Walla Walla River Basin Bacteria, pH, and Dissolved Oxygen Total Maximum Daily Load

Water Quality Effectiveness Monitoring Report

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Contact Information

Publications Coordinator
Environmental Assessment Program
Washington State Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600
Phone: 360-407-6764

Washington State Department of Ecology	https://ecology.wa.gov
• Headquarters, Olympia	360-407-6000
• Northwest Regional Office, Bellevue	425-649-7000
• Southwest Regional Office, Olympia	360-407-6300
• Central Regional Office, Union Gap	509-575-2490
• Eastern Regional Office, Spokane	509-329-3400

Cover photos:
Top: Low flow at the Walla Walla River downstream of the Byerly Road Bridge, August 16, 2016.
Bottom: High-flow at the same location, April 11, 2017.
Photos by Dan Dugger

Walla Walla River Basin Bacteria, pH, and Dissolved Oxygen Total Maximum Daily Load

Water Quality Effectiveness Monitoring Report

by
Dan Dugger

Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington

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Abstract

This 2014-2015 Walla Walla River Basin Effectiveness Monitoring (EM) study collected instream water quality data for comparison to a 2002-2003 Total Maximum Daily Load (TMDL) study. EM study results indicate Walla Walla Basin streams continue to have high fecal coliform bacteria (FC) counts, low daily minimum dissolved oxygen (DO), and high daily maximum pH.

The TMDL set FC and nutrient concentration reduction targets to improve the basin's water quality. Near equal numbers of sites showed either a reduction or increase in FC in 2014-15 relative to 2002-2003. Soluble reactive phosphorus (SRP) decreased at most sites. Dissolved inorganic nitrogen (DIN), the low-flow season limiting nutrient for eutrophication, increased at most sites. Urban and rural point and nonpoint sources as well as a 2015 snowpack drought contributed to water quality problems.

Improvements to wastewater treatment plants (WWTPs) provided the greater part of the observed reduction in FC and nutrient loads in receiving waters for the cities of College Place and Walla Walla.

Meeting water quality standards will require further identification and correction of point and nonpoint sources throughout the Walla Walla Basin. We recommend Ecology and Walla Walla Basin stakeholders gather best management practice (BMP) data to assess implementation progress, and conduct source tracking for specific locations with high FC and nutrient concentrations.

Background

During 2002 and 2003, the Washington State Department of Ecology (Ecology) conducted Walla Walla Basin TMDL monitoring studies for bacteria, pH, and dissolved oxygen (DO) (Swanson and Joy 2002, Swanson 2005, Joy and Swanson 2005, Joy et al. 2006 and 2007). These studies and analyses resulted in a Water Quality Implementation Plan (WQIP) (Baldwin et al. 2008) which outlined the implementation of best management practices (BMPs) and set 6-year and 10-year pollution reduction targets for fecal coliform bacteria (FC) and nutrients. These target reductions were established to bring the Walla Walla Basin into compliance with associated water quality standards by 2018.

This report describes monitoring results from a 2014-2015 effectiveness monitoring (EM) study intended to assess progress towards the 6-year reduction goals for FC and nutrients. The Quality Assurance Project Plan (QAPP) for this study is outlined in Ross (2014). We compare study results to TMDL targets and water quality standards. Results from this EM study will be used to adaptively manage pollution control efforts.

Study area

The study area for this project is the portion of the Walla Walla River Watershed located within the state of Washington (Figure 1).

Watershed overview

The Walla Walla River Watershed is located in southeastern Washington and northeastern Oregon. The river extends 61 river miles (RMs) from the headwaters to its confluence with the Columbia River in Washington (elevation 340 ft.). The drainage basin covers about 1,760 square miles and flows through four counties: Umatilla and Wallowa counties in Oregon, and Columbia and Walla Walla counties in Washington. Two-thirds of the Walla Walla drainage basin lies within Washington in Water Resource Inventory Area (WRIA) 32.

The Walla Walla Basin contains federally designated critical habitat for bull trout and steelhead trout, both of which are listed as threatened species protected under the Endangered Species Act (ESA) (Yun et al. 2016).

Major tributaries

The Touchet River, the Walla Walla River's largest tributary, flows through the northern third of the basin to its confluence at RM 22.0 (Figure 8). The Touchet River Basin includes the incorporated cities of Dayton, Waitsburg, and Prescott, and the unincorporated community of Touchet. Land use in the Touchet Basin, from Dayton to the confluence of the Walla Walla River, is predominantly agricultural with both irrigated and non-irrigated crops.

Mill Creek flows from Oregon into Washington and to the city of Walla Walla (Figure 21). The city of Walla Walla and the U.S. Army Corps of Engineers (USACE) built a control structure on Mill Creek in the 1940s to stop catastrophic flooding during the spring months. Currently, a portion of Mill Creek's flow is diverted for flood control and irrigation at RM 11.5 to Bennington Lake and at RM 10.5 into Garrison and Yellowhawk Creeks. Energy dissipater weirs and a concrete channel armor Mill Creek through the city of Walla Walla. Mill Creek then continues downstream through the city of Walla Walla. Below the city of Walla Walla, Mill Creek flows through agricultural areas to the confluence with the Walla Walla River (RM 33.6) (Figure 30).

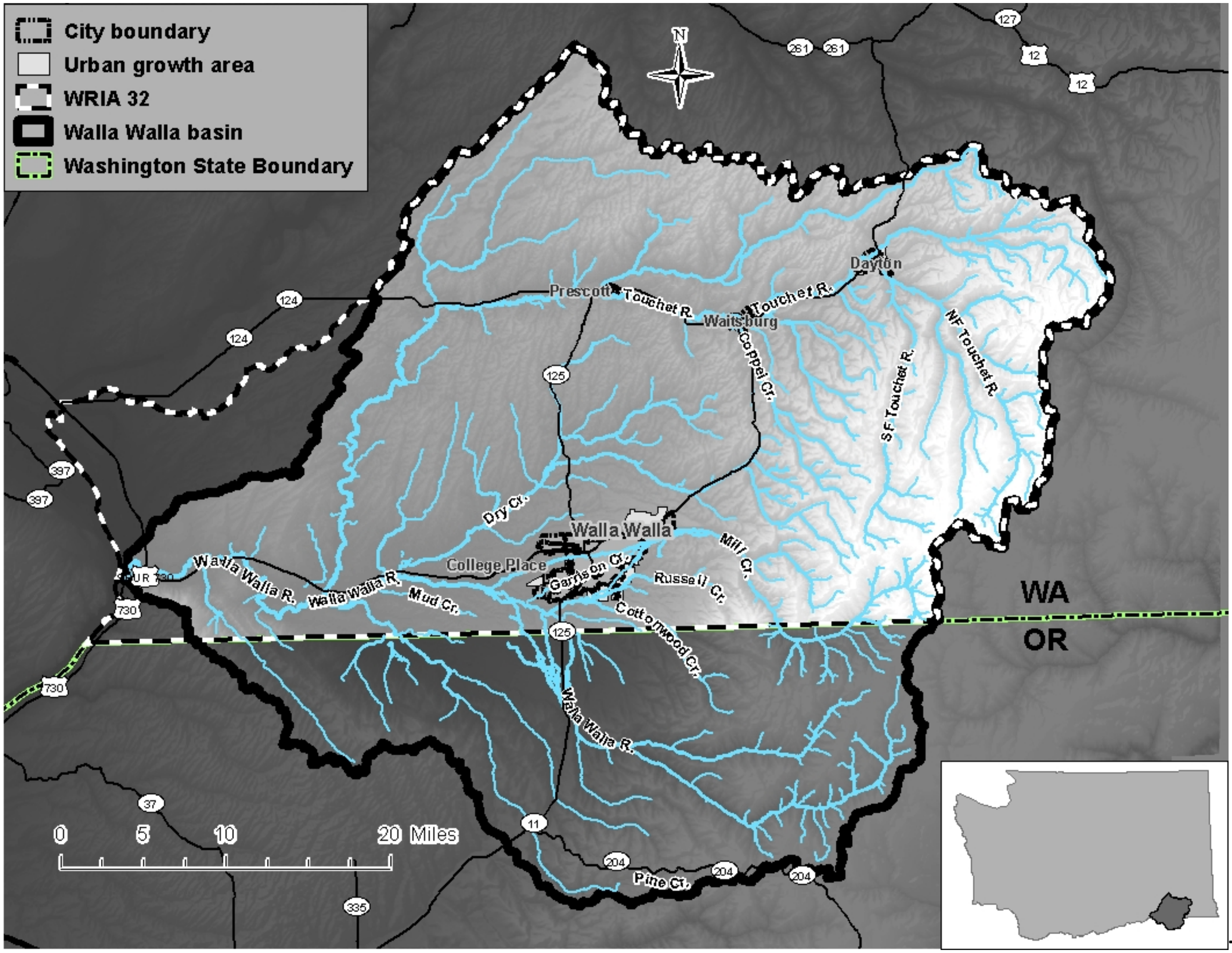


Figure 1. The Walla Walla Basin study area within Washington State and WRIA 32.

Land use

Forest-based land uses are present in the upper watersheds, but commercial agriculture is the dominant land use in the basin (Figure 2). Wheat, alfalfa, hay, and vegetables make up the largest percentage of agriculture. Pasture makes up roughly a quarter of irrigated land. Much of the natural habitat has been highly altered due to historical grazing, prescribed burning, wildfires, and agriculture. Riparian vegetation is limited in most areas throughout the basin, but considerable riparian enhancement has occurred through efforts by the local community (Smith 2012 and 2013, Cochrane 2016, WWCCD 2020).

The Walla Walla River headwaters are in Oregon, and the last 40 miles are in Washington. In Washington, the river has a low gradient with a wide floodplain. Agriculture is the dominant land use along the Walla Walla River. Major tributaries to the Walla Walla River are the Touchet River, Mill Creek, Dry Creek, and Pine Creek.

Most people in the Walla Walla River Basin live in urban areas. The 2015 census identified 59,976 people living in Walla Walla County. Incorporated cities are Walla Walla, College Place, Dayton, Waitsburg, and Prescott with a combined 2015 population of 45,649 (Table 1). (US Census Bureau 2020a and 2020b)

Table 1. Population estimates and changes for the Walla Walla Basin, 2002 to 2015 (US Census Bureau 2020a and 2020b).

County / City Name	2002 Population	2015 Population	% Change In Population
Walla Walla County, WA	55,666	59,932	7.7%
College Place, WA	7,967	9,002	13.0%
Prescott, WA	332	299	-9.9%
Waitsburg, WA	1,224	1,192	-2.6%
Walla Walla, WA	30,753	32,706	6.4%
Columbia County, WA	3,995	3,960	-0.9%
Dayton, WA	2,592	2,443	-5.7%
Umatilla County, OR	72,150	76,467	+6.0%
Milton-Freewater, OR	6,631	7,028	+6.0%

Climate

Local climate varies from warm and semi-arid in the western lowlands, to cool and relatively wet at higher elevations in the Blue Mountains. Temperatures in the basin range from above 100 °F in the summer to well below freezing in the winter. The lower portions of the basin receive less than 10 inches of annual precipitation, while the upper sections, in the Blue Mountains, can receive up to 60 inches. Most of the precipitation falls as snow in the winter months, causing a significant accumulation of snowpack in the mountains. Spring thaw, compounded with rain showers, is the source of flooding for the basin. Significant flood events occurred before this study in 1933, 1964, and 1996, and more recently in February 2020.

Changes to the study area between 2002 and 2015

From 2006 through 2014, agriculture continued to be the dominant land use in the Walla Walla River Basin, followed by residences in cities and towns, and a mix of forest and undeveloped lands (Figure 2).

