban	625	<1K	no	WR
59	Mt. Angel	City	Urban	3,415	>1K	no	WR
60	Newberg	City	Urban	23,795	>10K	no	WR
61	North Plains	City	Urban	3,095	MS4 Phase 1	no	NWR
62	Oakridge	City	Urban	3,280	>1K	no	WR
63	Oregon City	City	Urban	34,860	MS4 Phase 1	no	NWR
64	Philomath	City	Urban	4,715	MS4 Phase 2	no	WR
65	Portland	City	Urban	648,740	MS4 Phase 1	no	NWR
66	Rivergrove	City	Urban	505	MS4 Phase 1	no	NWR
67	Salem	City	Urban	165,265	MS4 Phase 1	no	WR
68	Sandy	City	Urban	10,990	>10K	no	NWR

No.	DMA NAME	DMA Category	Land Use	2018 Population	Municipal Stormwater/ Pop Status	New Mercury DMA?	DEQ Region
69	Scappoose	City	Urban	7,200	>5K	yes	NWR
70	Scio	City	Urban	920	<1K	no	WR
71	Scotts Mills	City	Urban	375	<1K	no	WR
72	Sheridan	City	Urban	6,190	>5K	yes	WR
73	Sherwood	City	Urban	19,505	MS4 Phase 1	no	NWR
74	Silverton	City	Urban	10,325	>10K	no	WR
75	Sodaville	City	Urban	345	<1K	no	WR
76	Springfield	City	Urban	60,865	MS4 Phase 2	no	WR
77	St. Helens	City	Urban	13,240	>10K	yes	NWR
78	St. Paul	City	Urban	435	<1K	no	WR
79	Stayton	City	Urban	7,810	>5K	no	WR
80	Sublimity	City	Urban	2,890	>1K	no	WR
81	Sweet Home	City	Urban	9,225	>5K	no	WR
82	Tangent	City	Urban	1,250	>1K	no	WR
83	Tigard	City	Urban	52,785	MS4 Phase 1	no	NWR
84	Tualatin	City	Urban	27,055	MS4 Phase 1	no	NWR
85	Turner	City	Urban	2,085	MS4 Phase 2	no	WR
86	Veneta	City	Urban	4,790	>1K	no	WR
87	Waterloo	City	Urban	235	<1K	no	WR
88	West Linn	City	Urban	25,830	MS4 Phase 1	yes	NWR
89	Westfir	City	Urban	260	<1K	no	WR
90	Willamina	City	Urban	2,160	>1K	yes	WR
91	Wilsonville	City	Urban	25,250	MS4 Phase 1	no	NWR
92	Wood Village	City	Urban	3,920	MS4 Phase 2	no	NWR
93	Woodburn	City	Urban	24,760	>10K	no	WR
94	Yamhill	City	Urban	1,090	>1K	yes	WR
95	Benton County	County	Urban	93,590	MS4 Phase 2	no	WR
96	Clackamas County	County	Urban	419,425	MS4 Phase 1	no	NWR
97	Columbia County	County	Urban	51,900	>10K	yes	NWR
98	Lane County	County	Urban	375,120	MS4 Phase 2	no	WR
99	Linn County	County	Urban	125,575	MS4 Phase 2	no	WR
100	Marion County	County	Urban	344,035	MS4 Phase 2	no	WR
101	Multnomah Co	County	Urban	813,300	MS4 Phase 1	no	NWR
102	Polk County	County	Urban	82,100	MS4 Phase 2	no	WR

No.	DMA NAME	DMA Category	Land Use	2018 Population	Municipal Stormwater/ Pop Status	New Mercury DMA?	DEQ Region
103	Washington County	County	Urban	606,280	MS4 Phase 1	no	NWR
104	Yamhill County	County	Urban	107,415	>10K	yes	WR
105	U.S. Army Corps of Engineers	Federal	Reservoir	NA	NA	yes	NWR/WR
106	U.S. Bureau of Land Management	Federal	Forestry	NA	NA	no	NWR/WR
107	U.S. Bureau of Reclamation	Federal	Reservoir	NA	NA	yes	NWR
108	U.S. Fish & Wildlife Service	Federal	Forestry	NA	NA	no	NWR/WR
109	U.S. Forest Service	Federal	Forestry	NA	NA	no	NWR/WR
110	Clean Water Services	Special District	Urban	NA	MS4 Phase 1	no	NWR
111	Eugene Water & Electric Board	Special District	Reservoir	NA	NA	no	WR
112	Metro	Special District	Other	NA	NA	no	NWR
113	Oak Lodge Water Services District	Special District	Urban	NA	MS4 Phase 1	yes	NWR
114	Portland General Electric	Special District	Reservoir	NA	NA	?	NWR
115	Port of Portland	Special District	Other	NA	MS4 Phase 1	no	NWR
116	Tualatin Hills Park and Recreation District	Special District	Other	NA	NA	yes	NWR
117	Oregon Dept. of Agriculture	State	Agriculture	NA	NA	no	NWR/WR
118	Oregon Dept. of Env. Quality	State	Other	NA	NA	no	NWR/WR
119	Oregon Dept. of Fish and Wildlife	State	Other	NA	NA	yes	NWR/WR
120	Oregon Dept. of Forestry	State	Forestry	NA	NA	no	NWR/WR
121	Oregon Dept. of Transportation	State	Other	NA	MS4 Phase 1	no	NWR/WR

No.	DMA NAME	DMA Category	Land Use	2018 Population	Municipal Stormwater/ Pop Status	New Mercury DMA?	DEQ Region
122	Oregon Dept. State Lands	State	Other	NA	NA	no	NWR/WR
123	Oregon Dept.Geology & Mineral Ind.	State	Other	NA	NA	yes	NWR/WR
124	Oregon Marine Board	State	Other	NA	NA	yes	NWR/WR
125	Oregon Parks and Recreation Department	State	Other	NA	NA	no	NWR/WR
126	Ash Creek Water Control District (Polk Co.)	Water Conveyance	Transport Water	NA	NA	yes	WR
127	Cedar Creek Irrigation District (Lane Co.)	Water Conveyance	Transport Water	NA	NA	yes	WR
128	Clackamas Bend Water Control District (Clackamas Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
129	Clackamas River Water District (Clackamas Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
130	Cloverdale Water Control District (Lane Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
131	Columbia County Drainage District #1 (Clackamas Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
132	Columbia Drainage District No. 1 and No. 9 (Multnomah Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
133	Cove Orchard Water Association (Yamhill Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
134	Creswell Irrigation	Water Conveyance	Transport Water	NA	NA	yes	WR

No.	DMA NAME	DMA Category	Land Use	2018 Population	Municipal Stormwater/ Pop Status	New Mercury DMA?	DEQ Region
	Association (Lane Co)						
135	Creswell Water Control District (Lane Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
136	Deer Island Drainage Improvement (Clackamas Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
137	Drainage District No. 8 (Washington Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
138	East Valley Water District (Marion Co)	Water Conveyance	Transport Water	NA	NA	no	WR
139	Fertile Improvement District (Lane Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
140	G A Miller Drainage District No 1 (Marion Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
141	Grand Prairie Water Control District (Linn Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
142	Greenberry Irrigation District (Benton Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
143	Hawn Creek District Improvement Co. (Yamhill Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
144	Job's Drainage District (Washington Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
145	Junction City Water Control District (Lane Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
146	Lacomb Irrigation District (Linn Co)	Water Conveyance	Transport Water	NA	NA	yes	WR

No.	DMA NAME	DMA Category	Land Use	2018 Population	Municipal Stormwater/ Pop Status	New Mercury DMA?	DEQ Region
147	Lake Labish Water Control District (Marion Co)	Water Conveyance	Transport Water	NA	NA	no	WR
148	Lower Clackamas River Water Control District 3 (Clackamas Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
149	McKay Creek Water Control District 2 (Washington Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
150	Molalla River Water Control District 3 (Clackamas Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
151	Muddy Creeks Irrigation District (Linn Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
152	Multnomah County Drainage District 1 (Multnomah Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
153	Murray, Smith & Associates, Inc. (Multnomah Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
154	North Lebanon Water Control District (Linn Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
155	Palmer Creek Water District Improvement Co. (Yamhill Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
156	Peninsula Drainage District No. 1 and No. 2 (Multnomah Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR

No.	DMA NAME	DMA Category	Land Use	2018 Population	Municipal Stormwater/ Pop Status	New Mercury DMA?	DEQ Region
157	Queener Irrigation Improvement District (Linn Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
158	Ranier Drainage Improvement Company (Columbia Co.)	Water Conveyance	Transport Water	NA	NA	yes	NWR
159	Rock Creek Water District (Polk/Yamhill Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
160	Sandy Drainage Improvement District No. 1 (Multnomah Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
161	Santiam Water Control District (Marion Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
162	Sauvie Island Drainage District (Multnomah Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
163	Scappoose Drainage Improvement Company (Columbia Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
164	Scio Water Improvement District (Linn Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
165	Shady Dell Water Control District (Clackamas Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
166	Sidney Irrigation District (Marion Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
167	South Santiam River Water Control District (Marion Co)	Water Conveyance	Transport Water	NA	NA	yes	WR

No.	DMA NAME	DMA Category	Land Use	2018 Population	Municipal Stormwater/ Pop Status	New Mercury DMA?	DEQ Region
168	Tualatin Valley Irrigation District (Washington Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
169	Washington County Drainage District No. 7 (Washington Co)	Water Conveyance	Transport Water	NA	NA	yes	NWR
170	West Labish Water Control District (Marion Co)	Water Conveyance	Transport Water	NA	NA	yes	WR
171	Woodburn Hubbard Drainage District (Marion Co)	Water Conveyance	Transport Water	NA	NA	yes	WR

Appendix F: Stormwater references and resources

1. Center for Watershed Protection resources: https://www.cwp.org/mission-vision
2. Coquille TMDL Low Impact Development (LID) Implementation Tool: Guidance Document: https://www.oregon.gov/deq/FilterDocs/coqlidguidance.pdf
3. EPA Stormwater resources: https://www.epa.gov/npdes/npdes-stormwater-program
4. Low Impact Development in Western Oregon: A Practical Guide to Watershed Health: https://www.oregon.gov/deq/wq/tmdls/Pages/TMDLs-LID.aspx
5. SRF Program website: https://www.oregon.gov/deq/wq/cwsrf
6. TMDL Implementation Guidance: Guidance for Including Post Construction Elements in TMDL Implementation plans: https://www.oregon.gov/deq/FilterDocs/tmdls-07wq004tmdlimplplan.pdf

Appendix G: Oregon permitted mercury air emissions

Table G-1. 2016 Reported Mercury Emissions from Permitted Sources in the Willamette Basin

Source Number	Source Name	2016 Mercury Emissions [kg/yr]
36-5034	Cascade Steel Rolling Mills	22.889
24-5398	Covanta Marion, Inc.	2.984
22-3501	Cascade Pacific Pulp, LLC	1.297
26-3021	American Petroleum Environmental Services	0.576
22-6002	Freres Lumber Co. Inc. Lyons Facility	0.467
22-3010	Weyerhaeuser Company - Foster Engineered Lumber Products	0.317
34-2066	Stimson Lumber Company - Forest Grove Facility	0.281
02-2298	Oregon State University	0.222
22-2525	Frank Lumber Co., Inc.	0.222
26-1876	Owens-Brockway Glass Container Inc.	0.209
26-1865	EVRAZ Portland - Rivergate	0.177
34-2681	Intel Corporation	0.163
02-2173	Hollingsworth & Vose Fiber Company	0.136
22-2522	Freres Lumber Plant # 3 Plywood Division	0.136
22-0143	Flakeboard America Limited, Duraflake	0.127
26-2068	ESCO Corporation	0.082
22-1034	Bear Mountain Forest Products, Inc.	0.073
34-0157	T5 Datacenters	0.073
26-2050	Oregon Health and Sciences University	0.068
36-8031	Boise Cascade - Willamina Veneer	0.059
05-1849	Cascades Tissue Group - Oregon	0.054
22-0547	TDY Industries, LLC dba ATI Specialty Alloys and Components	0.054
22-6024	ENTEK International LLC	0.054
26-0088	Mutual Materials Company	0.054
26-1867	PCC Structurals, Inc., LPC	0.050
02-9502	Valley Landfills, Inc.	0.041
22-6034	Georgia-Pacific Consumer Products LP - Halsey Mill	0.041
36-0011	Riverbend Landfill	0.041
03-2533	Interfor US Inc. – Molalla Division	0.036
26-3009	Arclin Portland Division	0.031
03-1791	Sanders Wood Products/RSG	0.027
22-0328	Oregon Metallurgical, LLC dba ATI Albany Operations	0.027
03-0011	Clackamas County Tri-City Water Pollution Control Plant	0.023
26-2204	The Boeing Company	0.023

Source Number	Source Name	2016 Mercury Emissions [kg/yr]
26-2968	Mondelez Global LLC	0.022
26-3240	Microchip Technology Inc.	0.022
26-3310	Metropolitan Service District. Saint Johns Landfill	0.022
24-5155	Oregon State Penitentiary	0.020
24-0060	Snyder's Lance Inc.	0.019
03-0010	Clackamas County Kellogg Creek Water Pollution Control Plant	0.018
03-0020	PCC Structurals, Inc., Deer Creek	0.018
03-2674	PCC Structurals, Inc., SSBO	0.018
26-0027	On Semiconductor	0.018
26-2914	Port of Portland	0.017
34-0067	CoorsTek Oregon Operations	0.017
26-3048	Oil Re-Refining Company	0.016
24-7067	NORPAC Foods, Inc. Stayton Plant #1	0.015
26-3067	Owens Corning Roofing and Asphalt, LLC	0.015
27-0012	Meduri Farms, Inc.	0.015
34-0010	SolarWorld Americas, Inc.	0.015
26-1815	Owens Corning Roofing & Asphalt, LLC	0.014
26-1894	Herbert Malarkey Roofing Company	0.014
34-9514	Agilyx Corporation	0.014
26-3267	U.S. Bancorp Columbia Center	0.013
34-0004	Hillsboro Landfill	0.013
26-2557	Blasen & Blasen Lumber Corp.	0.012
26-2952	United States Bakeries dba as Franz Bakery	0.011
26-0100	Columbia Boulevard WWTP	0.011
03-2624	Blount, Inc.	0.009
22-0011	Pacific Cast Technologies, Inc. dba ATI Cast Products	0.009
22-8045	OFD Foods, LLC - Plant 2 & 3	0.009
22-8056	EnerG2 Technologies, Inc.	0.009
26-1891	Ash Grove Cement Company - Rivergate	0.009
26-2197	Daimler Trucks North America, LLC.	0.009
26-3224	Vigor Industrial, LLC	0.009
34-0063	Lam Research	0.009
34-2804	Maxim Integrated	0.009
26-2390	Supreme Perlite Company	0.008
26-3291	The Boeing Company	0.008
34-2783	Bimbo Bakeries USA, Inc.	0.008
34-2813	Jireh Semiconductor Inc.	0.008
34-2638	Tektronix, Inc.	0.008
26-2777	Graphic Packaging International, Inc.	0.007
26-3135	Bullseye Glass Company	0.007

Source Number	Source Name	2016 Mercury Emissions [kg/yr]
26-3241	Sapa Extrusions	0.007
36-7004	McFarland Cascade Holdings Inc.	0.007
26-2025	Arc Terminals Holdings, LLC	0.007
26-3051	International Paper- Portland Container	0.007
34-0055	Qorvo US	0.006
24-8061	Boise Packaging & Newsprint, L.L.C. (subsidiary of Packaging Corporation of America)	0.006
26-2944	Gunderson, LLC.	0.006
22-8050	Stahlbush Island Farms, Inc.	0.005
26-2043	CertainTeed Corporation	0.005
34-0009	International Paper	0.005
26-1885	Galvanizers Company	0.005
26-2832	Portland State University	0.005
03-0098	PECO, Inc.	0.005
03-2634	Johnson Controls Battery Group, Inc.	0.005
03-2738	Consolidated Metco Inc.	0.005
03-2754	Safeway Clackamas Bread Plant	0.005
22-1024	Georgia-Pacific Chemicals LLC - Albany	0.005
26-2027	Chevron Products Company Willbridge Terminal	0.005
34-2678	Viasystems Corporation (dba TTM Technologies, Inc.)	0.005
26-2026	Phillips 66 Company	0.004
34-0005	Valmont Industries, Inc.	0.004
03-0050	Xerox	0.004
03-0099	Carver Readiness Center	0.004
26-3002	Siltronic Corporation	0.004
27-8034	Forest River, Inc.	0.003
27-0004	Forest River, Inc.	0.003
03-0093	Dave's Killer Bread	0.003
03-2505	Orchid Othropedic Solutions	0.003
34-2753	Rock Creek Advanced Wastewater Treatment Facility	0.003
34-9510	Summit Natural Energy	0.003
36-9504	City of Newberg WWTP	0.003
24-8062	Foster Farms, LLC - Donald Feedmill	0.003
34-2790	Tokyo Ohka Kogyo America, Inc.	0.003
22-6029	Panolam Industries Inc.	0.003
26-2572	Container Management Services, LLC	0.002
26-3272	Oldcastle APG West, Inc. dba Sakrete of the Pacific Northwest	0.002
02-9503	Pacific Northwest Generating Cooperative	0.002
22-6009	W. R. Grace	0.002
26-9550	Portland Service Center	0.002

Source Number	Source Name	2016 Mercury Emissions [kg/yr]
24-0070	Specialty Polymers, Inc.	0.002
27-0005	Elkay Wood Products Company	0.002
03-2719	Georgia-Pacific Gypsum, LLC	0.001
22-8043	Forest River, Inc.	0.001
34-2623	Durham Facility	0.001
26-1869	Columbia Steel Casting Co., Inc.	0.001
26-2030	BP West Coast Products, LLC: Portland Terminal - Seaport Midstream partners	0.001
22-8041	Selmet Inc.	0.001
24-9213	Panasonic Eco Solutions Solar America, LLC	0.001
36-8010	Hampton Lumber Mills, Inc. dba Willamina Lumber Company	0.001
03-0037	J and D Fertilizers, Ltd.	0.001
34-0058	International Paper Co.	0.001
26-1889	J.R. Simplot Company, Rivergate Terminal	0.001
34-0149	Avery Regional Service Center	0.001
26-2492	Northwest Pipe Company	0.001
26-3230	Lacamas Laboratories	0.001
24-0031	Superior Tire Service, Inc.	0.001
24-0136	City of Salem - Willow Lake WPCF	0.001
26-9554	Signature Graphics, Inc.	0.001

Appendix H: Willamette River Instream Surrogate TSS-THg Analysis

Draft of Willamette River Instream Surrogate TSS-THg Analysis

Janani Govindan, Dan Sobota, and Kevin Brannan

July 3, 2019

Executive Summary

The Oregon Department of Environmental Quality (ODEQ) requires that Total Maximum Daily Load (TMDL) targets for mercury concentrations are meet in the Willamette River. An analysis was conducted using regression models to assess how Total Suspended Solid (TSS) concentrations could be used as a surrogate measure for instream total mercury (THg) concentrations in the Willamette River Basin. The dataset used for the modeling comprised of 63 surrogate TSS-THg samples with mercury concentrations above detection limits that were collected from 17 different sites that were dispersed throughout 9 HUC 8 subbasins within the Willamette River Basin. The following models were conducted for the analysis: An Ordinary Least Squares (OLS) model, a Linear mixed effects (LME) model with dry/wet seasons as a fixed effect and sites as a random effect, and an LME model with sites (excluding dry/wet seasons as a fixed effect). The results for the OLS model indicated that only 32% of the variance in THg concentrations could be explained by differences in TSS concentrations. The OLS model results suggested that other factors, such as spatial and temporal patterns, need to be taken into account for the analysis. The results for the LME model with dry/wet seasons as a fixed effect indicated that 80% of the variance in THg concentrations within the Willamette River could be explained by differences in TSS concentrations and by differences in site location, while 81% of the variance was explained by the LME model with sites as a random effect. Overall, the results suggest that spatial patterns such as site locations play a more significant role than temporal patterns such as seasonal differences (dry/wet periods) in the analysis. Thus, the LME model with sites was selected for the instream analysis.

Recommendations based on the analysis are listed below:

1) The LME model with sites should be used as a basis for establishing guidelines for the Willamette Basin Mercury TMDL

2) The LME equation can be used to find estimated TSS concentrations and percent reductions of THg concentrations

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1.1 Introduction

The Oregon Department of Environmental Quality (ODEQ) has established a Total Maximum Daily Load (TMDL) for total mercury (THg) in the Willamette River and its tributaries to restore the beneficial use of fish consumption. The Willamette Basin Mercury TMDL was established to reduce concentrations of mercury to a level that no longer poses to be an unacceptable health risk to humans and aquatic wildlife. The Willamette Basin Mercury TMDL establishes acceptable loads (nonpoint sources) and wasteloads (point sources) of total mercury in the Willamette River Basin. The ODEQ has established an instream TMDL target THg concentration of 0.14 ng/L within the Willamette River Basin based on the simulated bioaccumulation of methylmercury for Northern Pikeminnow (ODEQ, 2019). However, because monitoring for total mercury can be difficult and cost-prohibitive, agencies and monitoring groups often use total suspended solids (TSS) as a surrogate for THg in stream. TSS is often used as a surrogate for pollutants, such as heavy metals and organic pollutants (Eckley & Branfireun, 2009). For example, TSS was used as a surrogate for DDT (Dichlorodiphenyltrichloroethane) to meet instream targets for the Lower Yakima TMDL in Washington (Johnson, 2007). A positive correlation between TSS and THg due to the capacity of THg to bind to particulate matter makes TSS a useful surrogate measure (Eckley & Branfireun, 2008). Therefore, provided that there is correlation between TSS and THg within the mainstem Willamette River and its tributaries, TSS could be used to predict instream THg concentrations in the Willamette River Basin (Hope & Rubin, 2004).

There are several major sources of THg concentrations within the Willamette River, including atmospheric deposition, soil/sediment erosion, and point source discharges from industrial facilities and stormwater outfalls. However, because controlling the sources of THg in atmospheric deposition is not tenable, DEQ has focused on controlling processes that increase of instream THg concentrations, including soil/sediment erosion (ODEQ, 2019).

The Environmental Protection Agency (EPA) and DEQ are using the watershed model Hydrological Simulation Program-FORTRAN (HSPF) to examine THg sources in surface water, subsurface systems, and soil/sediment erosion. Overall, this model can be used to assess the mass transport of THg from different land uses throughout the Willamette River Basin (TetraTech, 2019). For particulate THg, the HSPF model uses soil erosion rates simulated by the model paired with soil-THg data (weight of THg per weight of eroded soil) to calculate the mass transport of particulate THg to set particulate THg loads (TetraTech, 2019). Thus, the HSPF model provides calculations of the distribution of mercury in the water column and sediment.

1.2 Methods

TetraTech, contracted by the Environmental Protection Agency (EPA), provided the paired surrogate data (TSS and THg concentrations) used in the analysis. Data had been compiled from the Willamette River Basin Mercury database (WRB Hg database) and from the Water Quality Portal (WQP) (TetraTech, 2018). There were 187 instream TSS-THg samples collected along the Willamette River main stem (from Portland to Cottage Grove) and tributaries leading into the Willamette River (Tualatin River, Clackamas River, North Santiam River, etc.) (Table 1; Figure 1 and 2). Samples of total mercury concentrations collected along the Portland Harbor Superfund site were high probably because of decades of industrial contamination along the site. Also, the influence of tidal exchange may cause excess mercury to exchange with sediments differently than in a unidirectional flow environment. To avoid combining paired data from different aquatic environments, all of the surrogate samples collected from the Portland Harbor Superfund site were omitted from the dataset, resulting in a total of 185 samples. Additionally, non-detect (censored) data were excluded from the analysis, resulting in a total of 63 instream surrogate samples with detected mercury concentrations from 17 sampling locations (see discussion of methods for non-detect data in section 1.2.1) (Table 2).

All data were extracted from the WRB Hg database from 1/1/2002 to present. The 63 paired samples were collected from 9 different HUC 8 subbasins within the Willamette River Basin (Table 1; Figure 3). All of the 63 surrogate pairs had mercury concentrations with a detection limit of 0.5 ng/L (EPA Method 1631), which is above the instream target of 0.14 ng/L THg set for the Willamette. All of the samples used for the analysis were above this detection limit.

Each pair of surrogate TSS-THg data consisted of 1 TSS (mg/L) and 1 THg (ng/L) concentration that was collected at the same time and date. The sites (sampling locations) used in the analysis were defined by the latitude and longitude coordinates where the samples were collected.