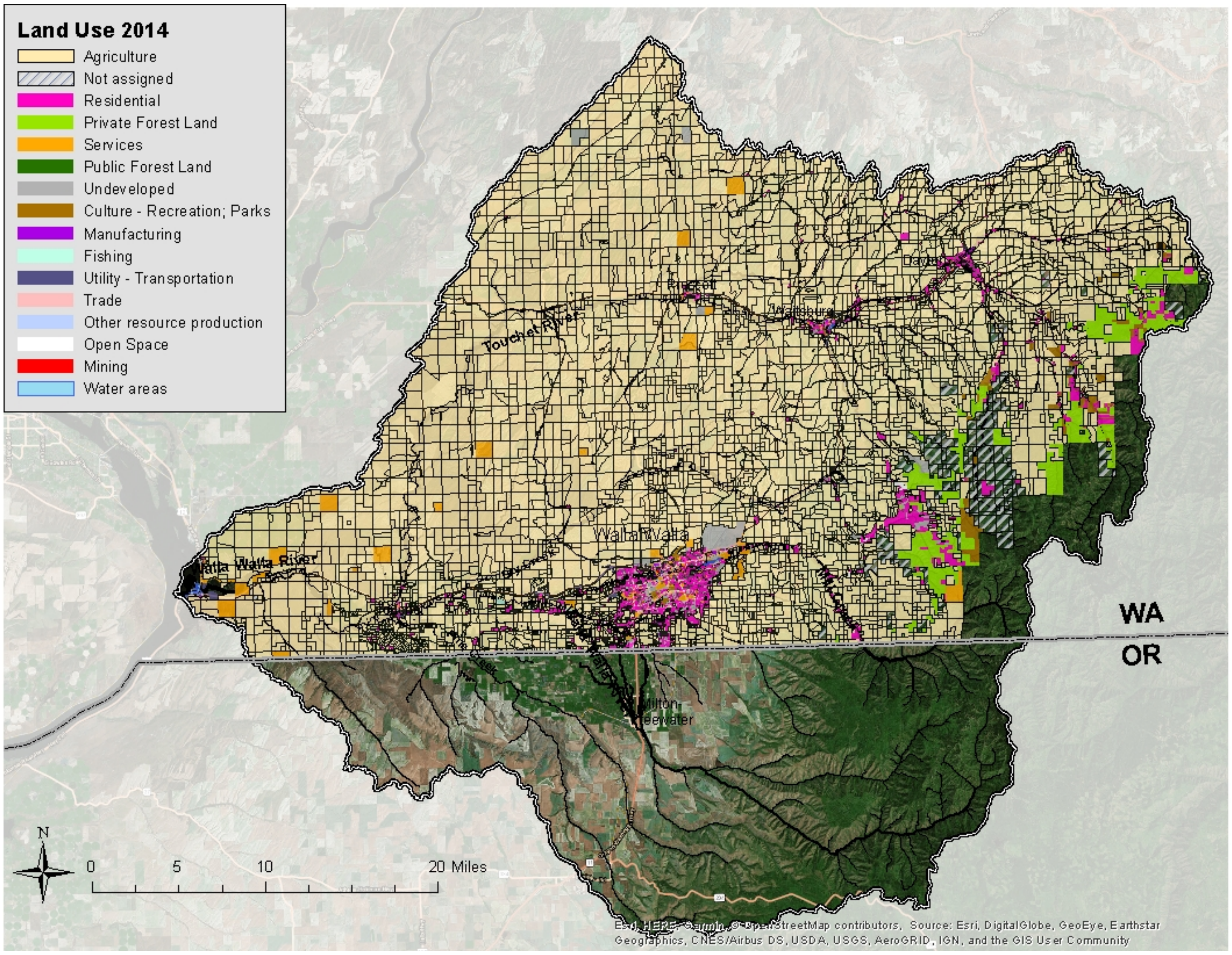


Figure 2. 2014 Walla Walla Basin Washington State parcel layers.

Since Ecology conducted the TMDL study in 2002, population increased across the watershed, with the greatest increases in urban areas surrounding the city of Walla Walla. Rural cities including Dayton, Waitsburg, and Prescott decreased in population. (Table 1)

To assess where residential development is occurring within the basin, we performed a GIS hotspot analysis on 2006 and 2014 parcel area data within the Walla Walla River Basin. A high Z score (>1.64) for a feature indicates parcel density is significantly denser (α<=0.10) when compared to surrounding areas. A low negative Z score (<1.64) value indicates a significant cold spot. The higher the Z score, the more intense the clustering or parcel density (Getis and Ord 1992, Ord and Getis 1995, Mitchell 2005).

In the Walla Walla Basin in Washington, the highest parcel densities (Z score > 1.64) occurred, in order of highest to lowest, within the cities of Walla Walla, College Place, Dayton, and Waitsburg. In Walla Walla County, between 2006 and 2014 the greatest increases in parcel density (change in Z-score > +1.64) occurred within the incorporated urban growth areas for the cities of Walla Walla and College Place.

Pollutants addressed by this TMDL Effectiveness Monitoring (EM) Study

303(d) listings

This first phase of the TMDL study assessed progress toward meeting water quality standards for FC, pH, and DO in the Walla Walla River Basin. We show 303(d) Category 4A listings in Figures 3, 4, 5 and Appendix H.

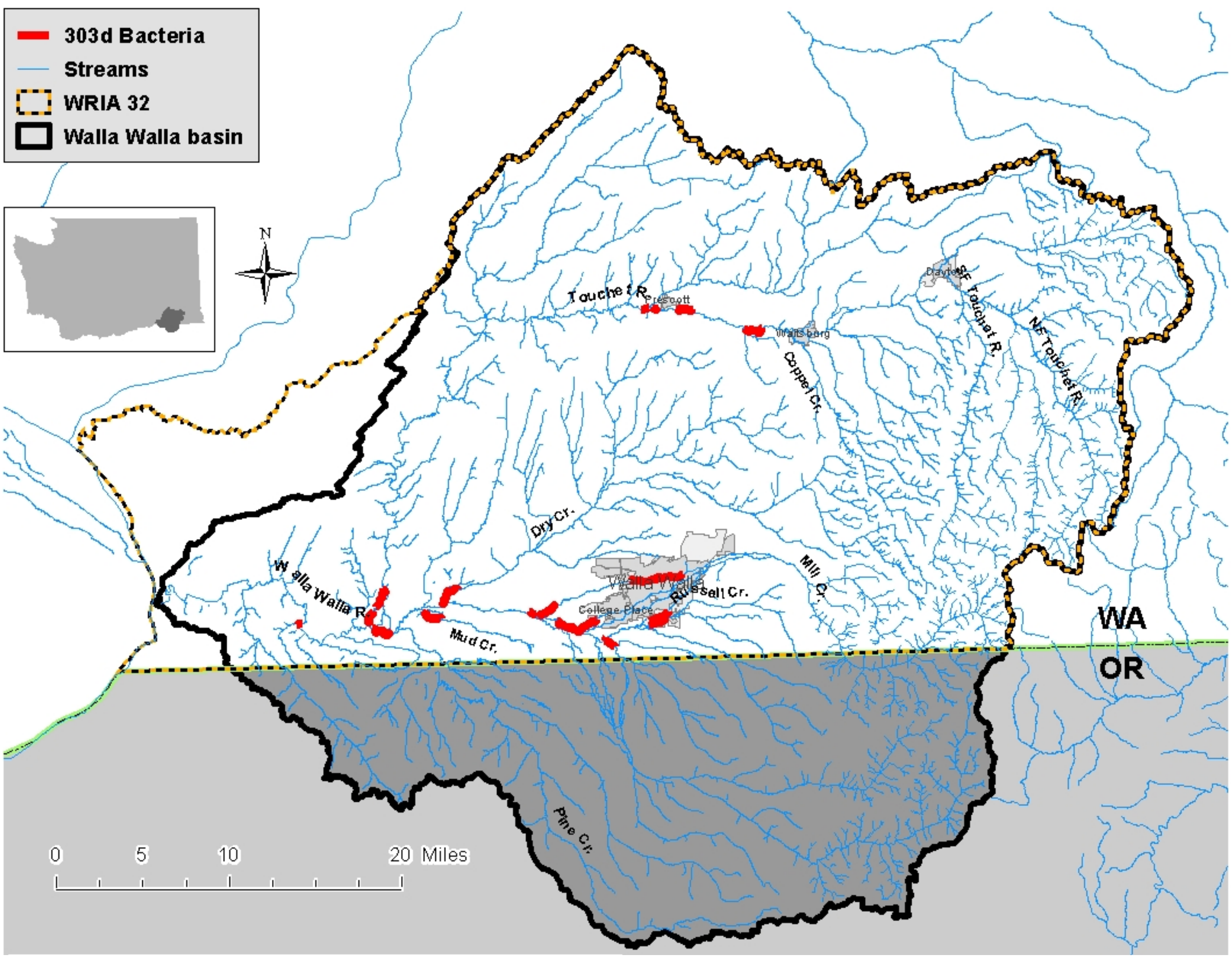


Figure 3. Walla Walla River Basin FC 303(d) 4A listings.

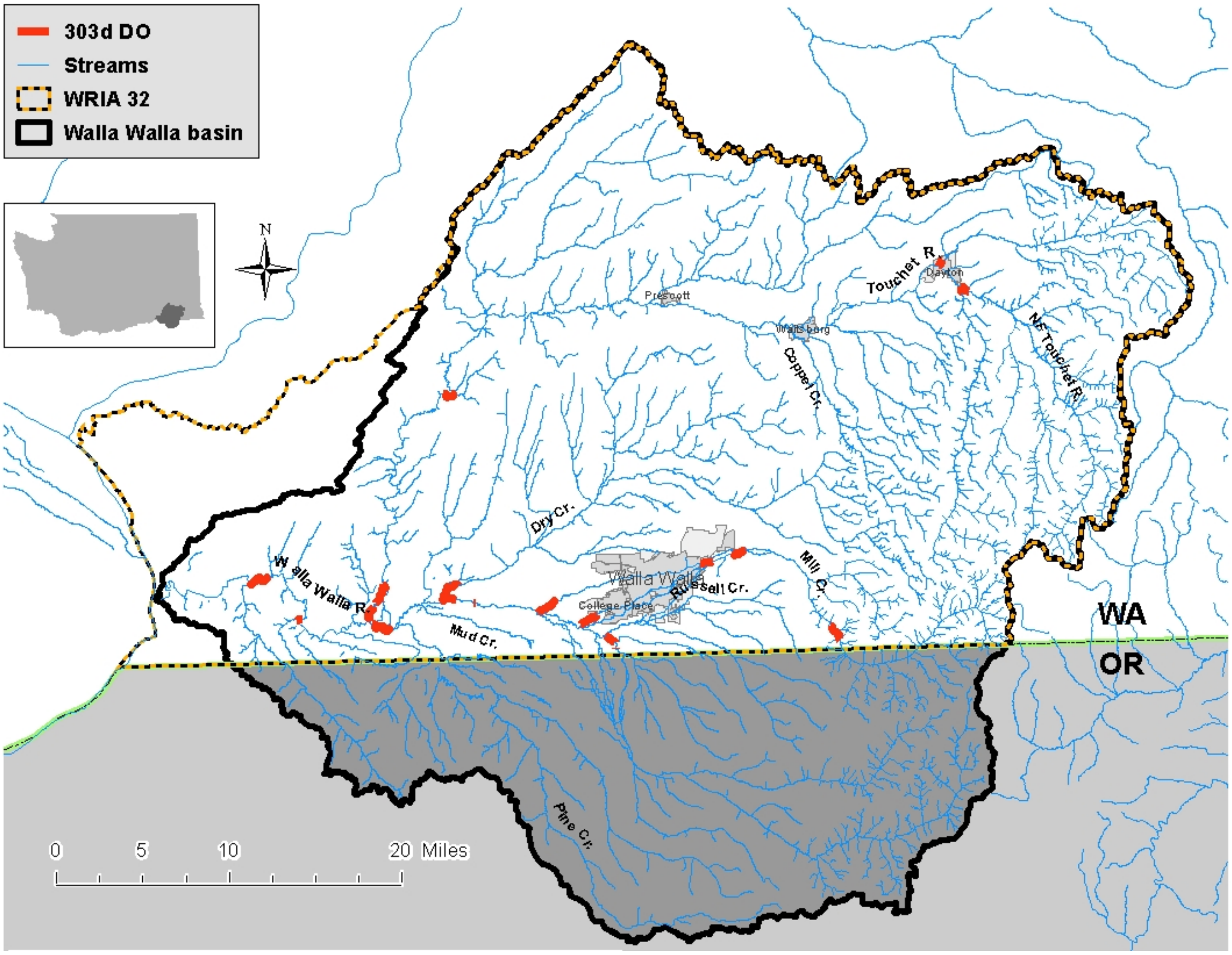


Figure 4. Walla Walla River Basin Dissolved Oxygen (DO) 303(d) 4A listings.