The following methods were used:

- An initial exploratory analysis was used to provide summary statistics of TSS and THg and insights on transformation needed.
- Box-Cox transformations were used to determine the most suitable power transformation to normalize the error distribution in the response variable.
- Linear models were used to quantify the relationship between TSS and THg:
  - Ordinary Least Square (OLS) model
  - Linear Mixed Effects (LME) model with sites as a random effect and dry/wet seasons as a fixed effect
  - Linear Mixed Effects (LME) model with sites as a random effect

The LME model was used to account for differences in site specific variation in parameters, and the addition of dry/wet seasons as a fixed effect was used to account for how dry/wet seasons impact the change in mean THg concentrations as seasons are one of the big drivers of precipitation within the Willamette River Basin (ODEQ, 2019). If the surrogate samples were collected from the months of June through October then it was classified as a dry season surrogate sample and if the surrogate samples were collected from the months of November through May then it was classified as a wet season surrogate sample.

To assess if the model sufficiently described the relationship between THg and TSS in the Willamette River, a diagnostic check of normality, constant variance, and independence was conducted for the two models. All analyses were conducted using R Version 3.5, Microsoft Office Excel (2016), and ArcMap version 10.5.1.

1.2.1 Addressing Non-Detect (Censored) data

The dataset contained 65% of non-detect (censored) data, as there were 122 TSS-THg surrogate pairs with non-detected mercury concentrations within the original dataset of 187 surrogate pairs that TetraTech had provided DEQ. A total of five method detection limits (MDLs) were reported for the THg concentrations (0.5 ng/L, 20 ng/L, 30 ng/L, 40 ng/l, and 80 ng/l). There are several statistical techniques, such as the Maximum Likelihood Estimation (MLE) and the Regression on Order Statistics (ROS), that can handle non-detect data with multiple detection limits and can used to estimate the distribution of non-detects and determine summary statistics such as the mean and standard deviation of THg concentrations (Helsel, 2005). However, the larger the magnitude of the detection (censoring) limits, the more uncertainty and information loss when it comes to estimating model parameters (ITRC, 2013). Therefore, with a significant difference in the order of magnitude between the detection limits (i.e. 0.5 ng/L versus

20, 30, 40, or 80 ng/L), the decision was made to remove the 122 non-detects from the dataset. A total of 63 surrogate pairs with detected THg concentrations were used for the instream analysis and all of the pairs had THg concentrations above their respective detection limit of 0.5 ng/L.

1.2.2 Ordinary Least Squares

The ordinary least squares (OLS) model was constructed using TSS as the independent variable (fixed effect) and THg as the dependent variable. The OLS model assumes normality in parameter estimates and in the distribution of residuals. THg Concentrations, as a function of TSS concentrations, were generated using the following equation:

$\mu\{Y|X\} = \beta_0 + \beta_1 X$ where,

Y (Response Variable) = log10 transformed THg concentrations (ng/L)

X (Predictor Variable) = log10 transformed TSS concentrations (mg/L)

β_0 = Intercept

β_1 = Slope (Rate of change in log10 transformed THg concentrations as a function of the change in log10 transformed TSS concentrations)

1.2.3 Linear Mixed-Effects Model

The LME model is similar to the OLS model, as it also uses the dependent variable (THg concentrations) and the fixed effect (TSS concentrations), but it also includes a random effects variable (sites). Random effects and fixed effects are both explanatory variables. However, random effects explain the change in the variance of the dependent variable and the fixed effect explains the change in the mean of the dependent value. In other words, we expect that mean THg concentrations will increase with TSS concentrations across all sites, but that the variance around the increase may depend on the given site.

Two LME models were used for the analysis, with both incorporating sites as a random effect. One LME model included dry/wet seasons as an additional fixed effect while the second LME model excluded the fixed effect of dry/wet seasons. By including dry/wet seasons as a fixed effect, we expect that the mean THg concentrations will increase or decrease according to whether the samples were collected during dry (months of June-October) or wet (months of November-May) seasons. Thus, in order to test the hypothesis that THg will increase with TSS and that mean THg concentrations will increase or decrease according to whether it is a dry or wet season, both site and seasonal variation should be taken into account using the mixed effects model approach.

A random intercept LME model was fitted to the data to model differences between sites within the same data set. A total of 63 paired samples were split into 17 groups of sites. The LME model used the following general equation (Helwig, 2017):

$\mu\{Y|X_1, X_2, V\} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \Sigma(V_i + \epsilon \sim N(0,\sigma^2))$ where,

Y (Response Variable) = log10 transformed THg concentrations (mg/L)

X_1 (Predictor Variable/Fixed Effect) = log10 transformed TSS concentrations (mg/L)

X_2 (Additional Fixed Effect) = seasons (dry/wet)

V_i (intercepts of each random effect) = sampling sites

β_0 = Intercept

β_1 = Slope (Rate of change in log10 transformed THg concentrations as a function of the change in log10 transformed TSS concentrations)

β_2 = Slope (Rate of change in log10 transformed THg concentrations as a function of change in seasons (dry/wet)

σ^2 = Error of the residuals (where N represents residuals that are normally distributed with a mean of zero and have a variance of σ^2)

1.2.4 Prediction Intervals

A 95 percent prediction interval was used to calculate a likely range of future THg values based on the LME models.

1.3 Results

The plots demonstrate a right-skewed distribution of sampling data (Figure 4). The skewed data were transformed to improve normality of the data distribution, which is needed to meet that assumptions for the OLS model. The variation in TSS-THg concentrations across all HUC 8 subbasins and within each individual HUC 8 subbasin was examined (Table 3, Table 4, and Table 5). Scatterplots were used to illustrate the variation in TSS-THg Concentrations across all HUC 8 subbasins and across dry/wet seasons (Figure 5, Figure 6, and Figure 7).The scatterplots indicate that there is a stronger correlation between TSS and THg concentrations within the Upper Willamette, Middle Willamette, and Clackamas subbasins and that THg and TSS concentrations tend to be higher in the wet season. As determined by the box-cox transformation, a log10 transformation was applied to the independent (predictor) and dependent (response) variables for development of the OLS regression (Figure 8).

The OLS model showed a significant ($p < 6.62 \times 10^{-8}$) correlation between THg and TSS concentrations. However, the OLS model provides a weak fit to the data as there is a large difference between the values of THg sample concentrations and the THg concentrations predicted by the OLS regression (Figure 9). An adjusted R-squared value of 0.372 indicates that TSS concentrations alone does explain a large amount of variation in THg concentrations (Table 6 and Table 9). The following OLS equation was determined:

(1) log_{10}(THg conc.) = 0.412 x log_{10}(TSS conc.) - 0.062

The LME model, with sites as a random effect and the addition of dry/wet seasons as a fixed effect showed a significant ($p < 3.68 \times 10^{-10}$) positive correlation between THg and TSS concentrations (Table 7; Figure 10). The conditional (fixed and random effects added together) R-squared value was 0.80 versus 0.465 for the marginal (fixed effects only) R-squared value (Table 9). The variance of THg due to TSS increased greatly with the addition of the random effects variable (Table 7). The following equation which resulted from the LME model was used:

(2) log_{10}(THg conc.) = 0.449 x log_{10}(TSS conc.) + 0.064 x (Seasons) - 0.086

The LME model without the fixed effect of dry/wet seasons performed slightly better than the LME model with seasons (Table 8; Figure 11). The conditional R-squared value of the model (0.81) was slightly bigger than the conditional R-squared value from the LME model including seasons (0.80) (Table 9). The variance of THg due to TSS increased greatly with the addition of the random effect in both LME models.

(3) log_{10}(THg conc.) = 0.506 x log_{10}(TSS conc.) - 0.089

Overall, both LME models performed better in quantifying the correlation between THg and TSS concentrations than the OLS model. The 95 percent prediction intervals for the range of samples and model parameters are displayed in Figure 10 and Figure 11. The diagnostic statistics for the OLS model and LME model are presented in Figure 12-14. Estimated TSS concentrations based on the LME model with sites as a random effect are listed in Table 10, and percent reductions of THg are listed in Table 11. In addition, a cumulative distribution function (cdf) plot of TSS sample concentrations for uncensored data is displayed in Figure 15.

1.4 Discussion

The OLS model results indicate that TSS concentrations could explain < 50% of variation in THg concentrations. Without taking sites or dry/wet seasons into account when developing the model, model error estimates may be too high for predictions. Additionally, the high uncertainty of the OLS model may result from spatial or temporal patterns in the data that needed to be taken into account within the model.

In order to account for spatial variability, a random effect of sites was incorporated into the LME models. To account for temporal variability, dry/wet seasons were included as a fixed effect in the LME model with sites as a random effect. Two LME models were fit to the sample data in order to quantify how much of the residual variation (variation in the error) in THg concentrations could be taken into account by the random effect of sites and to quantify if dry/wet seasons affected the mean of THg concentrations. Although both of the LME models performed well, the LME model which excluded dry/wet seasons as a fixed effect and included sites as a random effect performed slightly better than the LME model including dry/wet seasons as a fixed effect in explaining the variance in THg concentrations. Thus, the results of the analysis indicate that dry/wet seasons do not play a significant role in explaining the change in mean THg concentration values. These results also indicate that sites (sampling locations) play an important role in affecting variation in THg concentrations. Thus, the LME model with sites (excluding dry/wet seasons) was selected for the instream analysis.

1.5 Recommendations

The LME model with sites (sampling locations) only can be used to calculate TSS concentrations that correspond to designated THg concentrations. For instance, the LME equation can be used to find estimated TSS concentrations and calculate percent reductions of THg concentrations (example applications are listed below). Based on the strong relationship found between total suspended solids and total mercury interim goals were set for reductions in TSS concentration to measure progress in the reduction in total mercury loads. The approach is to set reductions in the 75-percentile for the TSS concentration over time. The initial 75 percentile of TSS concentration is based on the 2019 dataset used to develop the TSS and total mercury concentrations. The schedule is listed in Table 12. The 75th percentile for the total suspended solids concentrations can be seen in Figure 16, which is the empirical cumulative distribution function for the observed total suspended solids concentrations. The empirical cumulative distribution function will be reanalyzed when new data becomes available and a Bayesian inference approach to structured decision making (Conroy & Peterson, 2013) will be used to update the statistical distribution used to assess the progress in meeting the reduction targets and to reassess past targets if any had occurred.

LME Model Equation excluding seasons:

log_{10}(THg conc.) (mg/L) = 0.506 x log_{10}(TSS conc.) (mg/L) - 0.089

Example Application of LME Model excluding seasons:

(1) To find estimated TSS Concentrations (The range of THg concentrations were based on the THg summary statistics)

- ***Substitute 0.14 ng/L for the THg Concentration (instream THg target)***

0.14 ng/L =1.4 x 10^{-7}mg/L

Log10 (1.4 x 10^{-7}) = 0.506 x log10 (X) - 0.089

-6.85387 = 0.506 x log10 (X) – 0.089

(-6.85387 + 0.089) = 0.506 x log10 (X)

(-6.85387 + 0.089)/ 0.506 = log10 (X)

-13.3693 = log10 (X)

X = 4.272 x 10^{-14} TSS mg/L

(2) To find percent reductions in THg concentrations:

<u>Percent Reduction from 100 mg/L to 80 mg/L</u>

- Su***bstitute 100 mg/L for the TSS Concentration***

log10 (THg conc.) = 0.506 x log10 (100 mg/L) -0.089

log10 (THg conc.) = 0.923

$10^{(0.923)}$ = 8.38 mg/L

- ***Substitute 80 mg/L for the TSS Concentration***

log10 (THg conc.) = 0.506 x log10 (80 mg/L) -0.089

log10 (THg conc.) = 0.874

$10^{(0.874)}$ = 7.48 mg/L

- ***Use the following equation to find the percent reduction***

% Reduction = (Original value – New value)/ (Original value) x 100

(8.38-7.48)/ (8.38) x 100 = 10.7

1.6 Tables

Table 1: Full TSS-THg Dataset Provided by TetraTech for the Instream Willamette River Basin Surrogate Analysis