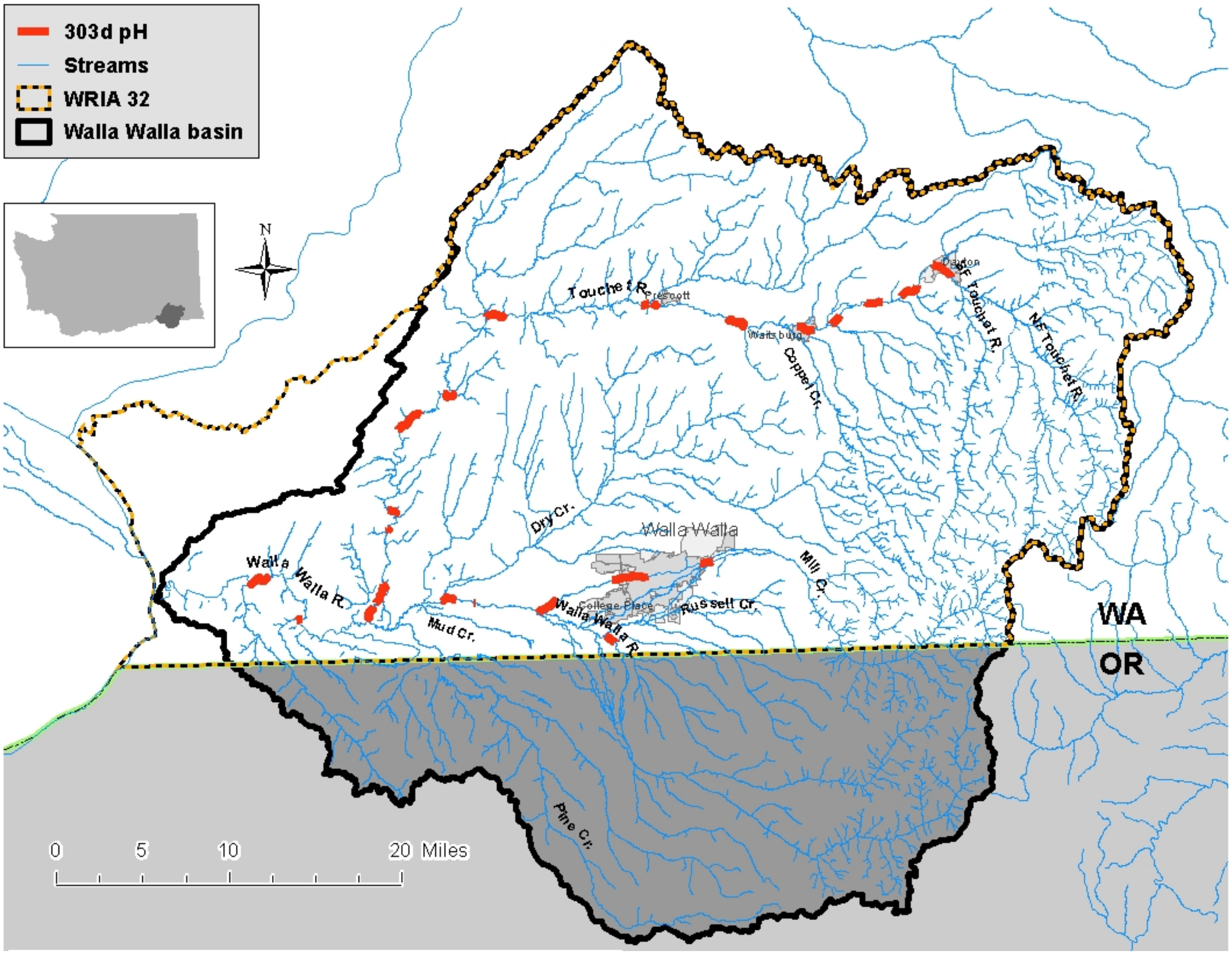


Figure 5. Walla Walla River Basin pH 303(d) 4A listings.

Potential sources of pollution

Point sources

Municipal wastewater

The cities of Walla Walla, College Place, Dayton, and Waitsburg have wastewater treatment plants (WWTPs) that discharge to surface water. Ecology issues these facilities National Pollutant Discharge Elimination System (NPDES) permits to regulate their surface water discharges. Ecology NPDES permit managers assess WWTP reported discharges against permit limits.

Ecology also issues state waste discharge permits. These permits apply to municipal WWTPs – industrial and commercial facilities that apply wastewater onto the ground. State waste discharge permits do not receive wasteload allocations in TMDLs.

Although the city of Waitsburg's WWTP discharges to a wetland, the wetland is adjacent to the Touchet River. Since the wetland connects to the river through subsurface flow (Pitz and Tarbutton 2010), the city of Waitsburg has an NPDES permit.

Table 2 provides a list of NPDES and state waste discharge permits that discharge directly to streams in the Walla Walla River Basin. The cities' current NPDES permits incorporate the wasteload allocations from the four Walla Walla TMDLs.

Table 2. NPDES permits in the Walla Walla Basin.

Entity	Discharge to	Type of Permit	Permit Number	Permit Expiration
City of Dayton	Touchet River	NPDES IP	WA0020729	09/29/2021
City of College Place	Garrison Creek	NPDES IP	WA0020656	02/28/2024
City of Waitsburg	Wetlands adjacent to the Touchet River	NPDES IP	WA0045551	06/30/2024
City of Walla Walla	Mill Creek	NPDES IP	WA0024627	06/30/2022
City of Walla Walla	varies	Phase II Stormwater	WAR046508	07/31/2024
Walla Walla County	varies	Phase II Stormwater	WAR046509	07/31/2024
Washington Dept. of Transportation	varies	Phase II Stormwater	WAR043000	04/05/2024
Walla Walla Water District #2	ground	State Waste Permit	ST0008040	08/31/2025

Table 3 shows the list of the NPDES permit limits assigned to the WWTPs. The WQIP required WWTPs receiving allocations to meet wasteload allocations within ten-years of the WQIP publication (by 2018) or by the permit modified compliance schedule[1]. The WQIP also required these entities to develop ordinances or other regulatory measures that prohibit illicit discharges, regulate construction activities, and implement post-construction protections to reduce stormwater impacts.[2] (Baldwin et al. 2008).

[1] Permit modified compliance schedules include:

- Modifications to the permit for the Dayton WWTP extend the deadline to meet the TMDL issued wasteload allocations to December 31, 2021. (Ecology 2015a)
- The College Place WWTP compliance schedule is modified to follow the 2 permit cycle compliance timeline provided in the approved TMDLs (five years per permit cycle beginning in 2013, compliance due by December 31, 2023). (Ecology 2014a)

[2] Additional information on the Phase II Municipal Stormwater Permits can be found at: https://ecology.wa.gov/Regulations-Permits/Permits-certifications/Stormwater-general-permits/Municipal-stormwater-general-permits.

Table 3. NPDES permit effluent limits for the monitored parameters relevant to this study at Walla Walla Basin wastewater treatment plants (WWTPs).

City	Parameter	Monthly Limit	Weekly Limit	Daily Limit
Dayton WWTP	Fecal coliform (FC)	Geometric mean (GM) ≤ 200 cfu/ 100 mL	GM ≤ 400 cfu/ 100 mL	NA
Dayton WWTP	pH & Dissolved Oxygen (DO) (nutrient load) [1]	NA	NA	• Dissolved Inorganic Nitrogen (DIN) ≤ 0.28 lbs. • Organic nitrogen ≤ 0.20 lbs. • Soluble Reactive Phosphorus (SRP) ≤ 0.13 lbs. • Organic phosphorus ≤ 0.09 lbs.
Waitsburg WWTP[2]	FC	GM ≤ 100 cfu/ 100 mL	GM ≤ 200 cfu/ 100 mL	NA
College Place WWTP [3]	FC	NA	GM ≤ 23 cfu/ 100 mL	Maximum ≤ 240 cfu/ 100 mL
Walla Walla WWTP [4]	FC	GM ≤ 100 cfu/ 100 mL	GM ≤ 200 cfu/ 100 mL	NA

1. Daily nutrient load limits for May through October.
2. The Waitsburg WWTP discharges to a wetland adjacent to the Touchet River and filters through groundwater before entering the river.
3. The College Place WWTP discharges to Garrison Creek from November through April and to land application from May to October. The permit also provides effluent limits for periodic May to October effluent releases to Garrison Creek.
4. The City of Walla Walla WWTP discharges to Mill Creek December to April only.

Stormwater

Special Condition S5 of the Eastern Washington Phase II Municipal Stormwater Permit requires cities, towns, and counties regulated by the permit to develop stormwater management programs. Walla Walla County, the city of Walla Walla, the Washington State Department of Transportation (WSDOT), and Walla Walla Water District #2 each reports potential discharges regulated for NPDES stormwater permits.

In January 2019, Ecology issued guidelines for a transition from the fecal coliform bacteria (FC) standard to an Escherichia coliform bacteria (E. coli) standard. Further implementation guidance indicates that Ecology will typically maintain a FC limit for facilities with an existing technology-based or water quality-based (TMDL) FC limit. These permits will include dual monitoring for FC and E. coli.

Nonpoint sources

Nonpoint source pollutants enter water through:

- Runoff (typically rainfall and snow melt washing pollutants from the land into rivers, streams, and groundwater).
- Direct deposition of pollutants into state waters.
- Habitat alteration and hydromodification (the alteration of the natural flow of water across a landscape, including channel modification or channelization).
- Atmospheric deposition. (Rau 2015)

Baldwin et al. (2008) assigned load allocations to address nonpoint pollution using a variety of approaches to reduce nutrients. The pH and DO Water Quality Implementation Report (Joy et al. 2007) recommended BMPs focus on addressing the following nonpoint sources to reduce instream nutrients:

- Over application of fertilizers (lawn, garden, and agricultural).
- Failed septic tanks.
- Allowing livestock to have unrestricted access to surface water.
- Failure to manage pet and livestock wastes correctly.
- Dumping lawn clippings and other organic matter into surface water.
- Erosion of sediment into surface water from all sources (ditches, road cuts, and off-road vehicles were specifically noted in Joy et al. 2007).

Water Quality Standards and Numeric Targets

Recreational uses

Fecal coliform bacteria (FC)

The FC criteria have two statistical components: a geometric mean (GM) and an upper limit value that 10% of the samples cannot exceed. In Washington State, the upper limit statistic (i.e., not more than 10% of the samples shall exceed) has been interpreted as a 90th percentile value of the log-normalized values.

Table 200 of the Washington Administrative Code (WAC 173-201A-200) designates all fresh surface waters in Washington State must meet Primary Contact Recreation criteria for FC (Table 4).

Table 4. Washington state FC criteria (WAC 173-201A-200).

Category	GM criteria	No more than 10% of results may exceed this value (aka; 10% Not To Exceed Value or 10% NTEV)
Primary contact	100 cfu/100 mL	200 cfu/100 mL

Beginning in January 2019, the updated WAC (173-201A-200) required the averaging period of bacteria sample data be ninety days or less. Appendix I presents a rolling ninety day (3-month) GM average of FC concentrations per site.

Aquatic life uses

In the Washington State surface water quality standards, freshwater aquatic life use categories are described using key species (salmonid versus warm-water species) and life-stage conditions (spawning versus rearing). Minimum and maximum concentrations of DO and pH are set as criteria to protect different categories of aquatic communities, some of which are specified for individual rivers, lakes, and streams.

The Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC Table 602 (WAC 173-201A-602) designates the aquatic life uses in Table 5 for our study waters. We list the aquatic life uses designated per site in Table 6 and note the numeric criteria in Table 7.

Table 5. Aquatic life uses for study waters in the Walla Walla Basin (WAC 173-201A-600).

Aquatic Life Use	Description
Char spawning and rearing.	The key identifying characteristics of this use are spawning or early juvenile rearing by native char (bull trout and Dolly Varden), or use by other aquatic species similarly dependent on such cold water. Other common characteristic aquatic life uses for waters in this category include summer foraging and migration of native char; and spawning, rearing, and migration by other salmonid species.
Core summer salmonid habitat.	The key identifying characteristics of this use are summer (June 15 - September 15) salmonid spawning or emergence, or adult holding; use as important summer rearing habitat by one or more salmonids; or foraging by adult and subadult native char. Other common characteristic aquatic life uses for waters in this category include spawning outside of the summer season, rearing, and migration by salmonids.
Salmonid spawning, rearing, and migration.	The key identifying characteristic of this use is salmon or trout spawning and emergence that only occurs outside of the summer season (September 16 - June 14). Other common characteristic aquatic life uses for waters in this category include rearing and migration by salmonids.

Table 6. Use designations per study site in the Walla Walla Basin (WAC 173-201A-602).

Aquatic Life Uses	Study Sites
Char spawning and rearing	32SFT-08.8 and 32MIL-24.6
Core summer salmonid habitat	32NFT-00.0 and 32SFT-00.3
Salmonid spawning, rearing, and migration	Default criteria for all fresh surface water sites when other criteria do not apply.

Table 7. Applicable Washington State pH and DO aquatic life use criteria in the Walla Walla Basin (WAC 173-201A-200).

Category	pH	DO lowest 1-day minimum
Char spawning and Rearing	6.5-8.5 with <0.2 s.u. change due to anthropogenic causes	9.5 mg/L
Core summer Salmonid habitat	Same as above	9.5 mg/L
Salmonid spawning, rearing and migration	6.5-8.5 with <0.5 s.u. change due to anthropogenic causes	8.0 mg/L

Dissolved oxygen (DO)

Aquatic organisms are very sensitive to reductions in the level of DO in the water. The health of fish and other aquatic species depends on maintaining an adequate supply of oxygen dissolved in the water. Oxygen levels affect growth rates, swimming ability, susceptibility to disease, and the relative ability to endure other environmental stressors and pollutants. While direct mortality due to inadequate oxygen can occur, Washington State designed the criteria to maintain conditions that support healthy populations of fish and other aquatic life.