Samples	Sampling Date	THg (ng/L)	TSS (mg/L)	THg non-detect (ND)	MDL of THg (ng/L)	Excluded from Analysis	Reasons Excluded
1	9/6/2002	187.000	4.40	NO	NA	YES	PDX Harbor Superfund Site
2	11/8/2004	40.000	5.00	YES	40.0	YES	ND THg
3	11/10/2004	40.000	5.00	YES	40.0	YES	ND THg
4	11/12/2004	40.000	7.00	YES	40.0	YES	ND THg
5	11/12/2004	40.000	5.00	YES	40.0	YES	ND THg
6	11/12/2004	40.000	5.00	YES	40.0	YES	ND THg
7	11/15/2004	40.000	8.00	YES	40.0	YES	ND THg
8	11/17/2004	40.000	5.00	YES	40.0	YES	ND THg
9	11/18/2004	40.000	5.00	YES	40.0	YES	ND THg
10	11/19/2004	40.000	5.00	YES	40.0	YES	ND THg
11	11/19/2004	40.000	8.00	YES	40.0	YES	ND THg
12	11/22/2004	40.000	7.00	YES	40.0	YES	ND THg
13	11/23/2004	40.000	7.00	YES	40.0	YES	ND THg
14	11/23/2004	40.000	6.00	YES	40.0	YES	ND THg
15	11/29/2004	40.000	5.00	YES	40.0	YES	ND THg
16	11/30/2004	40.000	5.00	YES	40.0	YES	ND THg
17	12/1/2004	40.000	5.00	YES	40.0	YES	ND THg
18	12/1/2004	40.000	7.00	YES	40.0	YES	ND THg
19	12/1/2004	40.000	5.00	YES	40.0	YES	ND THg
20	12/1/2004	40.000	5.00	YES	40.0	YES	ND THg
21	12/1/2004	40.000	5.00	YES	40.0	YES	ND THg
22	12/2/2004	40.000	5.00	YES	40.0	YES	ND THg
23	12/2/2004	40.000	5.00	YES	40.0	YES	ND THg
24	12/2/2004	40.000	5.00	YES	40.0	YES	ND THg
25	3/1/2005	40.000	5.00	YES	40.0	YES	ND THg
26	3/3/2005	40.000	5.00	YES	40.0	YES	ND THg
27	3/4/2005	40.000	10.00	YES	40.0	YES	ND THg
28	3/4/2005	40.000	5.00	YES	40.0	YES	ND THg
29	3/4/2005	40.000	5.00	YES	40.0	YES	ND THg
30	3/4/2005	40.000	5.00	YES	40.0	YES	ND THg
31	3/7/2005	40.000	6.50	YES	40.0	YES	ND THg

Samples	Sampling Date	THg (ng/L)	TSS (mg/L)	THg non-detect (ND)	MDL of THg (ng/L)	Excluded from Analysis	Reasons Excluded
32	3/9/2005	40.000	6.00	YES	40.0	YES	ND THg
33	3/10/2005	40.000	6.00	YES	40.0	YES	ND THg
34	3/11/2005	40.000	5.00	YES	40.0	YES	ND THg
35	3/11/2005	40.000	5.25	YES	40.0	YES	ND THg
36	3/14/2005	40.000	7.00	YES	40.0	YES	ND THg
37	3/15/2005	40.000	5.00	YES	40.0	YES	ND THg
38	3/16/2005	40.000	9.00	YES	40.0	YES	ND THg
39	3/16/2005	40.000	14.00	YES	40.0	YES	ND THg
40	3/16/2005	40.000	5.00	YES	40.0	YES	ND THg
41	3/16/2005	40.000	10.00	YES	40.0	YES	ND THg
42	3/16/2005	40.000	5.00	YES	40.0	YES	ND THg
43	3/17/2005	40.000	5.00	YES	40.0	YES	ND THg
44	3/17/2005	40.000	6.00	YES	40.0	YES	ND THg
45	3/17/2005	40.000	7.00	YES	40.0	YES	ND THg
46	5/23/2005	2.170	17.00	NO	0.5	NO	NA
47	7/5/2005	80.000	9.00	YES	80.0	YES	ND THg
48	7/5/2005	80.000	15.00	YES	80.0	YES	ND THg
49	7/5/2005	80.000	13.00	YES	80.0	YES	ND THg
50	7/5/2005	80.000	7.00	YES	80.0	YES	ND THg
51	7/6/2005	80.000	8.00	YES	80.0	YES	ND THg
52	7/8/2005	80.000	10.00	YES	80.0	YES	ND THg
53	7/8/2005	80.000	5.50	YES	80.0	YES	ND THg
54	7/8/2005	80.000	7.00	YES	80.0	YES	ND THg
55	7/11/2005	80.000	17.00	YES	80.0	YES	ND THg
56	7/12/2005	80.000	25.00	YES	80.0	YES	ND THg
57	7/13/2005	80.000	8.00	YES	80.0	YES	ND THg
58	7/14/2005	80.000	4.00	YES	80.0	YES	ND THg
59	7/15/2005	80.000	10.00	YES	80.0	YES	ND THg
60	7/15/2005	80.000	13.00	YES	80.0	YES	ND THg
61	7/15/2005	80.000	5.00	YES	80.0	YES	ND THg
62	7/15/2005	80.000	7.00	YES	80.0	YES	ND THg
63	7/18/2005	80.000	7.00	YES	80.0	YES	ND THg
64	7/19/2005	80.000	5.00	YES	80.0	YES	ND THg
65	7/20/2005	80.000	8.00	YES	80.0	YES	ND THg
66	7/20/2005	80.000	12.00	YES	80.0	YES	ND THg

Samples	Sampling Date	THg (ng/L)	TSS (mg/L)	THg non-detect (ND)	MDL of THg (ng/L)	Excluded from Analysis	Reasons Excluded
67	7/20/2005	80.000	3.00	YES	80.0	YES	ND THg
68	7/20/2005	80.000	4.00	YES	80.0	YES	ND THg
69	1/19/2006	80.000	49.00	YES	80.0	YES	ND THg
70	1/20/2006	80.000	62.00	YES	80.0	YES	ND THg
71	1/21/2006	80.000	49.00	YES	80.0	YES	ND THg
72	9/4/2006	20.000	7.00	YES	20.0	YES	ND THg
73	9/5/2006	20.000	1.00	YES	20.0	YES	ND THg
74	9/5/2006	20.000	4.00	YES	20.0	YES	ND THg
75	9/6/2006	20.000	10.00	YES	20.0	YES	ND THg
76	9/6/2006	20.000	5.00	YES	20.0	YES	ND THg
77	9/7/2006	20.000	9.00	YES	20.0	YES	ND THg
78	9/8/2006	20.000	12.00	YES	20.0	YES	ND THg
79	9/12/2006	20.000	10.50	YES	20.0	YES	ND THg
80	9/13/2006	20.000	3.00	YES	20.0	YES	ND THg
81	11/2/2006	30.000	2.00	YES	20.0	YES	ND THg
82	11/2/2006	25.000	2.50	NO	20.0	YES	PDX Harbor Superfund Site
83	11/2/2006	20.000	4.50	YES	20.0	YES	ND THg
84	11/3/2006	20.000	4.25	YES	20.0	YES	ND THg
85	11/3/2006	20.000	5.25	YES	20.0	YES	ND THg
86	11/3/2006	20.000	3.50	YES	20.0	YES	ND THg
87	11/3/2006	20.000	4.50	YES	20.0	YES	ND THg
88	11/3/2006	20.000	5.00	YES	20.0	YES	ND THg
89	11/4/2006	20.000	4.50	YES	20.0	YES	ND THg
90	11/4/2006	20.000	3.50	YES	20.0	YES	ND THg
91	11/4/2006	20.000	4.00	YES	20.0	YES	ND THg
92	11/4/2006	20.000	3.00	YES	20.0	YES	ND THg
93	11/4/2006	20.000	5.00	YES	20.0	YES	ND THg
94	11/4/2006	20.000	3.50	YES	20.0	YES	ND THg
95	11/4/2006	20.000	5.50	YES	20.0	YES	ND THg
96	11/5/2006	20.000	3.00	YES	20.0	YES	ND THg
97	11/5/2006	20.000	4.50	YES	20.0	YES	ND THg
98	11/5/2006	30.000	3.00	YES	20.0	YES	ND THg
99	11/5/2006	20.000	3.50	YES	20.0	YES	ND THg
100	1/15/2007	30.000	12.50	YES	20.0	YES	ND THg

Samples	Sampling Date	THg (ng/L)	TSS (mg/L)	THg non-detect (ND)	MDL of THg (ng/L)	Excluded from Analysis	Reasons Excluded
101	1/15/2007	40.000	13.00	YES	20.0	YES	ND THg
102	1/15/2007	40.000	12.00	YES	20.0	YES	ND THg
103	2/21/2007	20.000	15.75	YES	20.0	YES	ND THg
104	2/22/2007	20.000	15.60	YES	20.0	YES	ND THg
105	2/23/2007	20.000	21.00	YES	20.0	YES	ND THg
106	2/24/2007	20.000	17.50	YES	20.0	YES	ND THg
107	2/24/2007	20.000	36.00	YES	20.0	YES	ND THg
108	2/25/2007	20.000	15.25	YES	20.0	YES	ND THg
109	2/26/2007	20.000	21.50	YES	20.0	YES	ND THg
110	2/26/2007	20.000	14.25	YES	20.0	YES	ND THg
111	2/27/2007	20.000	27.00	YES	20.0	YES	ND THg
112	2/27/2007	20.000	33.00	YES	20.0	YES	ND THg
113	3/1/2007	20.000	22.00	YES	20.0	YES	ND THg
114	3/1/2007	20.000	18.25	YES	20.0	YES	ND THg
115	3/1/2007	20.000	19.50	YES	20.0	YES	ND THg
116	3/2/2007	20.000	23.00	YES	20.0	YES	ND THg
117	3/3/2007	20.000	18.50	YES	20.0	YES	ND THg
118	3/3/2007	20.000	16.75	YES	20.0	YES	ND THg
119	3/4/2007	20.000	21.50	YES	20.0	YES	ND THg
120	3/5/2007	20.000	17.50	YES	20.0	YES	ND THg
121	3/8/2007	20.000	10.50	YES	20.0	YES	ND THg
122	3/9/2007	20.000	10.50	YES	20.0	YES	ND THg
123	3/10/2007	20.000	10.00	YES	20.0	YES	ND THg
124	4/5/2010	2.950	9.00	NO	0.5	NO	NA
125	4/5/2010	2.950	11.00	NO	0.5	NO	NA
126	4/5/2010	1.060	4.00	NO	0.5	NO	NA
127	4/5/2010	3.060	20.00	NO	0.5	NO	NA
128	4/5/2010	2.770	11.00	NO	0.5	NO	NA
129	4/6/2010	0.968	1.00	NO	0.5	NO	NA
130	4/7/2010	5.260	5.00	NO	0.5	NO	NA
131	4/7/2010	1.360	2.00	NO	0.5	NO	NA
132	4/7/2010	3.610	5.00	NO	0.5	NO	NA
133	4/7/2010	1.110	4.00	NO	0.5	NO	NA
134	4/8/2010	1.880	15.00	NO	0.5	NO	NA
135	4/19/2010	3.610	8.00	NO	0.5	NO	NA

Samples	Sampling Date	THg (ng/L)	TSS (mg/L)	THg non-detect (ND)	MDL of THg (ng/L)	Excluded from Analysis	Reasons Excluded
136	4/20/2010	1.440	6.00	NO	0.5	NO	NA
137	4/20/2010	1.560	5.00	NO	0.5	NO	NA
138	4/21/2010	1.420	6.00	NO	0.5	NO	NA
139	4/21/2010	1.390	4.00	NO	0.5	NO	NA
140	7/19/2010	0.500	2.00	YES	0.5	YES	ND THg
141	7/19/2010	1.000	2.00	NO	0.5	NO	NA
142	7/19/2010	1.120	3.00	NO	0.5	NO	NA
143	7/19/2010	0.651	3.00	NO	0.5	NO	NA
144	7/20/2010	0.500	1.00	YES	0.5	YES	ND THg
145	7/20/2010	2.100	2.00	NO	0.5	NO	NA
146	7/20/2010	1.100	1.00	NO	0.5	NO	NA
147	7/21/2010	1.240	2.00	NO	0.5	NO	NA
148	7/21/2010	1.400	6.00	NO	0.5	NO	NA
149	7/22/2010	0.811	2.00	NO	0.5	NO	NA
150	7/26/2010	0.819	3.00	NO	0.5	NO	NA
151	7/26/2010	0.792	2.00	NO	0.5	NO	NA
152	7/27/2010	0.820	5.00	NO	0.5	NO	NA
153	7/27/2010	0.726	1.00	NO	0.5	NO	NA
154	7/28/2010	0.944	4.00	NO	0.5	NO	NA
155	7/28/2010	0.896	6.00	NO	0.5	NO	NA
156	10/18/2010	0.892	4.00	NO	0.5	NO	NA
157	10/18/2010	0.999	5.00	NO	0.5	NO	NA
158	10/19/2010	0.869	3.00	NO	0.5	NO	NA
159	10/19/2010	0.886	2.00	NO	0.5	NO	NA
160	10/20/2010	1.240	4.00	NO	0.5	NO	NA
161	10/21/2010	0.826	2.00	NO	0.5	NO	NA
162	10/26/2010	2.270	1.00	NO	0.5	NO	NA
163	10/26/2010	5.170	10.00	NO	0.5	NO	NA
164	10/26/2010	1.720	3.00	NO	0.5	NO	NA
165	10/27/2010	3.100	5.00	NO	0.5	NO	NA
166	10/27/2010	1.650	5.00	NO	0.5	NO	NA
167	10/27/2010	2.370	6.00	NO	0.5	NO	NA
168	10/27/2010	2.350	8.00	NO	0.5	NO	NA
169	10/27/2010	0.959	3.00	NO	0.5	NO	NA
170	10/28/2010	2.820	8.00	NO	0.5	NO	NA

Samples	Sampling Date	THg (ng/L)	TSS (mg/L)	THg non-detect (ND)	MDL of THg (ng/L)	Excluded from Analysis	Reasons Excluded
171	10/28/2010	1.840	2.00	NO	0.5	NO	NA
172	1/3/2011	4.010	15.00	NO	0.5	NO	NA
173	1/3/2011	1.410	3.00	NO	0.5	NO	NA
174	1/4/2011	3.340	7.00	NO	0.5	NO	NA
175	1/4/2011	0.847	3.00	NO	0.5	NO	NA
176	1/4/2011	2.410	10.00	NO	0.5	NO	NA
177	1/5/2011	0.622	1.00	NO	0.5	NO	NA
178	1/5/2011	4.040	3.00	NO	0.5	NO	NA
179	1/5/2011	1.850	2.00	NO	0.5	NO	NA
180	1/6/2011	2.330	6.00	NO	0.5	NO	NA
181	1/6/2011	0.934	4.00	NO	0.5	NO	NA
182	1/10/2011	1.960	9.00	NO	0.5	NO	NA
183	1/10/2011	1.890	8.00	NO	0.5	NO	NA
184	1/11/2011	1.790	6.00	NO	0.5	NO	NA
185	1/13/2011	3.180	65.00	NO	0.5	NO	NA
186	1/13/2011	2.770	15.00	NO	0.5	NO	NA
187	1/14/2011	3.450	30.00	NO	0.5	NO	NA

Table 2: Sampling Sites for the Instream Willamette River TSS-THg Surrogate Analysis

Sampling Site	Number of Samples	HUC 8 Code	HUC 8 Description	Longitude	Latitude
1	3	17090001	Middle Fork Willamette	-122.46	43.60
2	4	17090001	Middle Fork Willamette	-122.91	44.00
3	4	17090002	Coast Fork Willamette	-122.97	43.98
4	3	17090003	Upper Willamette	-123.11	44.07
5	4	17090003	Upper Willamette	-123.17	44.27
6	4	17090003	Upper Willamette	-123.25	44.55
7	4	17090004	Mckenzie	-123.05	44.11
8	4	17090005	North Santiam	-123.01	44.72
9	4	17090007	Middle Willamette	-123.05	44.94
10	4	17090007	Middle Willamette	-123.04	45.09
11	4	17090007	Middle Willamette	-122.97	45.29
12	4	17090007	Middle Willamette	-122.64	45.34
13	1	17090007	Middle Willamette	-122.65	45.34
14	4	17090010	Tualatin	-122.68	45.35

Sampling Site	Number of Samples	HUC 8 Code	HUC 8 Description	Longitude	Latitude
15	4	17090011	Clackamas	-122.60	45.37
16	4	17090011	Clackamas	-122.56	45.40
17	4	17090012	Lower Willamette	-122.76	45.58

Table 3: Summary Statistics for Untransformed TSS (mg/L) and THg Concentrations (ng/L) across all HUC 8 Subbasins

	TSS Concentrations (mg/L)	THg Concentrations (ng/L)
Min.	1.00	0.622
1st Qu.	3.00	0.964
Median	5.00	1.560
Mean	6.87	1.901
3rd Qu.	8.00	2.590
Max.	65.00	5.260

Table 4: Summary Statistics for Untransformed THg Concentrations (mg/L) for each individual HUC 8 Subbasin

HUC 8 Code	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
17090001	0.622	1.034	1.360	1.413	1.785	2.27
17090002	2.100	3.555	4.605	4.143	5.192	5.26
17090003	1.000	2.058	2.390	2.397	2.987	3.61
17090004	0.847	0.979	1.110	1.202	1.380	1.65
17090005	0.651	0.863	0.947	0.901	0.984	1.06
17090007	0.726	0.869	1.440	1.624	2.170	3.18
17090010	1.400	2.465	3.215	2.960	3.710	4.01
17090011	0.811	0.914	1.415	1.573	1.850	3.45
17090012	0.896	1.154	1.315	1.329	1.490	1.79

Table 5: Summary Statistics for Untransformed TSS Concentrations (ng/L) for each individual HUC 8 Subbasin

HUC 8 Code	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
17090001	1	1.00	1.0	1.57	2.00	3
17090002	2	2.75	4.0	5.00	6.25	10
17090003	2	4.50	6.0	6.17	8.25	11
17090004	3	3.50	4.0	4.00	4.50	5
17090005	3	3.00	3.5	3.50	4.00	4

HUC 8 Code	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
17090007	1	3.00	5.0	10.65	11.00	65
17090010	6	7.50	8.0	9.25	9.75	15
17090011	2	2.00	3.5	8.00	8.25	30
17090012	4	4.00	5.0	5.00	6.00	6

Table 6: OLS Model Summary Results for all HUC 8 Subbasins

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.0622	0.0506	-1.23	2.24e-01
DL_final_removed$log_fin_TSS	0.4118	0.0670	6.15	1.00e-07

Table 7: LME Model Summary Results for all HUC 8 Subbasins with Sites as a Random Effect and Dry/Wet Seasons as a Fixed Effect

Effect	Group/Term	Estimate	Std.Error	Statistic	df	p.value
Fixed	(Intercept)	-0.124	0.052	-2.4	34	2.3e-02
Fixed	log_fin_TSS	0.449	0.059	7.6	55	3.7e-10
Fixed	Season_categorywet season	0.064	0.035	1.8	48	7.8e-02
Effect	**Group/Term**	**Estimate**	**Std.Deviation**			
Random	Site ID (Intercept) Variance	0.0238	0.154			
Random	Residual Variance	0.0138	0.118			

Table 8: LME Model Summary Results for all HUC 8 Subbasins with Sites as a Random Effect but without the Fixed Effect of Dry/Wet Seasons

Effect	Term	Estimate	Std.Error	Statistic	df	p.value
Fixed	(Intercept)	-0.128	0.054	-2.4	34	2.2e-02
Fixed	log_fin_TSS	0.506	0.051	10.0	53	8.6e-14
Effect	**Estimate**	**Estimate**	**Std.Deviation**			
Random	Site ID (Intercept) Variance	0.0251	0.158			
Random	Residual Variance	0.0143	0.119			

Table 9: R-Squared Results for All Regression Models

Regression Model	R-Squared Value[a]
OLS Model	0.372
LME Model with Dry/wet Seasons as a fixed effect	0.803
LME Model without Dry/wet Seasons as a fixed effect	0.807

Note: [a] The Adjusted R-Squared value and the Conditional R-Squared value was used for both OLS Models and the LME Model

Table 10: Estimated Concentrations of TSS based on the LME Model Equation (the range of THg Concentration values were based on summary results)

TSS Concentrations (mg/L)	THg Concentrations (ng/L)
4.27e-14	0.140
8.14e-13	0.622
1.94e-12	0.964
5.01e-12	1.560
7.41e-12	1.901
1.36e-11	2.590
5.53e-11	5.260

Table 11: Estimated Percent Reduction of THg Concentrations based on the LME Model

TSS Concentration Reduction (%)	THg Concentration Reduction (%)
20 (from 100 to 80 mg/L)	10.7
40 (from 100 to 60 mg/L)	22.8
60 (from 100 to 40 mg/L)	37.1
70 (from 100 to 30 mg/L)	45.7
80 (from 100 to 20 mg/L)	55.7
90 (from 100 to 10 mg/L)	68.9

Table 12 : Schedule for interim goals for reducing TSS concentrations

Years from 2019	Reduction in 95 Percentile of TSS	Estimated Reductions in TSS Concentration (mg/L)	Cumulative Reduction in THg Concentration (mg/L)
0	0%	17	0
5	10%	15	2
10	25%	13	4
20	50%	8.5	8.5
30	75%	4.2	13

Note: [a] Based on the 95 Percentile of TSS Concentrations from the Dataset of 63 Surrogate Pairs. The current TSS Estimate Concentration is 17 mg/L.

1.7 Figures

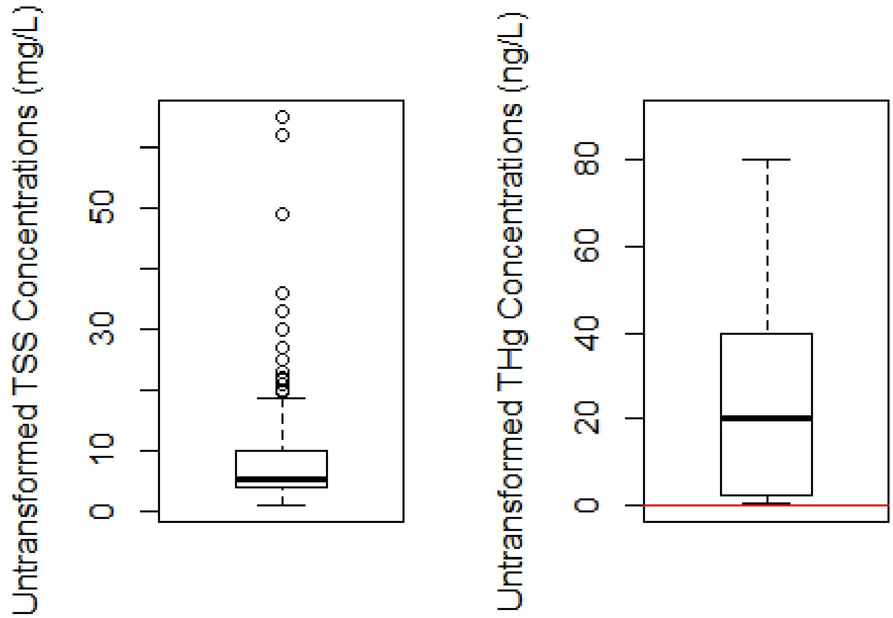

Figure 1: Boxplot of Untransformed TSS (mg/L) and THg Concentrations (ng/L) from the Original Dataset of 187 Surrogate Pairs. The Red line represents an Instream Target Mercury Concentration of 0.14 ng/L.

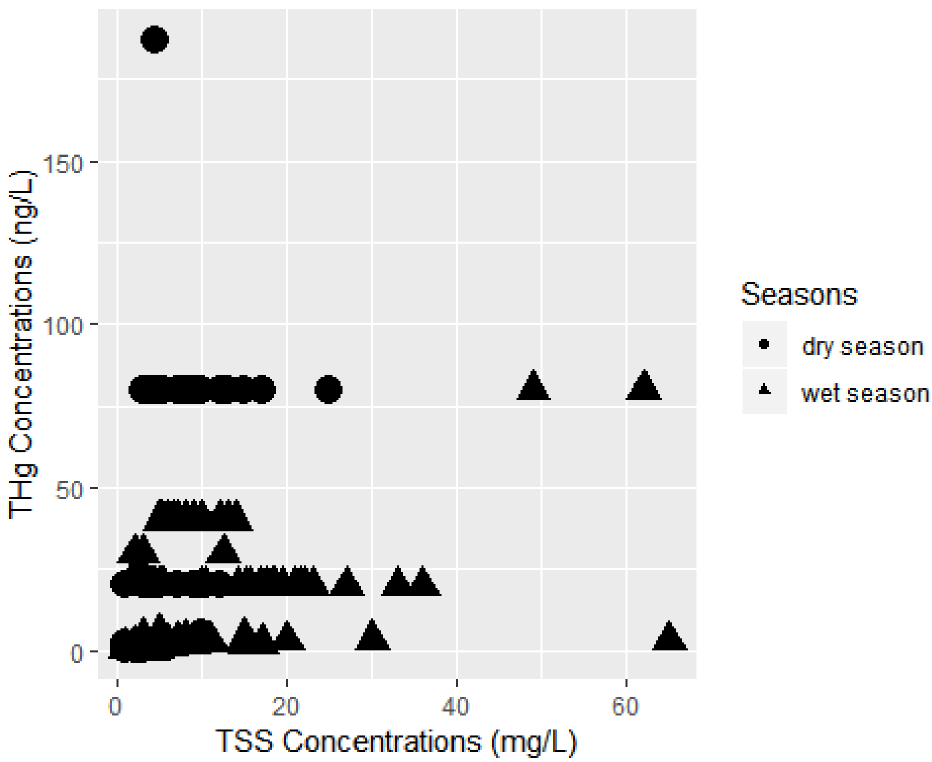

Figure 2: Dry and Wet Season Scatterplot of Untransformed TSS (mg/L) and THg Concentrations (ng/L) from the Original Dataset of 187 Surrogate Pairs.