Oxygen levels can fluctuate over the day and night in response to changes in climatic conditions as well as the respiratory requirements of aquatic plants and algae. Since the health of aquatic species is tied predominantly to the pattern of daily minimum oxygen concentrations, the criterion is based on the lowest 1-day minimum oxygen concentrations that occur in a water body.

The DO criterion for salmonid spawning, rearing, and migration states [WAC 173-201A-200(1)(d)]:

> *The one-day minimum dissolved oxygen concentration shall not fall below 8.0 mg/L more than once every ten years on average. When DO is lower than the criterion (or are within 0.2 mg/L of the criterion) due to natural conditions, then cumulative human-caused activities will not decrease the dissolved oxygen more than 0.2 mg/L.*

The criterion of 8.0 mg/L is used to maintain conditions where a water body is naturally capable of providing full support for its designated aquatic life uses. Table 602 in the WAC also designates that DO concentrations in surface waters of WRIA 32 shall exceed 5.0 mg/L (WAC 173-201A-602). The standards recognize, however, that not all waters are naturally capable of staying above the fully protective DO criterion. When a water body is naturally lower in oxygen than the criterion, the state provides an additional allowance for further depression of oxygen conditions due to human activities. In this case, the combined effects of all human activities must not cause more than a 0.2 mg/L decrease below that naturally lower (inferior) oxygen condition.

pH

The pH of natural waters is a measure of acid-base equilibrium achieved by the various dissolved compounds, salts, and gases. It is an important factor in the chemical and biological systems of natural waters. pH both directly and indirectly affects the ability of waters to have healthy populations of fish and other aquatic species. Changes in pH affect the degree of dissociation of weak acids or bases. This effect is important because the toxicity of many compounds is affected by the degree of dissociation. While some compounds (e.g., cyanide) increase in toxicity at lower pH, others (e.g., ammonia) increase in toxicity at higher pH.

While there is no definite pH range within which aquatic life is unharmed and outside which it is damaged, there is a gradual deterioration as the pH values are further removed from the normal range. However, at the extremes of pH lethal conditions can develop. For example, extremely low pH values (<5.0) may liberate sufficient carbon dioxide from bicarbonate in the water to be directly lethal to fish.

The state established pH criteria in the Washington State surface water quality standards primarily to protect aquatic life. The criteria also serve to protect waters as a source for domestic water supply. Water supplies with either extreme pH or that experience significant changes of pH even within otherwise acceptable ranges are more difficult and costly to treat for domestic water purposes. pH also directly affects the longevity of water collection and treatment systems, and low pH waters may cause compounds of human health concern to be released from the metal pipes of the distribution system.

The pH criterion for salmonid spawning, rearing, and migration states [WAC 173-201A-200(1)(d)]:

pH must be kept within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.5 units.

TMDL targets

We assessed progress toward the TMDL target reductions for all results based on the 2014 (6-year) target reductions set in the WQIP (Baldwin et al. 2008).

In cases where the calculated 2014 target reduction would be lower than the long-term target reductions, we used the higher (less stringent) targets.

Interim 6-year (2014) TMDL targets

The WQIP (Baldwin et al. 2008) set reduction targets for 6-years following implementation (2014) for FC and nutrients (Table 8). Ecology intends these interim targets to guide efforts towards long-term compliance with Washington State FC, pH, and DO criteria (Tables 4 to 7).

Table 8. 2014 (Year 6) interim water quality targets from the 2008 WQIP.

TMDL	Target Parameter	Target Reduction
Fecal Coliform Bacteria (FC)	FC (cfu/100 mL) (% decrease in colonies)	59%
pH & Dissolved Oxygen (DO)	Nutrient seasonal average concentration (mg/L) (reduction from 2002 levels)	60%

The Table 8 targets show the recommended reduction towards natural background seasonal average concentrations of the following study parameters:

- Fecal coliform bacteria (FC)
- Nutrients:
  - Dissolved inorganic nitrogen (DIN)
  - Soluble reactive phosphorus (SRP)
  - Organic nitrogen (OrgN)
  - Organic phosphorus (OrgP).

We determined the seasonal average concentrations for periods of seasonal low-flow (typically June to October) and seasonal high-flow (typically November to May). In 2015, snowmelt occurred much earlier than usual, and stream levels reached low-flow conditions by May, so we included the May 2015 samples in the low-flow season data set.

Long-term 10-year (2018) TMDL targets

TMDL long-term FC reduction goals

The WQIP (Baldwin et al. 2008) determined that when water-quality improvement efforts achieve long-term target reductions, FC concentrations should achieve WA state criteria (Table 4). The WQIP set these goals for 10-years following approval of the TMDL (2018).

To achieve both geometric mean (GM) and 90th percentile (10% NTEV) FC criteria, Ecology set statistical rollback targets for both measures. Ecology applied the statistical rollback method as follows:

The GM (approximately the median in a lognormal distribution) and 90th percentile statistics are calculated and compared to the FC criteria. If one or both do not meet the criteria, the whole distribution is "rolled-back" to match the most restrictive of the two criteria. (Joy and Swanson 2005)

As applicable, on a per site basis, Ecology used statistical rollback to decrease the target value of either the GM or 10% NTEV to meet the other more restrictive criterion. Ecology adjusted both GM and 10% NTEV targets for applicable sites in this study. We show applicable GM and 10% NTEV statistical rollback targets in the FC tables and figures in the *Results* section.

TMDL long-term nutrient reduction goals

The WQIP (Baldwin et al. 2008) set 10-year (2018) final concentration goals for nutrients for selected waters within the basin in order to help improve pH and DO water quality, and, where possible, meet state water-quality criteria (Table 9).

Nonpoint sources in Table 9 include groundwater and diffuse sources, which we calculated from the differences in loading and discharge between upstream and downstream sites.

Table 9. TMDL long-term (10-year, 2018) nutrient targets.

Location	Source type	Target concentrations (µg/L)
Touchet River and tributaries	Surface water	DIN = 55, organic nitrogen = 39, SRP = 25, organic phosphorus = 18
Touchet River and tributaries	Nonpoint	DIN = 205, SRP = 50
Mill Creek and other urban tributaries	Surface water	DIN = 76, SRP = 47
Mill Creek and other urban tributaries	Nonpoint	DIN = 387, SRP = 85
Walla Walla River and minor tributaries	Surface water	DIN = 200, SRP = 40

Expected reduction results for pH and dissolved oxygen (DO)

Expected reductions of DIN and SRP from tributary and nonpoint sources through TMDL implementation should reduce the diel maximum pH and increase the diel minimum DO. However, natural background conditions in some reaches may preclude achieving state water-quality criteria for pH and DO. The following language from Joy et al. (2007) describes the reaches and conditions where meeting pH and DO criteria may not be possible in the timeframe of this study:

"The best potential pH and DO conditions [could not be determined during the TMDL study] because of uncertainties about improvements in water temperature, water volume, and groundwater nutrient loads. Steps taken to decrease surface water nutrient loads from point, tributary, and nonpoint sources should have helped improve pH and DO conditions. However, some reaches of the Walla Walla River are unlikely to meet applicable pH and DO numeric criteria even after nutrient reductions are made because of low flows, high light exposure, high water temperatures, and large groundwater DIN loads."

Lower Mill Creek and Garrison Creek

- *"… the DIN and SRP concentrations in lower Mill Creek and Garrison Creek were the highest compared with other surface waters in the basin. Sometimes instream concentrations approached those found in wastewater effluent… Considering the advanced state of enrichment of nutrients in these waterbodies, substantial reductions would be required to improve water quality to conditions approaching natural background."*

Touchet River Basin

- *Relatively high nutrient loading above the [North and South Forks of the Touchet River] … prevents upper reaches of the Touchet River from meeting the pH and DO Class A criteria, even when loading above the forks is reduced by one-third to simulate reference conditions.*
- *"The combined effect of increasing shade and decreasing nutrient loading is predicted to result in daily minimum DO compliance … in about 80% of the river… [, and] expected to significantly increase compliance with pH standards in about 60% of the river."*
- *"None of the model scenarios demonstrated a situation where pH and DO criteria would be met in all reaches of the river. … It appears unlikely that DIN and phosphorus concentrations of groundwater can be reduced much in the lower reaches of the Touchet River (from RM 34 to the confluence with the Walla Walla River). Those reaches may continue to be out of compliance with DO criteria after identified sources are controlled."*

Walla Walla River (Basin)

- *"If tributaries to the Walla Walla River reduce nutrient concentration to levels approaching Mill Creek and Touchet River headwaters…, then DIN and SRP loads in the tributaries are estimated to decrease by 20% to 90%." (*see Table 10 below and Table 16 in Joy et al. 2007)
- *"…the large groundwater component of DIN [in the Walla Walla River basin] would continue to stimulate primary productivity so that pH and DO concentrations would still have wide diel ranges and would not be in compliance with applicable criteria. As observed in the lower Touchet River, the groundwater nutrient concentrations may be a function of the underlying geology and soils in the Level 4 Pleistocene Lake Basin Ecoregion."*

Table 10: Reductions estimated in annual SRP and DIN loads (lbs/day) from selected tributaries to the Walla Walla River if instream concentrations reduce to headwater concentrations or those recorded at the Oregon border at the state line.
Reproduced from Table 16 of Joy et al. 2007.

Tributary	Headwater SRP	Headwater DIN	State line SRP	State line DIN
Yellowhawk Creek	22%	91%	22%	71%
Garrison Creek	94%	96%	94%	91%
Mill Creek	58%	99%	65%	79%
Touchet River	29%	61%	22%	54%

SRP: soluble reactive phosphorus
DIN: dissolved inorganic nitrogen.

Goals and Objectives

This project evaluates whether water quality in the Walla Walla River Basin met six-year (2014) interim FC, pH, and DO water quality targets from Table 2 of the WQIP (Baldwin et al. 2008).

Project goals

The goal of this TMDL effectiveness-monitoring (EM) project was to determine if water quality met or made progress towards meeting standards and targets.

Study objectives

The objectives of this study were:

- Quantify concentrations and loadings of bacteria and nutrients in streams and rivers across WRIA 32.
- Determine if water quality met the TMDL Water Quality Implementation Plan 6-year interim (2014) targets.
- Determine if water quality trends over time are improving.

To meet its objectives, this project relied on data collected by Ecology staff during the 2014-2015 EM study period. During this time, we also used data collected by other organizations that met Ecology's data quality requirements. We compile, analyze, and present the study data in this final technical report.

Methods

Data collection methods

Ecology field study

Sampling schedule

We completed sampling runs from July 2014 through June 2015 (Table 11). Due to drought conditions in 2015, the low-flow season began about one month early (in May 2015) relative to the TMDL study when low-flow conditions began in June 2003. Our sampling run schedule resulted in five high-flow season and twelve low-flow season sampling events.

Table 11. 2014-2015 sampling schedule.

2014	2015
July 8-10	Jan 13-15
July 22-24	Feb 3-5
Aug 5-7	Feb 9-11 [1]
Aug 19-21	Mar 10-11
Sept 9-10	Apr 14-16
Sept 23-25	May 5-6
Oct 7-8	May 19-20
Oct 28-30	June 2-4
Dec 9-10	June 23-24

1. Targeted sampling for annual maximum flows

We conducted an additional high-flow season survey February 9 to 11, 2015 to capture the annual maximum flows. This sampling was not representative of typical high-flow season conditions, so we analyzed this sampling separately, and did not include it in the analysis of high-flow season results.

Fixed network discrete sampling

We established a fixed network of stations for discrete water quality sampling (Table 12 and Figures 8, 21, and 30). At these stations we sampled instream water during site visits twice monthly during the low-flow season, July-October 2014 and May-June 2015, and monthly during the high-flow season, December 2014 to April 2015. We selected sampling sites based on TMDL targets (Tables 8 and 9), the geographic extent of the 303(d) listings in the watershed (Figures 6 to 8), and implementation of pollution control actions.

Table 12. Walla Walla effectiveness monitoring (EM) fixed network stations.