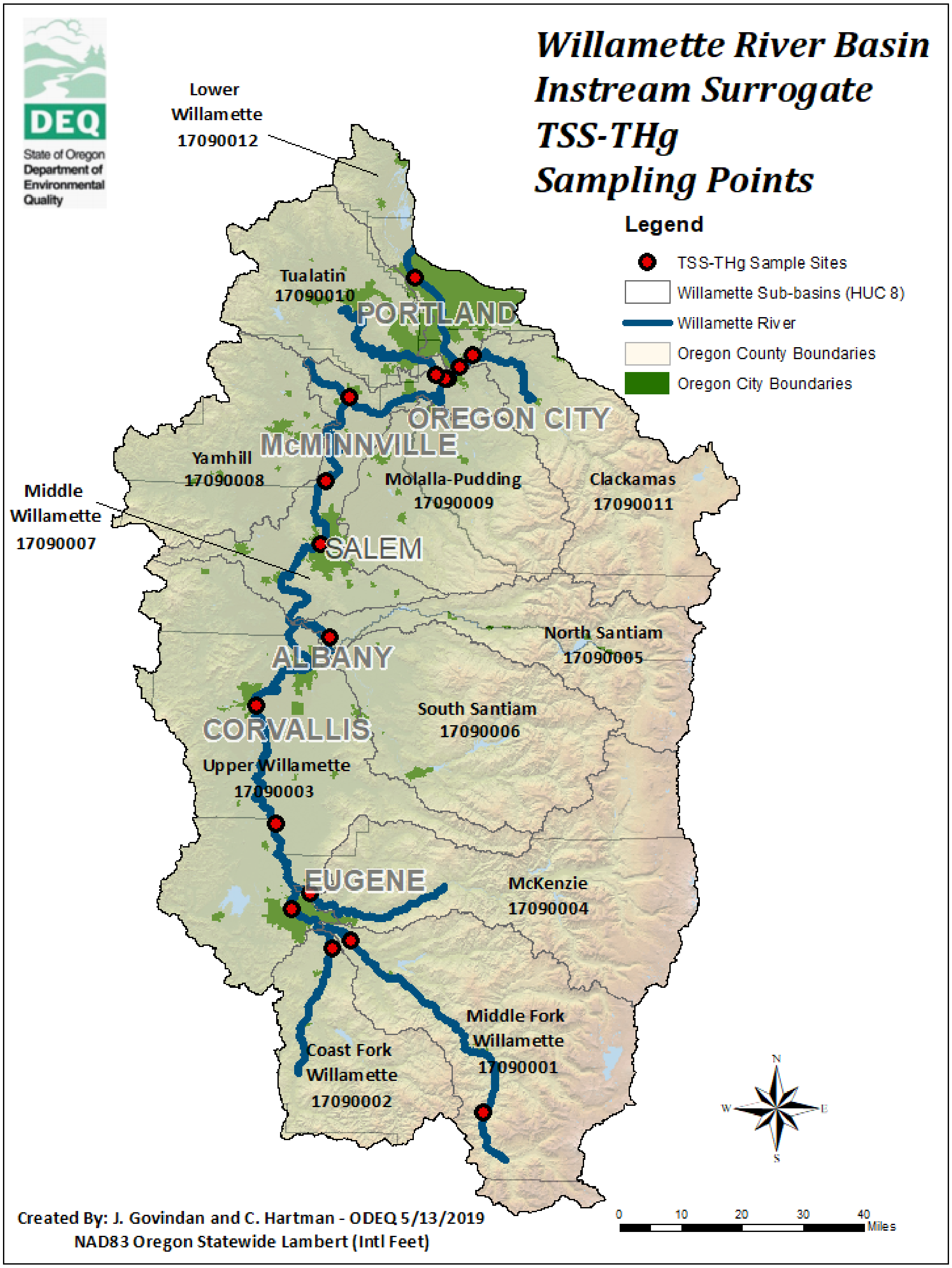

Figure 3: Willamette River Basin Instream Surrogate TSS-THg Sampling Sites Map.

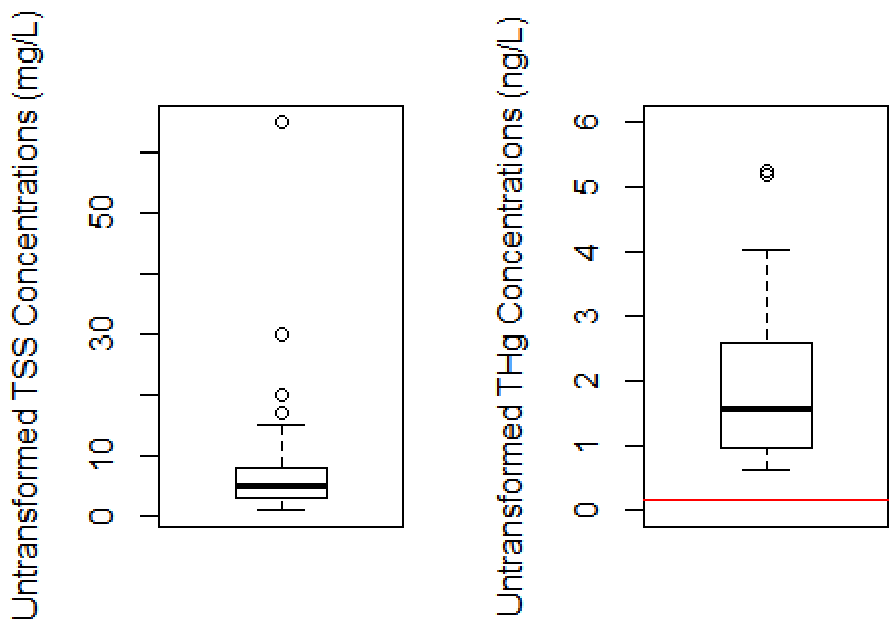

Figure 4: Boxplot of Untransformed TSS (mg/L) and THg Concentrations (ng/L) based on the Dataset of 63 Surrogate Pairs. The Red line represents an Instream Target Mercury Concentration of 0.14 ng/L.

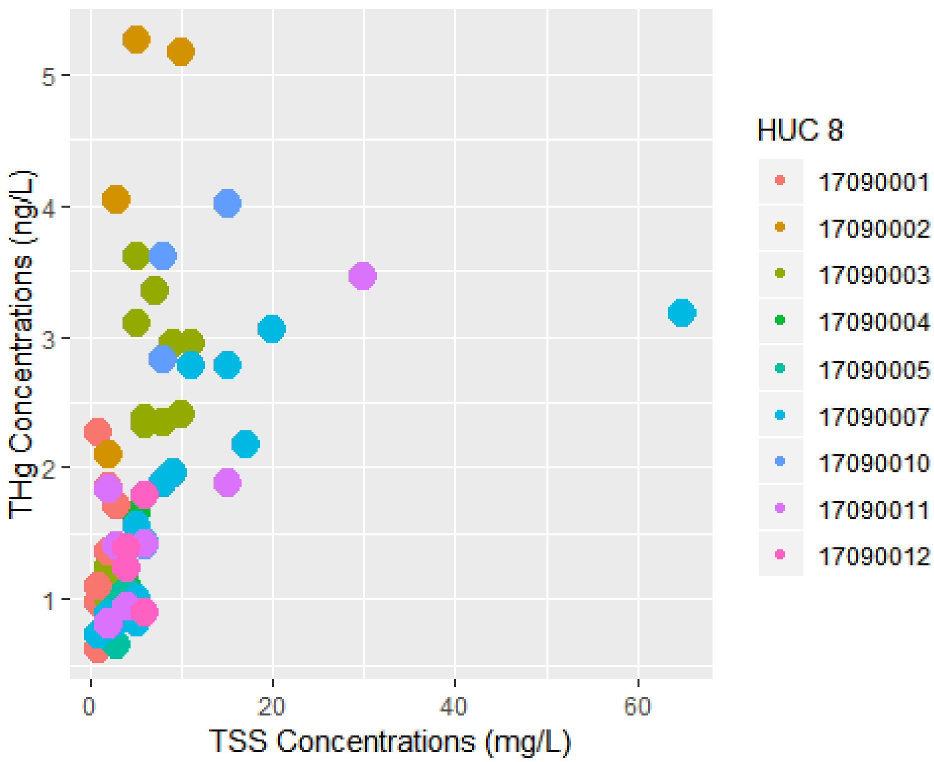

Figure 5: Scatterplot of Untransformed TSS (mg/L) and THg Concentrations (ng/L) according to HUC 8 Subbasin based on the Dataset of 63 Surrogate Pairs.

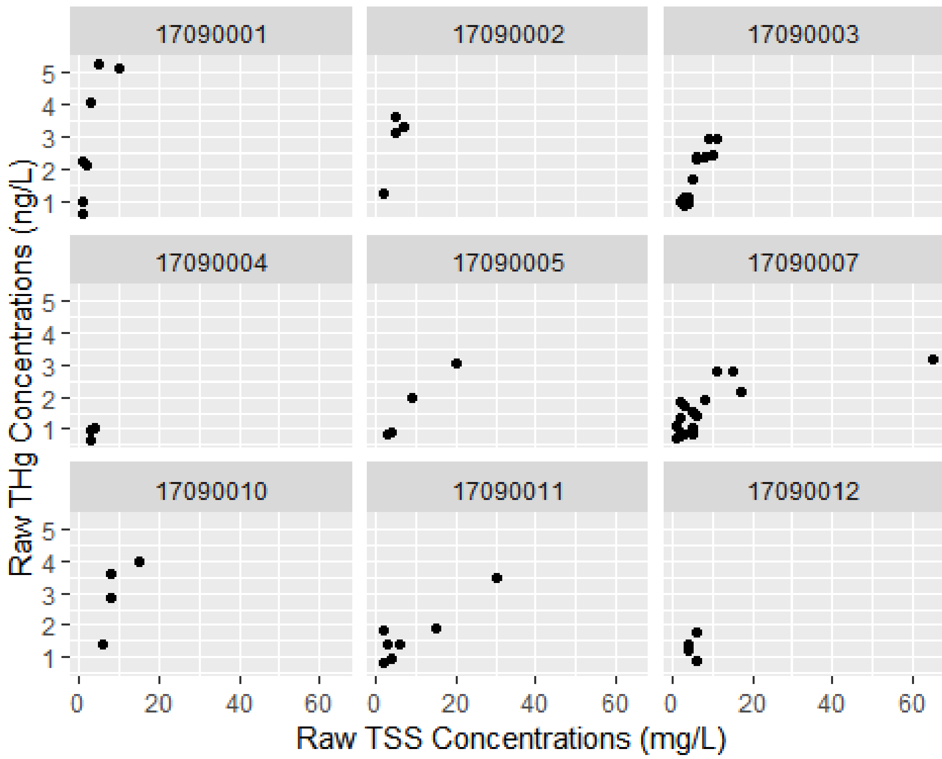

Figure 6: Scatterplot of TSS (mg/L) and THg Concentrations (ng/L) for each individual HUC 8 Subbasin based on the Dataset of 63 Surrogate Pairs.

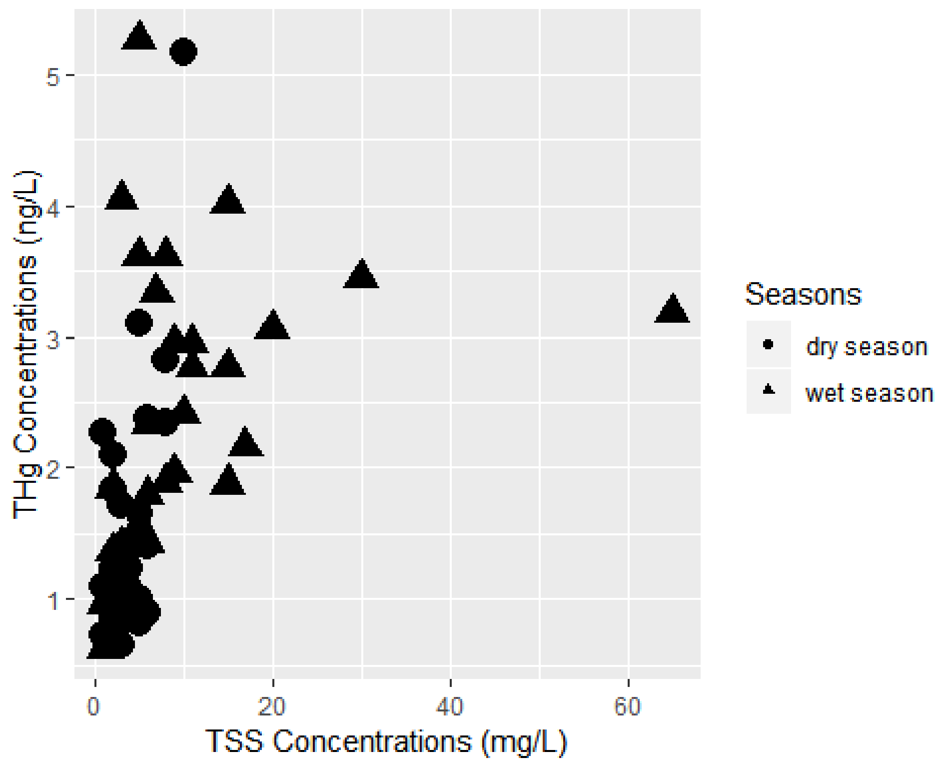

Figure 7: Dry and Wet Season Scatterplot of Untransformed TSS (mg/L) and THg Concentrations (ng/L) based on the Dataset of 63 Surrogate Pairs.

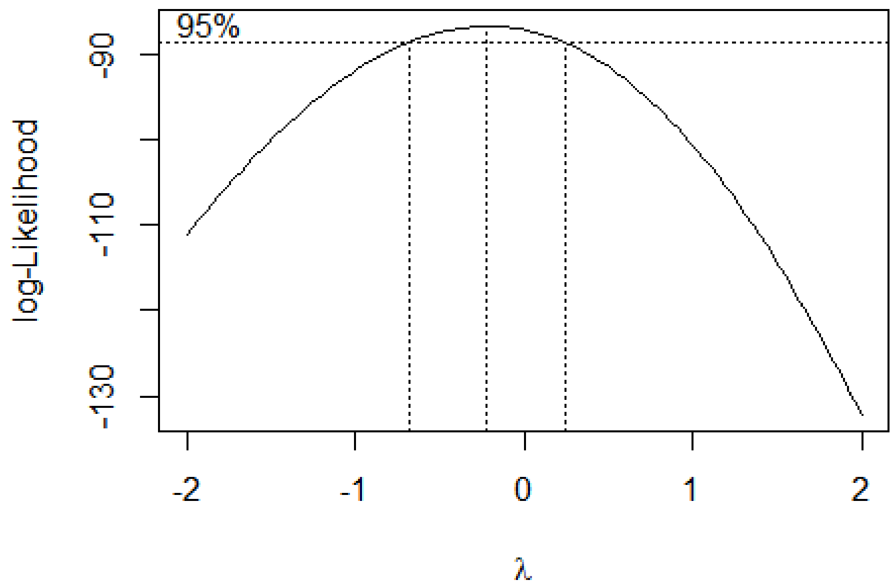

Figure 8: Box-cox Transformation of Dependent Variable of THg concentrations

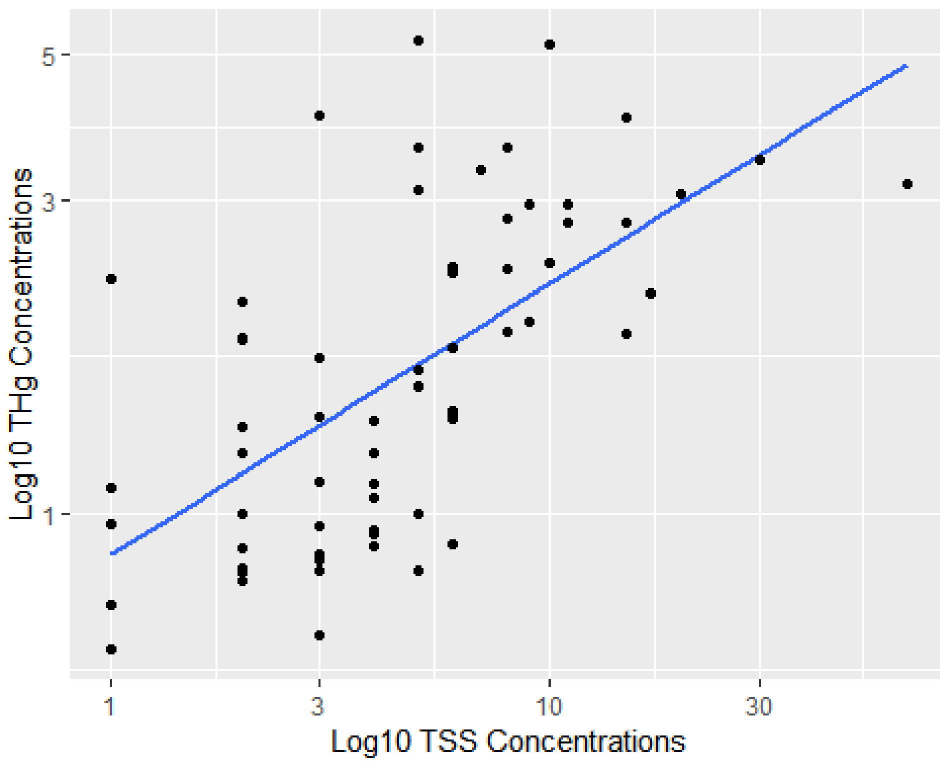

Figure 9: OLS Model Scatterplot for all HUC 8 Subbasins based on the Dataset of 63 Surrogate Pairs.

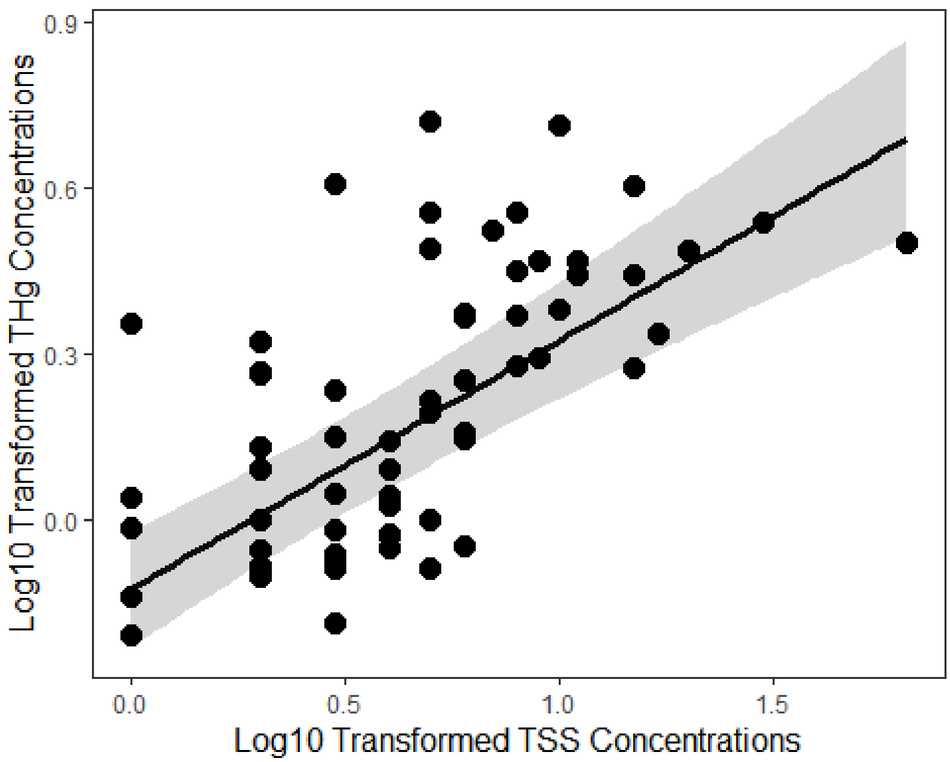

Figure 10: 95 Percent Prediction Interval (fixed effect only) for LME Model Regression with Seasons as an Additional Fixed Effect and with Sites as a Random Effect for the 63 Instream THg-TSS surrogate sample pairs.

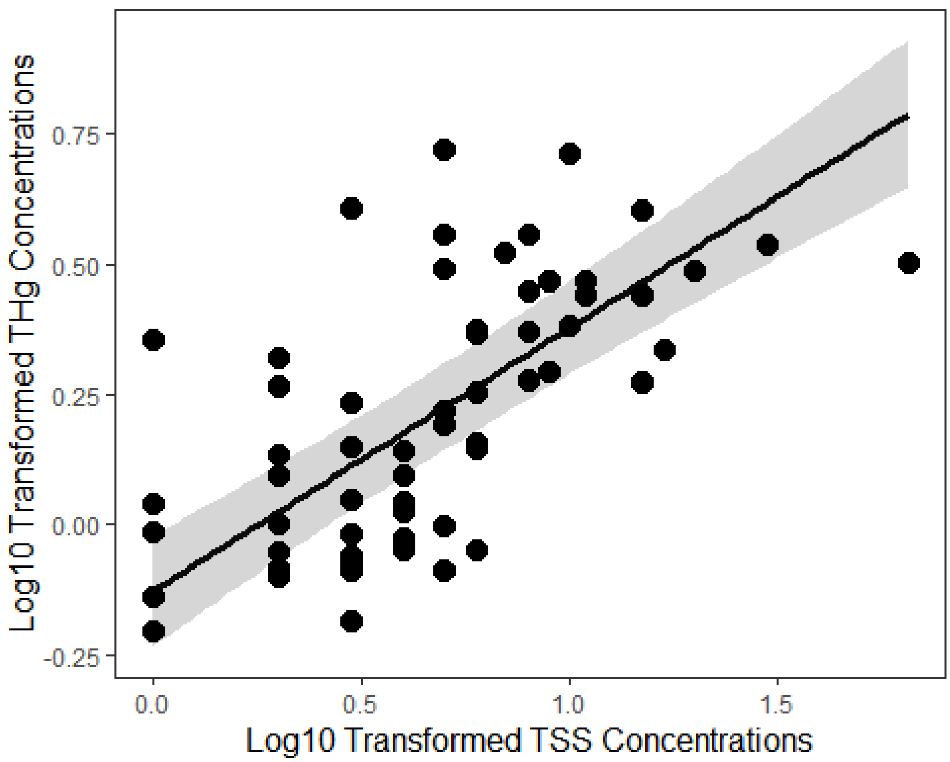

Figure 11: 95 Percent Prediction Interval (fixed effect only) for LME Model Regression with Sites as a Random Effect for the 63 Instream THg-TSS surrogate sample pairs.

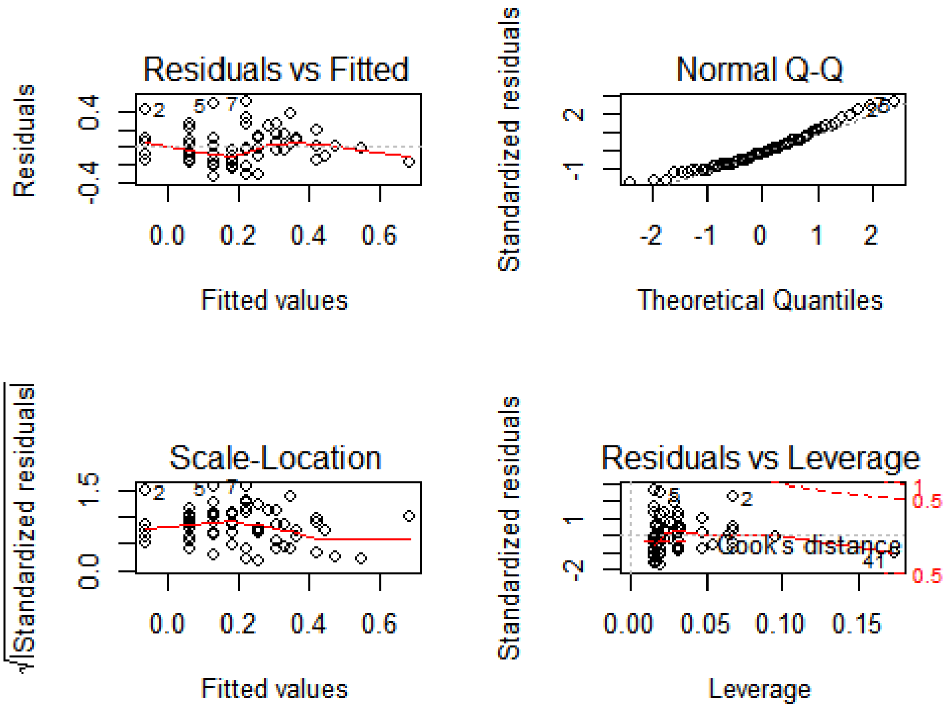

Figure 12: Diagnostic Plot for OLS Model for all 63 Instream THg-TSS Surrogate Samples. The residuals versus fitted values plot checks for the assumptions of linearity. The Q-Q plot checks for the assumptions of normality, while the scale-location plot checks for homoscedasticity (equal variance). The Cook's Distance plot (residuals versus leverage) helps identify any significant outliers that can influence the regression coefficients of the OLS model.