Station ID	Station Description	NAD083 Latitude	NAD083 Longitude	Stream Gauge	Hydrolab Deployment
32SFT-08.8	SF Touchet @ Rainwater	46.1924	-117.9557	–	–
32SFT-00.3	SF Touchet @ Magill Lane	46.2966	-117.9581	–	–
32NFT-00.0 (32E050)	NF Touchet @ mouth	46.3014	-117.9599	Ecology	Yes
32TOU-52.2	Touchet R above Dayton WWTP	46.31582	-118.0038	–	–
32TOU-51.2	Touchet @ Ward Rd	46.3013	-118.0134	–	–
32COP-00.5	Coppei Creek @ Hwy 124	46.2690	-118.1675	WWBWC	-
32TOU-40.5 (32B100)	Touchet nr Bolles Rd (32B100)	46.2740	-118.2213	Ecology	Yes
32TOU-34.2	Touchet @ Hwy 125	46.2943	-118.3405	–	–
32TOU-25.0	Touchet @ Lamar Rd	46.2883	-118.5320	–	–
32TOU-17.8	Touchet @ Luckenbill Rd	46.2229	-118.5772	–	–
32TOU-07.0	Touchet @ Touchet N Rd	46.1224	-118.6503	–	–
32TOU-02.0 (32B075)	Touchet @ Cummins Rd	46.0571	-118.6689	Ecology	Yes
32MIL-24.7	Mill Creek @ Tiger Creek Rd	45.9885	-118.0641	USGS	–
32MIL-11.5	Mill/Yellowhawk/Garrison Cr. nr Reservoir Rd	46.0764	-118.2729	USGS	–
32MIL-08.9	Mill Creek @ Wilbur St	46.0690	-118.3125	–	–
32MIL-04.8	Mill Creek @ Gose Rd	46.0643	-118.3886	–	–
32YEL-03.5	Yellowhawk Creek @ Plaza Rd	46.0327	-118.3447	–	–
32RUS-00.1	Russell Creek @ Plaza Rd	46.0291	-118.3447	–	–
32COT-01.0	Cottonwood Creek @ Plaza Rd	46.0256	-118.3461	–	–
32WAL-39.6	Walla Walla @ Peppers Br Rd	46.003	-118.383	WWBWC	–
32YEL-00.2	Yellowhawk Creek @ Old Milton Rd	46.0193	-118.3995	WWBWC	–
32ELW-00.6	East Br Little Walla Walla @ Springdale Rd	46.013	-118.4116	WWBWC	–
32WAL-36.5 (32A105)	Walla Walla @ Beet Rd	46.0238	-118.4270	Ecology	Yes
32GAR-00.5	Garrison Creek @ Mission Rd	46.0278	-118.4296	WWBWC	–
32MIL-00.5	Mill Creek @ Sweagle Rd	46.0416	-118.4709	–	–
32WLW-00.8	W Br Little Walla Walla @ Sweagle Rd	46.0344	-118.4718	WWBWC	–
32WAL-32.8 (32A100)	Walla Walla @ Detour Rd	46.0429	-118.4907	Ecology	Yes
32DRY-00.1	Dry Creek @ Dodd Farm	46.0552	-118.5925	WWBWC	–
32MUD-00.5	Mud Creek @ Borgen Rd (Barney Rd)	46.0421	-118.6147	WWBWC	–
32PIN-01.4	Pine Creek @ Sand Pit Rd	46.0277	-118.6326	–	–
32WAL-22.7	Walla Walla @ Touchet-Gardena Rd	46.0292	-118.6707	–	–
32WAL-15.6	Walla Walla @ Byerly Rd	46.0377	-118.7665	USGS	–
32WAL-09.3	Walla Walla River @ Pierces RV park	46.0681	-118.8241	WWBWC	–

WWBWC: Walla Walla Basin Watershed Council   USGS: United States Geological Survey

Though we did not sample WWTP outfalls, we show the outfall locations with our sampling sites in Figures 8, 21, and 30, and Appendix F, Figures F1, F4, F9, and F14 to indicate their proximity to our sampling collection locations.

We sampled a few additional locations that Ecology did not survey during the TMDL to fill in gaps in our understanding of water quality conditions throughout the basin. We distributed these sites to provide sufficient geographical coverage to evaluate progress in meeting interim targets for FC, pH, and DO.

We sampled during site visits to fixed network stations for the following parameters:

- Fecal coliform bacteria (FC)
- Total nitrogen (TN; also called Total persulfate nitrogen or TPN)
- Ammonia nitrogen (NH_3)
- Nitrite and nitrate nitrogen (NO_2NO_3)
- Total phosphorus (TP)
- Soluble reactive phosphorus (SRP; also called Dissolved phosphorus or Dissolved orthophosphates)

We attempted to collect 10% of samples with Quality Control samples. For laboratory samples, we collected about 9% replicates and 1% blanks. For replicate samples, we calculated the percent Relative Standard Deviation (% RSD) to estimate our field and laboratory sampling variation.

When practical, we measured instantaneous flows when we sampled sites without flow gauging equipment. We calculated discharge by measuring velocities and depths at variable width intervals across the stream (Shedd 2011).

Continuous flow monitoring and water quality measurements

Ecology's Freshwater Monitoring Unit manages five active flow-gauging stations in the Walla Walla River Basin (Tables 12 and 13). We installed and maintained continuous water quality monitoring stations at these gauges following a set of protocols for Ecology's statewide ambient monitoring program (Hallock 2009). At these stations, we collected continuous measurements for DO, pH, temperature, and specific conductance during the low-flow critical season (July to October 2014 and May to July 2015).

Table 13. Ecology's active flow gaging stations in the Walla Walla River Basin.

Site name	Ecology flow monitoring Station ID	EM Study ID	Period of record for stage and flow	Deployment dates for continuous water quality monitoring
North Fork Touchet River @ confluence.	32E050	32NFT-00.0	2002-present	August 5 to November 10, 2014
Touchet River @ Bolles Rd	32B100	32TOU-40.5	2002-present	June 30 to November 10, 2014
Touchet River @ Cummins Rd	32B075	32TOU-02.0	2002-present	July 2 to November 10, 2014 and June 2 to August 6, 2015
Walla Walla River @ Mojonnier (Beet) Rd	32A105	32WAL-36.5	2007-present	July 1 to October 6, 2014
Walla Walla River @ Detour Rd	32A100	32WAL-32.8	2002-present	July 2 to November 10, 2014 and May 4 to August 6, 2015

In addition to the flow data obtained from our Ecology gauging stations, we used flow records from United States Geological Survey (USGS) and Walla Walla Basin Watershed Council (WWBWC) stations to calculate loads for our fixed network stations when available. (Table 12)

We deployed all continuous monitoring equipment in the well-mixed main flow, avoiding eddies and backwaters.

We collected fixed network discrete samples at all Ecology flow gauging stations. We also deployed thermistors recording continuous (15-minute interval) temperature records at all fixed network locations.

External data sources

For this study, we also used field data and reports from the WWBWC and USGS, as well as from WWTPs in the cities of College Place, Dayton, Waitsburg, and Walla Walla.

Gauging data

We used flow-gauging data collected by the USGS and WWBWC for continuous instream flow estimates when available (Appendix E).

Discharge Monitoring Reports (DMRs)

As a permit requirement, WWTPs submit monthly DMRs to Ecology's Water Quality Program for comparison to permit effluent limits.

We looked at published DMR data from Walla Walla Basin WWTP point sources to account for possible downstream effects at our sampling stations (Appendix F).

Data analysis methods

We calculated three nutrient parameters from the sample parameters.

- Dissolved Inorganic Nitrogen (DIN):
  - The sum of NH_3 and NO_2NO_3. Formula: DIN = NH_3 + NO_2NO_3
- Organic Nitrogen (OrgN):
  - The difference between TN and DIN. Formula: OrgN = TN – DIN
- Organic Phosphorus (OrgP):
  - The difference between TP and SRP. Formula [3]: OrgP = TP – SRP

Data from the fixed-network provided an estimate of the seasonal averages of nutrients and FC seasonal GM and 10% NTEV statistics. We compared data with interim and long-term TMDL targets and Washington State criteria (Tables 4 to 9), using the least stringent of the applicable targets.

We compared TMDL targets to the arithmetic mean, and for FC, we calculated the GM and the percentage of samples exceeding the 10% NTEV. For all parameters, we calculated 80% confidence intervals leaving 10% uncertainty on either side of the statistic to assess the data distribution around the results. We used the “boot.ci” R statistical software package using the bias-corrected and accelerated (BCa) bootstrap method to generate confidence intervals. The BCa method corrects for bias and skewness in the distribution of bootstrap estimates.

We used a Beales ratio estimator formula (Dolan et al. 1981) to calculate the seasonal nutrient loads at sites with adequate pollutant and streamflow data. The Beales formula provides a better annual or seasonal estimate of pollutant loads compared to the average instantaneous load obtained from a few sampling events. When a site lacked continuous flow gauging data, we estimated the seasonal load using the Beales formula with continuous gauging data from an associated nearby station within the same stream or in an adjacent stream thread.

Trend analysis for the Walla Walla River at River Mile 15.6

Flow and water quality sampling conducted by both Ecology and the USGS allowed us to analyze trends at the Walla Walla River at the Byerly Road Bridge at River Mile 15.6 (32WAL-15.6). This downstream site represents cumulative flows and residual pollutants from most of the Walla Walla Basin. Collectively, Ecology’s Ambient Water Quality Monitoring station 32A070 provided monthly FC and nutrient sampling data, and the USGS station 14018500 provided continuous flow records from October 1989 to July 2019.

We used the Seasonal Kendall Trend Test (Hirsch et al. 1982) to test against the null hypothesis that the distribution of data was random. The Seasonal Kendall accounts for seasonal blocks and other covariates in concert with the result parameter. The model outputs indicate the direction and probability of change and the contribution of each covariate to the model. The

[3] Our formula for estimating organic phosphorus (OrgP) gives the portion of phosphorus that is not readily available for algal uptake, including both acid-hydrolysable inorganic phosphorus and organic phosphorus, both in dissolved and particulate forms. (APHA 2005)

Theil-Sen's slope is the median of all slopes calculated between each month's data. The direction of the Theil-Sen's slope indicates the direction of the change in the parameter. Kendall's Tau also indicates the direction of change, and the magnitude of Tau contributes to the Z-score and probability (p-value) of a relationship occurring between the variable (water quality) and time (year). A $p<0.05$ means there are significant differences at the 95% confidence level in concentration over time.

We analyzed trends for seasonal flow, FC, DIN, and SRP at 32WAL-15.6. We adjusted all parameter p-values for the monthly seasonal block, and we adjusted the FC and nutrient parameter p-values for the seasonal flow covariate. The Seasonal Kendall requires more than ten years of monthly data to estimate the seasonal variance and trend (Hirsch and Slack 1984), so we tested both the 13-year period from the June 2002 TMDL through the June 2015 EM studies, and the 30-year period of combined flow and nutrient sampling, October 1989 through July 2019. We analyzed low-flow season months (June to October, Table 57) separately from high-flow season months (November to May, Table 58).

Treatment of non-detects

Non-detects are unknown values below analytical testing detection or reporting limits, which result from measuring trace amounts of some water quality parameters. We identify non-detects whenever we do not detect the presence of a parameter above the laboratory set limit.

We substituted half the value of the reporting limit for all lab sample non-detects to use in data summary statistics, and figures, except where noted otherwise below.

If a calculated parameter (DIN, OrgN, or OrgP) included a component sample parameter (NH_3, NO_2NO_3, TN, SRP, or TP) with a non-detect, we substituted half the reporting limit for each non-detect value in the calculation and qualified the calculated parameter value as an estimate.

If through subtraction, the calculated parameter value fell below the minimum component-parameter reporting limit, we qualified the calculated result as a non-detect and substituted half the minimum component-parameter reporting limit as the non-detect result.

Results and Discussion

Climate differences between the TMDL and EM studies

Water Year 2015 drought

During the EM study in Water Year (WY) 2015 (October 2014 through September 2015), high winter temperatures and a lack of precipitation as snow resulted in low snowpack levels in the Walla Walla River Basin (Table 14). Walla Walla stream flows reached baseflow conditions by early April 2015, two months early (Anderson et al. 2016). May 2015 flows resembled typical low-flow season baseflow, instead of the expected spring high-flows from a non-drought year (Figure 6).

Due to these drought conditions, we analyzed the May 2015 results with the July to October 2014 and June 2015 low-flow season samples.

Table 14. Upper Touchet Basin snowpack levels (percentage of median) for Water Years 2003 and 2015.

WY	Dec. 1	Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1
2003	30%	62%	59%	59%	81%	101%
2015	54%	60%	46%	37%	21%	0%

In contrast, during the TMDL in WY 2003 (October 2002 through September 2003), a low initial snowpack increased through the spring to 100% of median levels in May (Table 14). In the preceding low-flow seasons for both the TMDL (June to October 2002) and EM (July to October 2014) studies, baseflow conditions were similar between the two years.

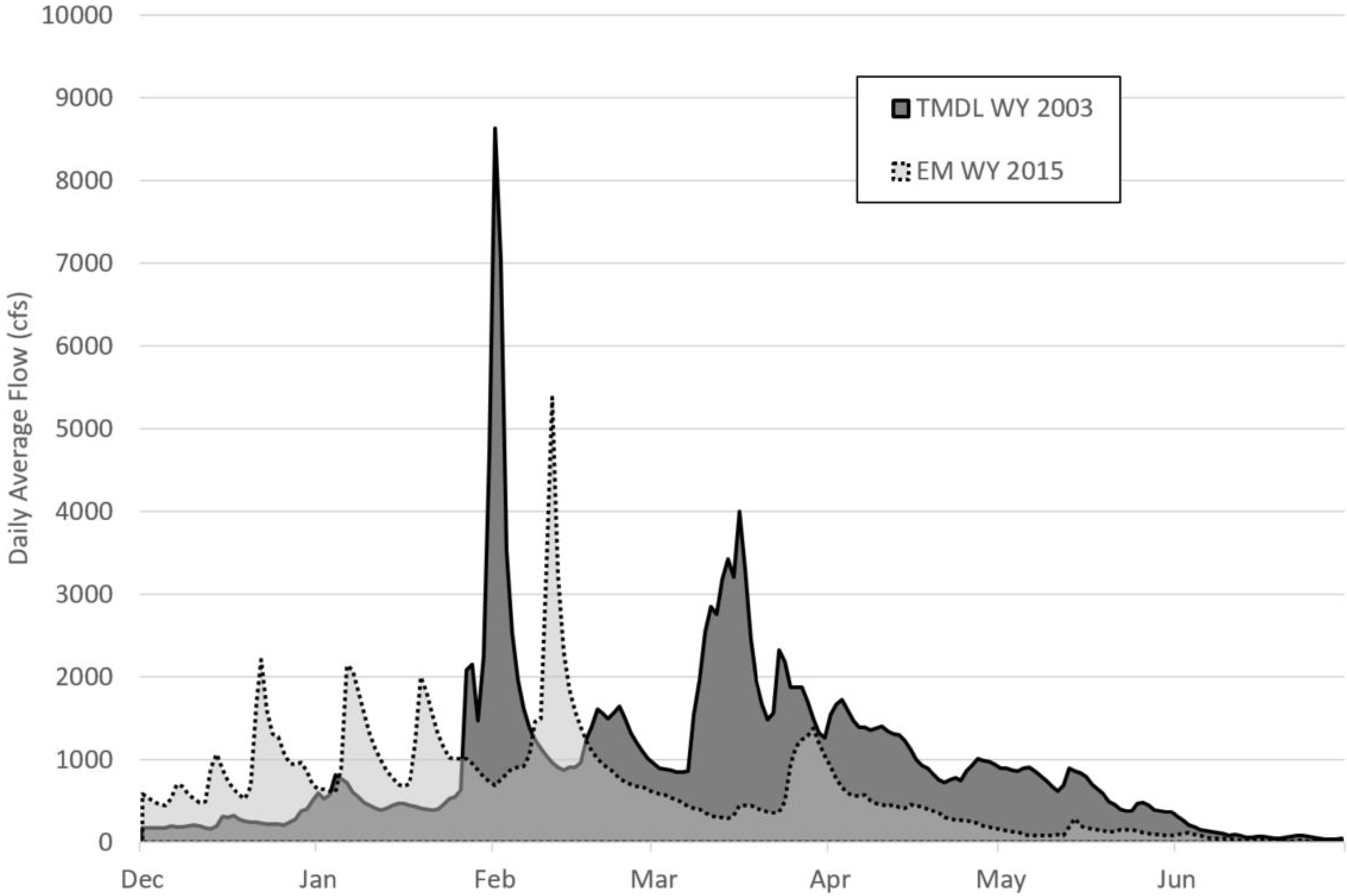


Figure 6. Daily average WY 2003 and WY 2015 spring flows on the Walla Walla River at USGS Station 14018500 (RM 18.2) by month.

February 2015 high-flow event

In addition to our regular sampling, our study intentionally targeted a high-flow event during water year (WY) 2015. We excluded high-flow event samples from the comparison to TMDL targets because the event sampling was not representative of typical stream conditions. We targeted the high-flow event to assess the effect of high sediment loads and riparian flooding on FC and nutrients.

We sampled during a rain-on-snow event February 9 to 11, 2015. Daily mean flow at the Walla Walla River at Byerly Road (32WAL-15.6) peaked near 5,380 cfs on February 11, 2015, the highest flow that occurred during the season. In contrast, peak flows during the TMDL sampling year were near 8,640 cfs on February 1, 2003 (Figure 6).

Samples collected February 9-11, 2015 contained higher than average concentrations of FC and all nutrient parameters (see Appendix K for full results). Organic phosphorus concentrations in particular were disproportionately higher than other sampling event concentrations, in some cases exceeding ten times the maximum results from other sampling events (Figure 7).

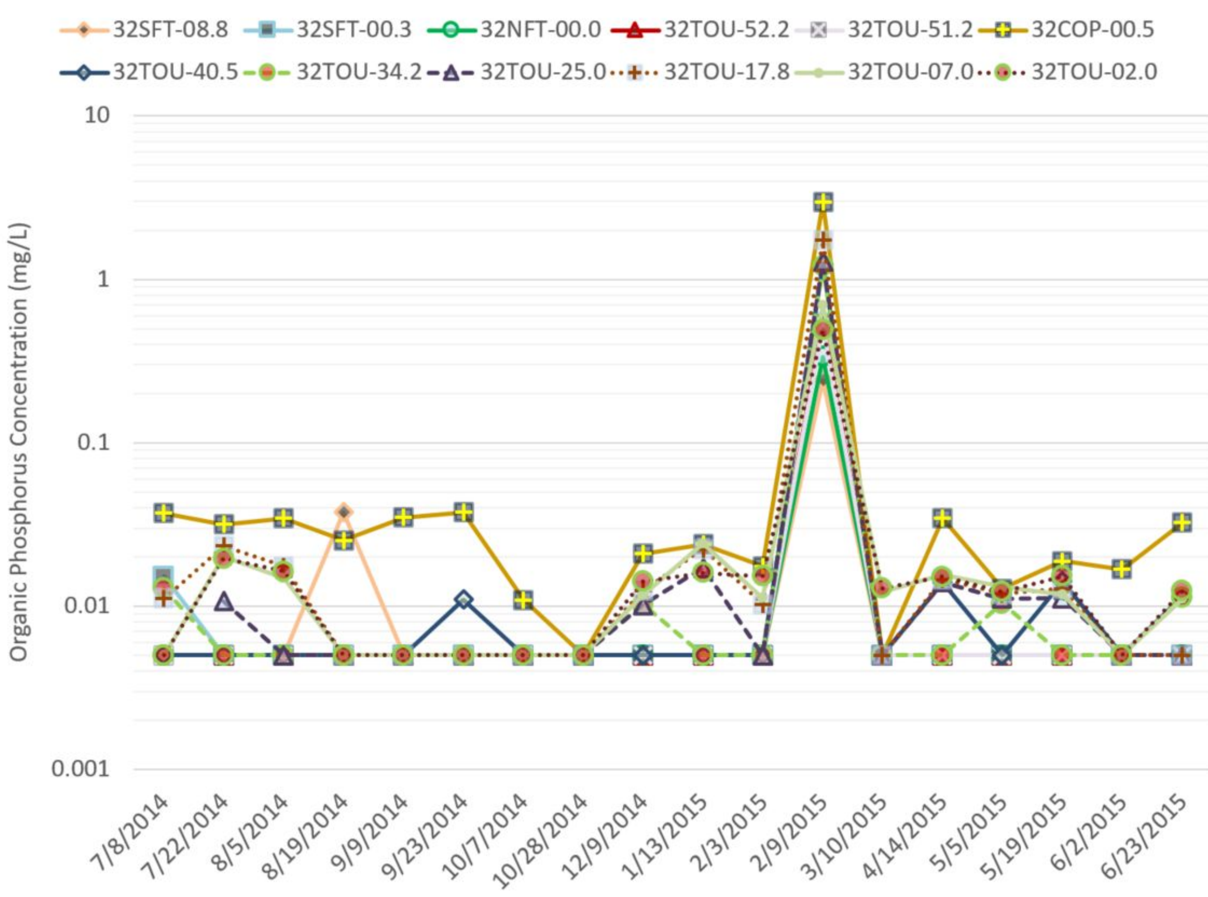


Figure 7. Touchet River Basin organic phosphorus concentrations per date. [1]

1. Sample dates in this figure represent the first day of a two to three-day sampling event.

Reach assessments

In this section, we compare and discuss the 2014-2015 effectiveness monitoring (EM) results in relation to the TMDL targets and results from the 2002-2003 TMDL study.

Figures in this section use box plots to show the range of concentrations per parameter in both the EM and TMDL studies. We grouped sampling sites in the plots by location in the basin, and by upstream to downstream connection.

The plotted boxes show the bootstrapped 80% confidence intervals (CIs) on the mean (the geometric mean for FC and the arithmetic mean for nutrients). We used 80% CIs to compare our TMDL and EM study data sets because a lack of overlap would occur at a one-sided Type I error rate of ≤10% for each of the compared data sets. At Ecology, 10% is a commonly accepted error rate for water quality data set comparisons. A Type I error rate indicates the probability of a false rejection of a null hypothesis, and, in our comparisons where the null hypothesis is no change in concentration, shows the probability that the sample concentrations were indicated as different when in truth they were not different. The maximum Type I error rate for our data sets which did not overlap was likely lower than 10%, as an error rate for paired CIs is usually lower than the error rate for a single CI (Payton et al. 2003).

We display and note the 2014 interim TMDL targets on the figures and tables where applicable. When the 2014 reduction targets were less than the 2018 final TMDL targets, we use the less restrictive (higher) targets. We directly assess the FC 10% NTEV in column figures following the boxplots.

All data collected during this study are available in Ecology's Environmental Information Management (EIM) database. Search study ID JROS0025.

- Appendix A shows our quality assurance and quality control results.
- Appendix B shows 15-minute-interval water quality monitoring results for five Ecology flow and water-quality monitoring stations deploying multi-parameter sondes and water-level (stage) monitoring equipment during this study for the deployment dates in Table 13.
- Appendix C shows charts of our 15-minute interval continuous temperature data per site.
- Appendix D plots our discrete meter measurements collected per site visit by date.
- Appendix E charts USGS and WWBWC flow monitoring data for the Walla Walla River Basin sites.
- Appendix F shows NPDES permitted WWTP Discharge Monitoring Report (DMR) results with instream results from this study's bacteria and nutrient sampling adjacent to the WWTP outflows.
- Appendix G summarizes NPDES stormwater permit monitoring.
- Appendix J summarizes the lognormal distribution tests for study results.
- Appendix K lists laboratory results from both Manchester Environmental Laboratories (MEL) and Walla Walla Regional Water Testing Services (WWRWTS). All our study sampling results are also available from Ecology's EIM database under Study ID JROS0025.

Touchet River Basin

This section summarizes the TMDL and Effectiveness Monitoring (EM) study results from the Touchet River Basin. The area includes the incorporated towns of Dayton, Waitsburg, and Prescott, and unincorporated Touchet (Figure 8).

Dayton and Waitsburg have NPDES permitted WWTPs (Figure 8). The Dayton WWTP currently discharges to the Touchet River at RM 52.1. The Waitsburg WWTP discharges to a wetland adjacent to the Touchet River near RM 43.4. In Appendix F, we describe these facilities' effluent results and compare them to this study's adjacent instream data where available.

Touchet River Basin results and target comparisons are in Tables 15 to 28, and Figures 9 to 20.