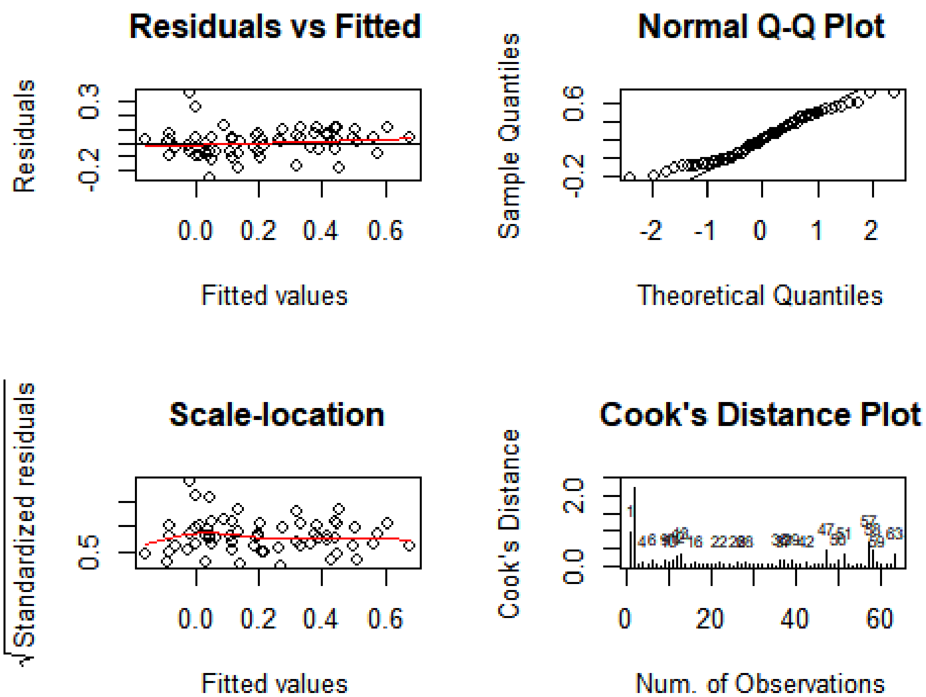

Figure 13: Diagnostic Plot for LME Model with Seasons as an Additional Fixed Effect and Sites a Random Effect for all 63 Instream THg-TSS Surrogate Samples. The residuals versus fitted values plot checks for the assumptions of linearity. The Q-Q plot checks for the assumptions of normality, while the scale-location plot checks for homoscedasticity (equal variance). The Cook's Distance plot (residuals versus leverage) helps identify any significant outliers that can influence the regression coefficients of the LME model.

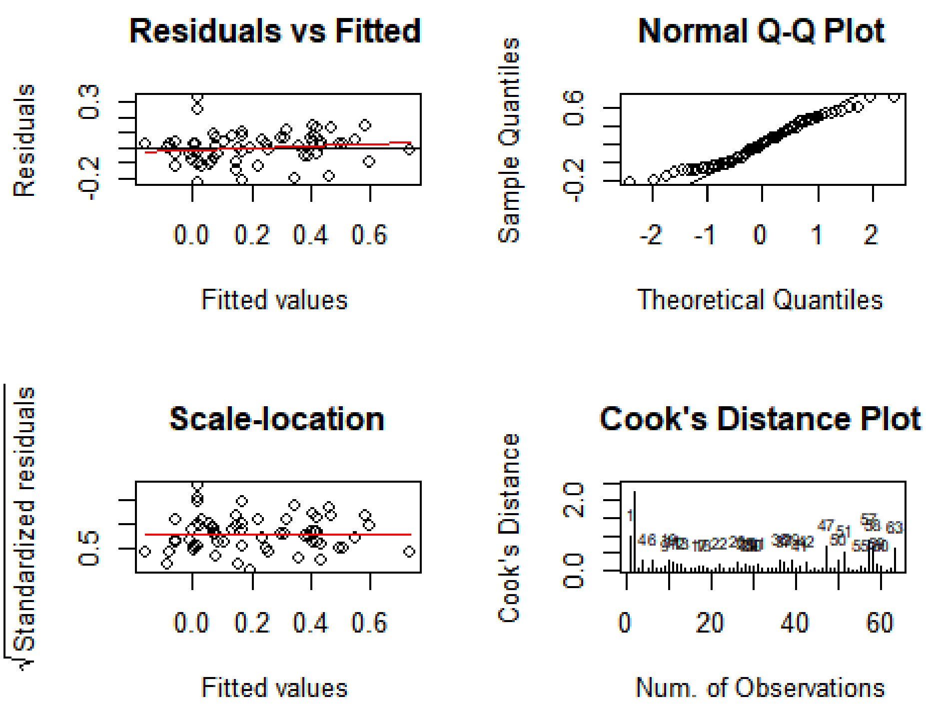

Figure 14: Diagnostic Plot for LME Model with Sites as a Random Effect for all 63 Instream THg-TSS Surrogate Samples. The residuals versus fitted values plot checks for the assumptions of linearity. The Q-Q plot checks for the assumptions of normality, while the scale-location plot checks for homoscedasticity (equal variance). The Cook's Distance plot (residuals versus leverage) helps identify any significant outliers that can influence the regression coefficients of the LME model.

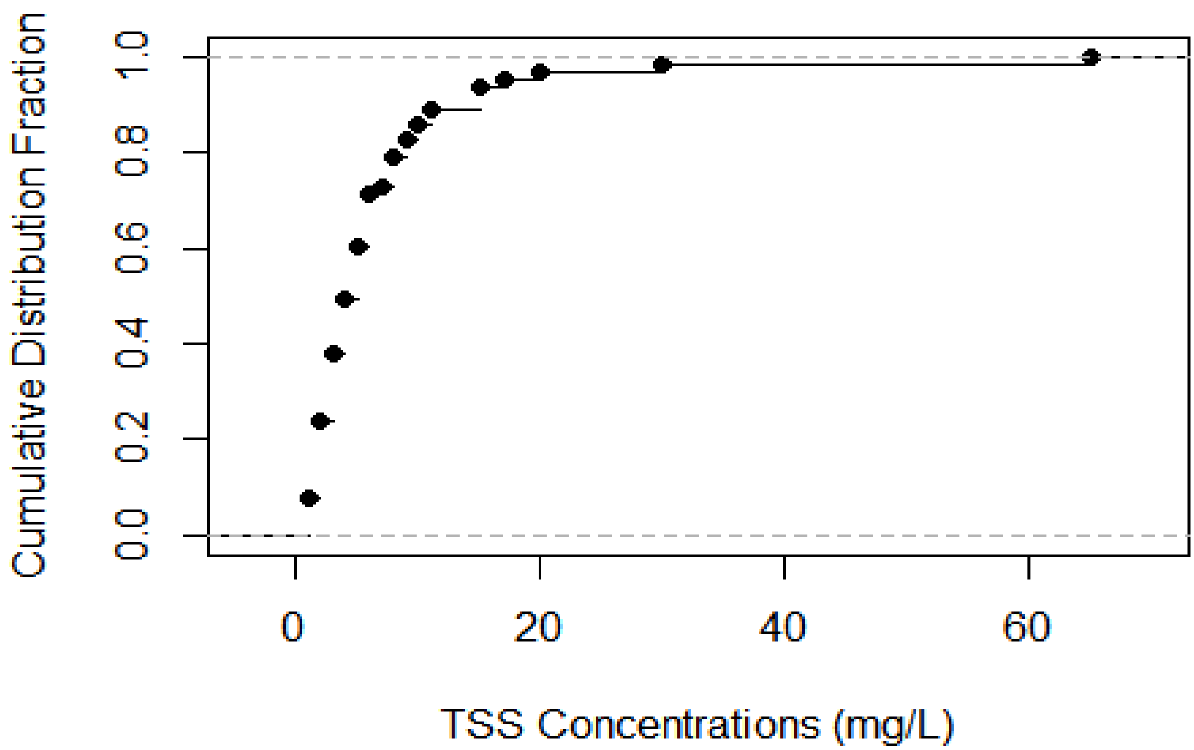

Figure 15: Empirical Cumulative Distribution of TSS Concentrations across all sites.

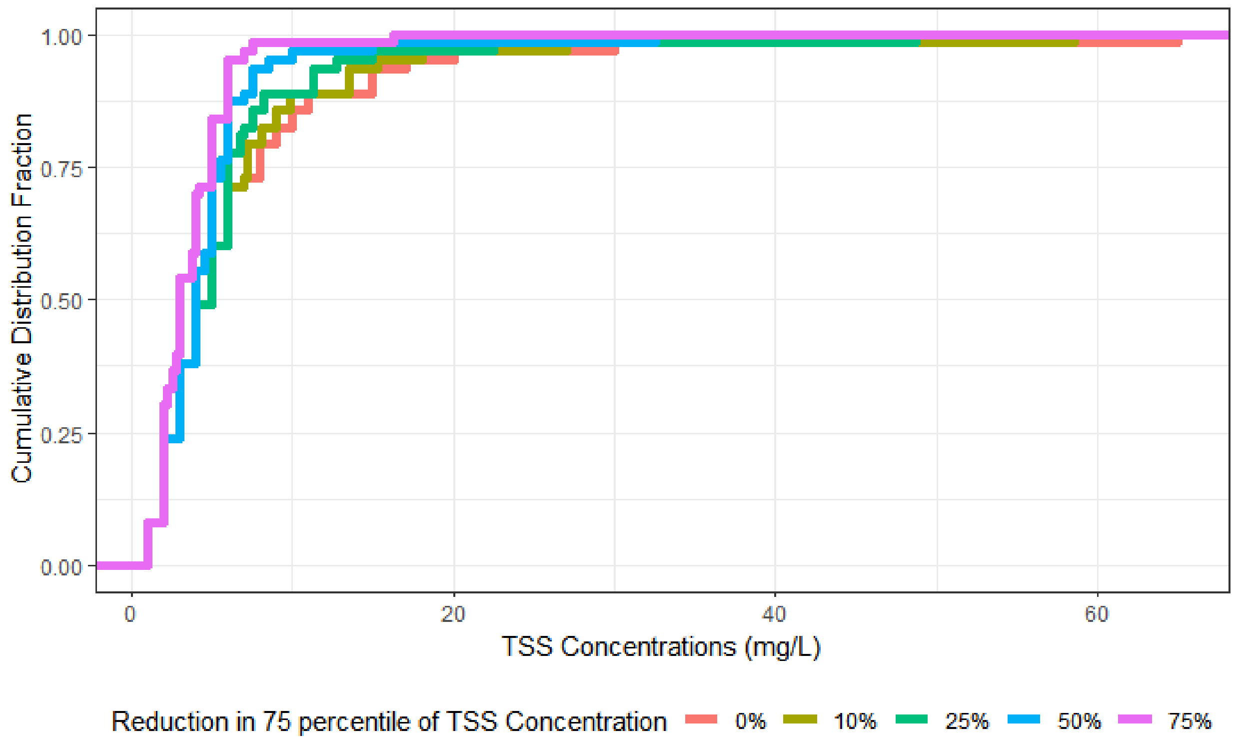

Figure 16: Empirical Cumulative Distribution of TSS Concentrations with Reductions in the Upper Quartile Range (75th percentile) of TSS Concentrations across all sites. The 0% Reduction line represents the cdf plot of current TSS concentrations (mg/L) that were accounted for within the study (same as Figure 15).

2. References

Conroy, M. J., & Peterson, J. T. (2013). Decision Making in Natural Resource Management: A Structured, Adaptive Approach. Hoboken: Wiley-Blackwell.

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