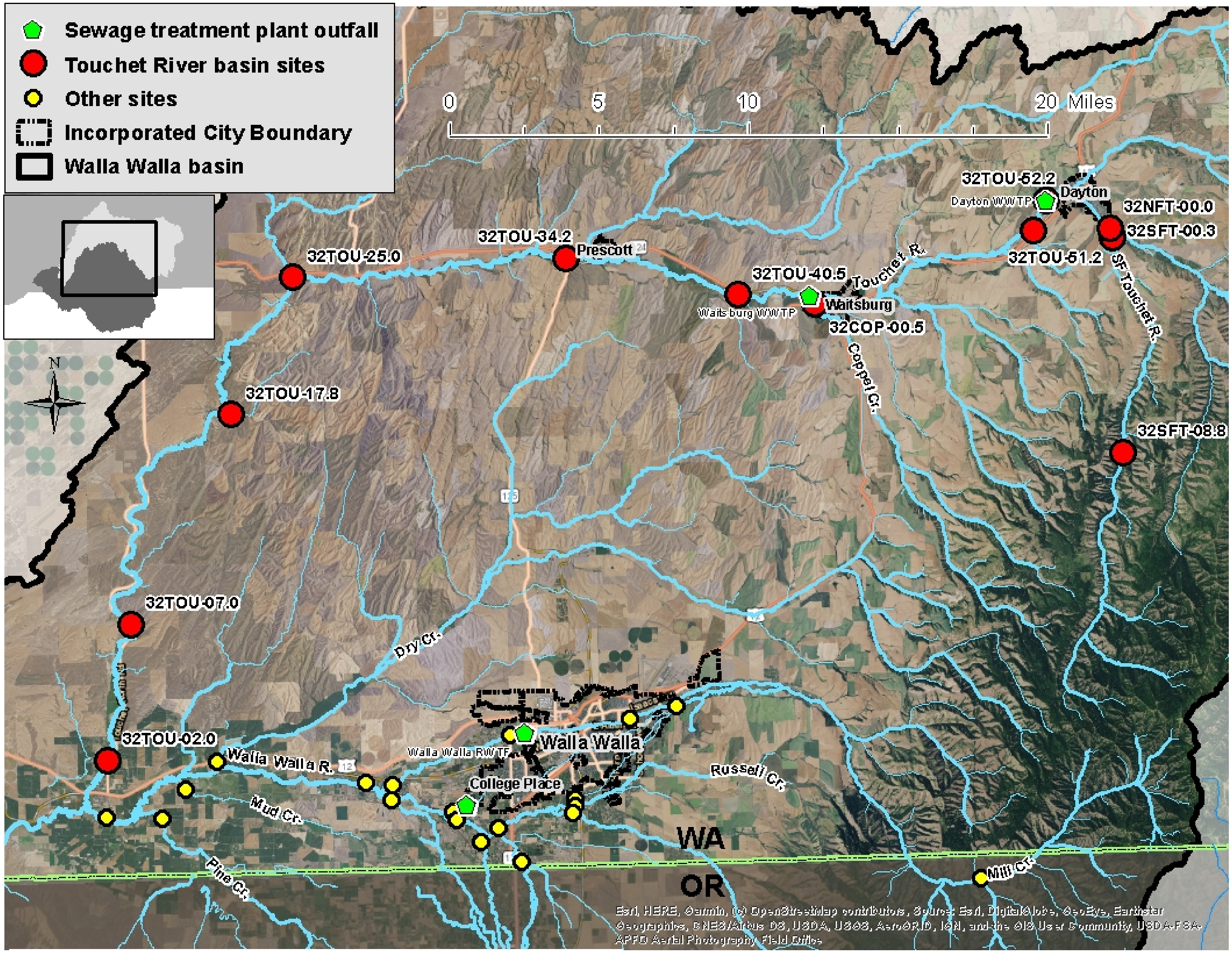


Figure 8. Touchet River Basin sites.

Fecal coliform (in the Touchet River Basin

Low-flow season

Table 15: Touchet River sites low-flow season FC concentrations and targets

EM Site ID	EM Site Name	GM targets[1]	TMDL count	TMDL GM[2]	TMDL GM, 80% CI[3]	EM count	EM GM[2]	EM GM, 80% CI[3]	% Change in GM[2]	10% NTEV targets[1]	TMDL % of samples above 10% NTEV[2]	EM % of samples above 10% NTEV[2]
32SFT-08.8	SF Touchet R @ Rainwater	100	0	NA	NA	12	***15***	[10, 21]	NA	200	NA	***0%***
32SFT-00.3	SF Touchet R @ Magill Rd	100	9	***12***	[9, 16]	12	***69***	[40, 101]	+464% (increase)	200	***0%***	17%
32NFT-00.0	NF Touchet R near mouth	100	9	***26***	[20, 34]	12	***40***	[26, 54]	+55% (increase)	200	***0%***	***0%***
32TOU-52.2	Touchet R above Dayton STP	100	3	***20***	[18, 22]	11	***30***	[21, 40]	+47% (increase)	200	***0%***	***0%***
32TOU-51.2	Touchet R @ Ward Rd	100	9	***31***	[22, 53]	12	111	[65, 196]	+259% (increase)	200	11%	33%
32COP-00.5	Coppei Creek @ Hwy 124	100	3	216	[200, 220]	12	248	[191, 348]	+15% (increase)	169	100%	58%
32TOU-40.5	Touchet R @ Bolles Rd	100	9	***37***	[25, 52]	12	***82***	[58, 110]	+122% (increase)	200	***0%***	17%
32TOU-34.2	Touchet R @ Hwy 125	34	9	102	[60, 187]	12	98	[66, 140]	-4%	200	33%	33%
32TOU-25.0	Touchet R @ Lamar	60	3	71	[40, 120]	11	***30***	[22, 40]	-57%	200	33%	***0%***
32TOU-17.8	Touchet R @ Luckenbill Rd	100	9	***35***	[22, 54]	12	***33***	[22, 45]	-8%	200	11%	***0%***
32TOU-07.0	Touchet R @ Touchet N Rd	100	9	***60***	[48, 81]	12	***30***	[15, 53]	-50%	200	11%	***8%***
32TOU-02.0	Touchet R @ Cummins Rd	52	8	173	[104, 309]	12	92	[53, 143]	-47%	200	50%	42%

1. Targets below the state standards were calculated using statistical rollback to meet reductions at both the geometric mean (GM) and the 10% NTEV.
2. Results in ***Bold Italic*** met 2014 GM reduction targets.
3. 80% CI = Two-sided 80 percent confidence intervals (CI) on the GM in the format [lower CI, upper CI].

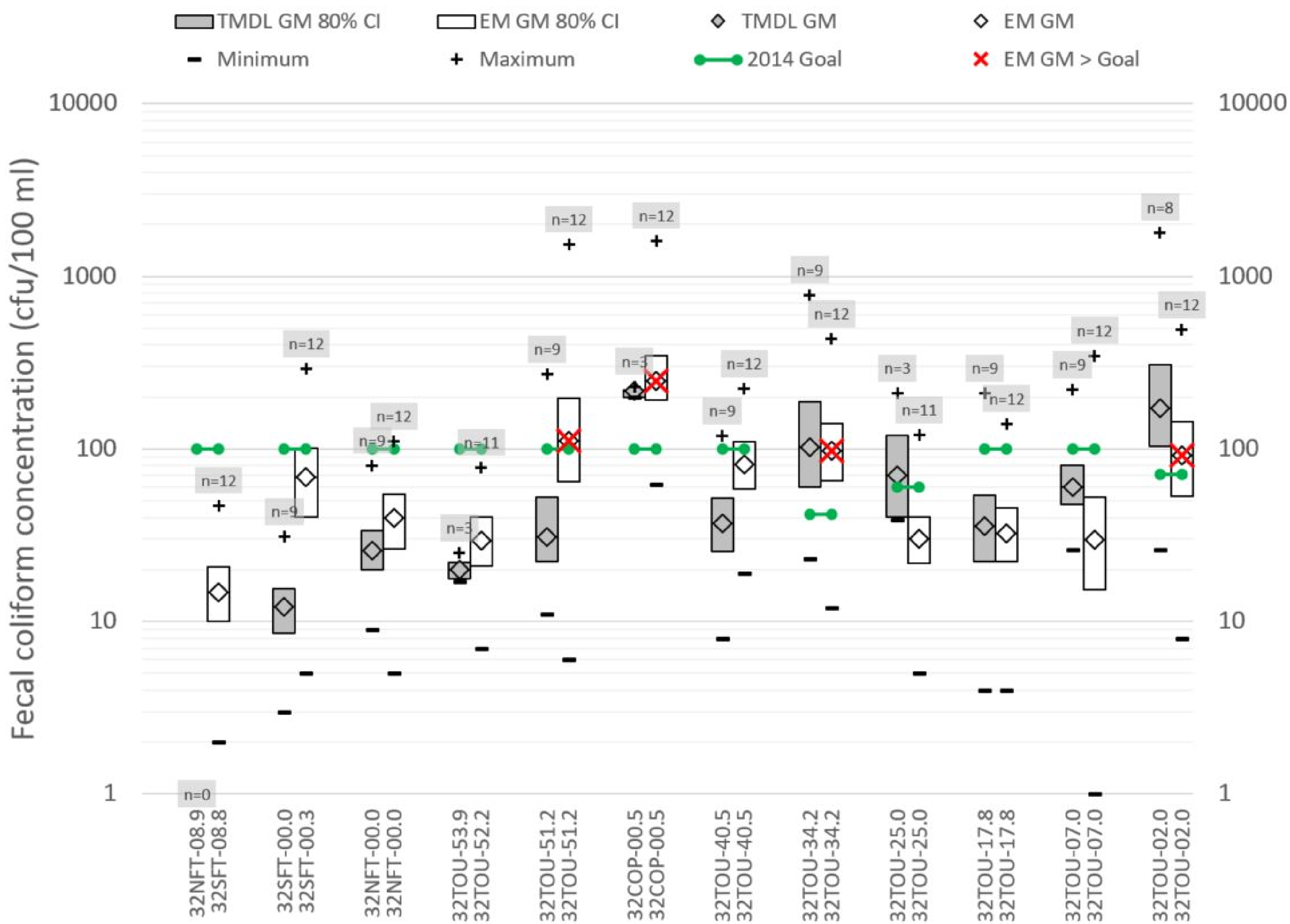


Figure 9: Low-flow season Touchet River Basin TMDL and EM study FC geometric means with 80% CI and 2014 TMDL goals.

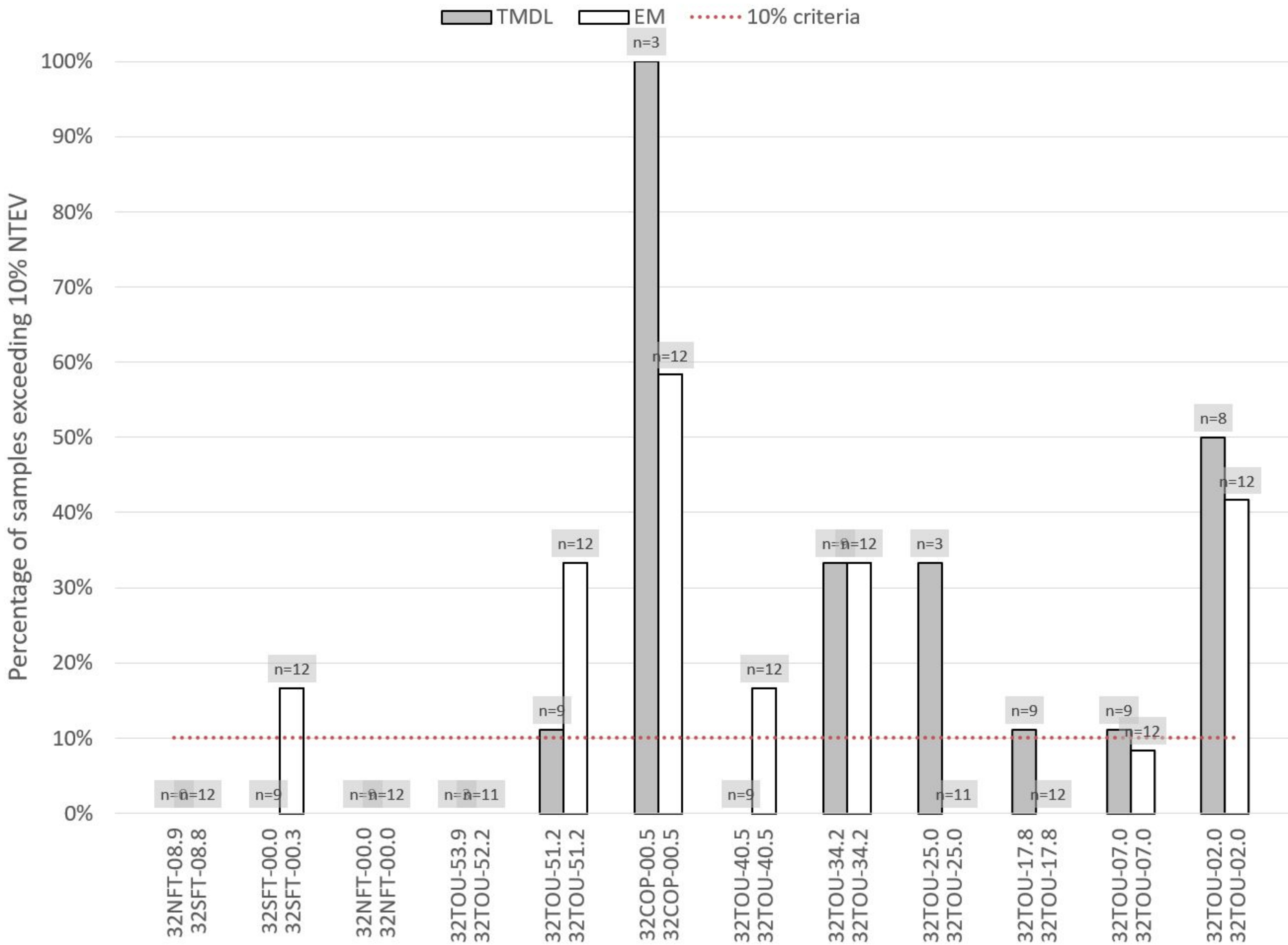


Figure 10: Low-flow season Touchet River Basin percentage of FC samples above the 10% Not to Exceed Value (NTEV) during the 2002-2003 TMDL and the 2014-2015 Effectiveness Monitoring (EM).

High-flow season

Table 16: Touchet River sites high-flow season FC concentrations and targets

EM Site ID	EM Site Name	GM targets[1]	TMDL count	TMDL GM[2]	TMDL GM, 80% CI[3]	EM count	EM GM[2]	EM GM, 80% CI[3]	% Change in GM[2]	10% NTEV targets[1]	TMDL % of samples above 10% NTEV[2]	EM % of samples above 10% NTEV[2]
32SFT-08.8	SF Touchet R @ Rainwater	100	0	NA	NA	5	***7***	[3, 14]	NA	200	NA	***0%***
32SFT-00.3	SF Touchet R @ Magill Rd	100	5	***5***	[2, 9]	5	***11***	[7, 17]	+130% (increase)	200	***0%***	***0%***
32NFT-00.0	NF Touchet R near mouth	100	7	***7***	[4, 11]	5	***9***	[8, 10]	+37% (increase)	200	***0%***	***0%***
32TOU-52.2	Touchet R above Dayton STP	100	3	***10***	[5, 15]	5	***23***	[18, 29]	+118% (increase)	200	***0%***	***0%***
32TOU-51.2	Touchet R @ Ward Rd	100	7	***4***	[2, 7]	5	120	[59, 323]	+3016% (increase)	200	***0%***	20%
32COP-00.5	Coppei Creek @ Hwy 124	100	2	***29***	[9, 96]	5	120	[84, 164]	+309% (increase)	169	***0%***	40%
32TOU-40.5	Touchet R @ Bolles Rd	100	7	***10***	[7, 16]	5	***45***	[21, 114]	+335% (increase)	200	***0%***	20%
32TOU-34.2	Touchet R @ Hwy 125	34	7	***23***	[14, 36]	5	38	[18, 96]	+64% (increase)	200	***0%***	20%
32TOU-25.0	Touchet R @ Lamar	60	2	***58***	[28, 120]	5	***41***	[16, 103]	-29%	200	***0%***	20%
32TOU-17.8	Touchet R @ Luckenbill Rd	100	7	***21***	[12, 41]	5	***28***	[14, 59]	+34% (increase)	200	14%	20%
32TOU-07.0	Touchet R @ Touchet N Rd	100	7	***16***	[10, 25]	5	***11***	[3, 33]	-32%	200	***0%***	20%
32TOU-02.0	Touchet R @ Cummins Rd	52	3	56	[36, 76]	5	***17***	[9, 32]	***-70%***	200	***0%***	***0%***

1. Targets below the state standards were calculated using statistical rollback to meet reductions at both the geometric mean (GM) and the 10% NTEV.
2. Results in ***Bold Italic*** met 2014 GM reduction targets.
3. 80% CI = Two-sided 80 percent confidence intervals (CI) on the GM in the format [lower CI, upper CI].

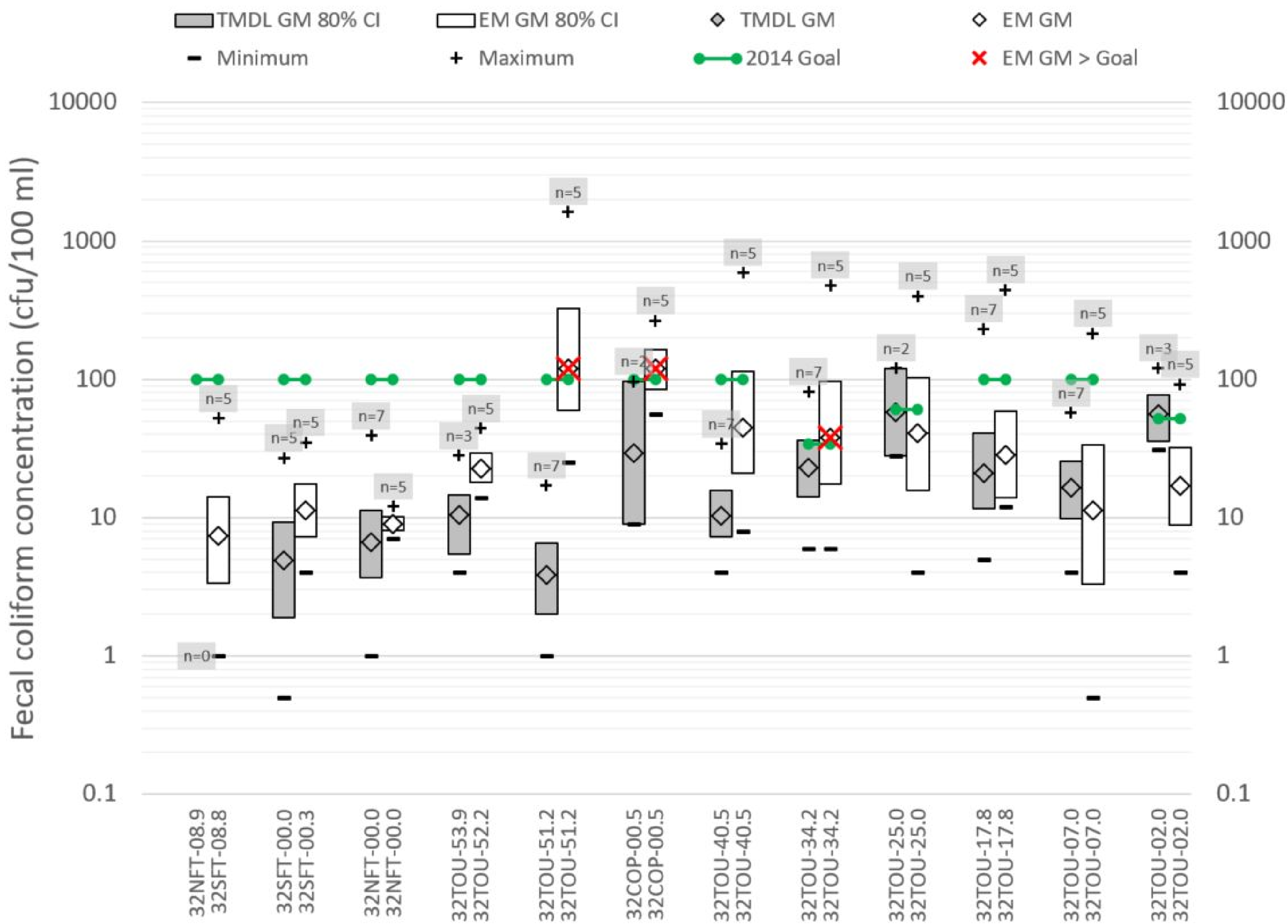


Figure 11: High-flow season Touchet River Basin TMDL and EM study FC geometric means with 80% CI and 2014 TMDL goals.

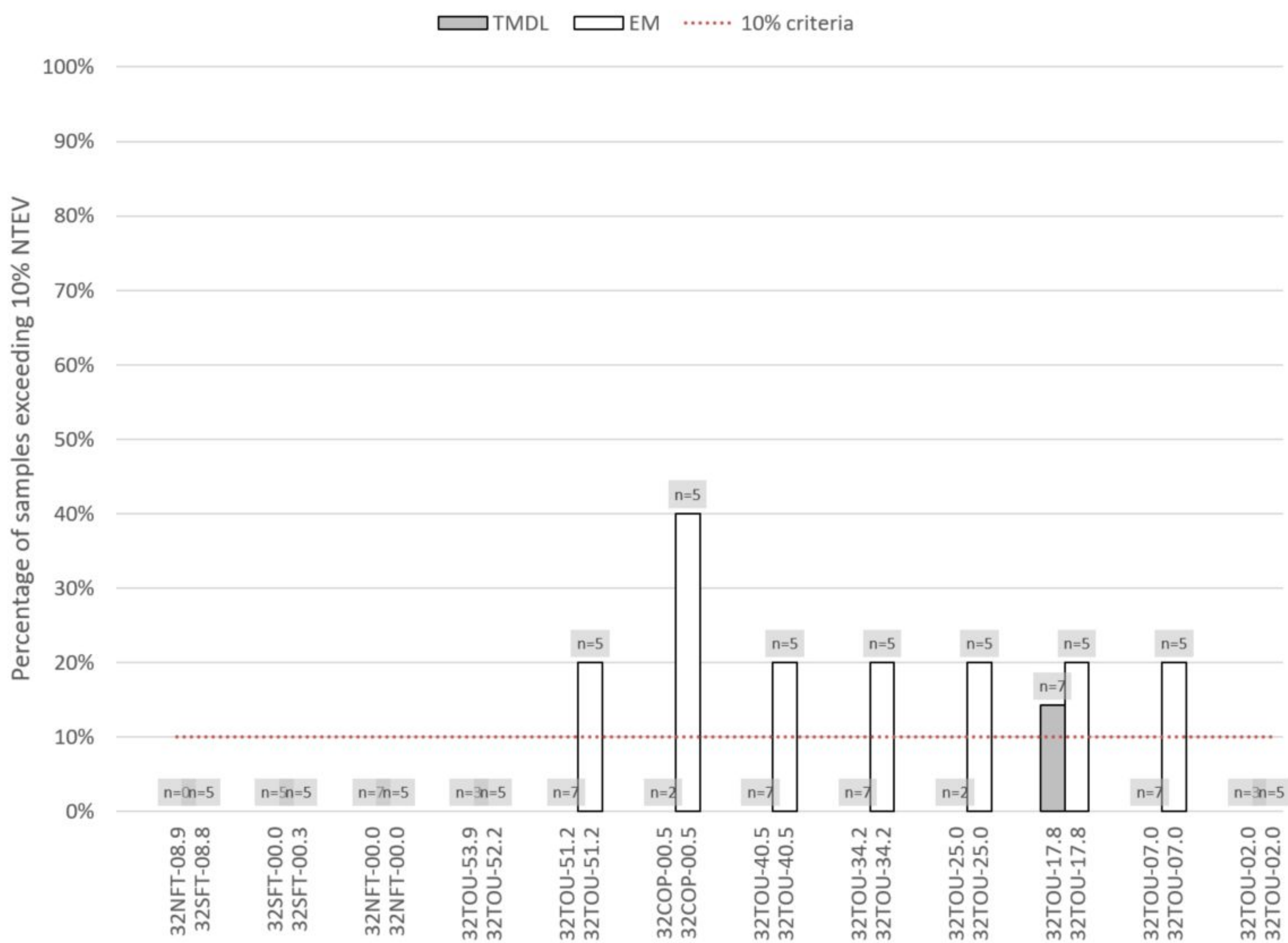


Figure 12: **High-flow Touchet River Basin percentage of FC samples above the 10% Not to Exceed Value (NTEV) during the 2002-2003 TMDL and the 2014-2015 Effectiveness Monitoring (EM) studies.**

Soluble Reactive Phosphorus (SRP) in the Touchet River Basin

Low-flow season

Table 17. Touchet River Basin changes in low-flow season SRP arithmetic mean (ArMn) concentrations.

EM Site ID	EM Site Name	Target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32SFT-08.8	SF Touchet R @ Rainwater	0.025	0	NA	NA	12	0.026	[0.025, 0.027]	NA
32SFT-00.3	SF Touchet R @ Magill Rd	0.025	7	0.034	[0.032, 0.036]	12	0.031	[0.029, 0.032]	-10%
32NFT-00.0	NF Touchet R near mouth	0.025	7	0.039	[0.037, 0.042]	12	0.038	[0.037, 0.040]	-2%
32TOU-52.2	Touchet R above Dayton STP	0.025	1	0.036	NA	11	0.035	[0.033, 0.036]	-4%
32TOU-51.2	Touchet R @ Ward Rd	0.029	7	0.072	[0.065, 0.078]	12	0.070	[0.066, 0.074]	-3%
32COP-00.5	Coppei Creek @ Hwy 124	0.028	3	0.071	[0.067, 0.075]	12	0.070	[0.065, 0.074]	-1%
32TOU-40.5	Touchet R @ Bolles Rd	0.025	7	0.055	[0.051, 0.059]	12	0.049	[0.046, 0.052]	-11%
32TOU-34.2	Touchet R @ Hwy 125	0.025	8	0.057	[0.053, 0.063]	12	0.052	[0.049, 0.056]	-9%
32TOU-25.0	Touchet R @ Lamar	0.025	1	0.061	NA	11	0.052	[0.049, 0.055]	-15%
32TOU-17.8	Touchet R @ Luckenbill Rd	0.025	7	0.063	[0.057, 0.069]	12	0.050	[0.047, 0.055]	-20%
32TOU-07.0	Touchet R @ Touchet N Rd	0.025	8	0.057	[0.051, 0.063]	12	0.039	[0.035, 0.043]	-31%
32TOU-02.0	Touchet R @ Cummins Rd	0.025	7	0.059	[0.054, 0.067]	12	0.040	[0.035, 0.044]	-33%

1. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
2. 80% CI = Two-sided 80 percent confidence intervals (CI) on the ArMn in the format [lower CI, upper CI].

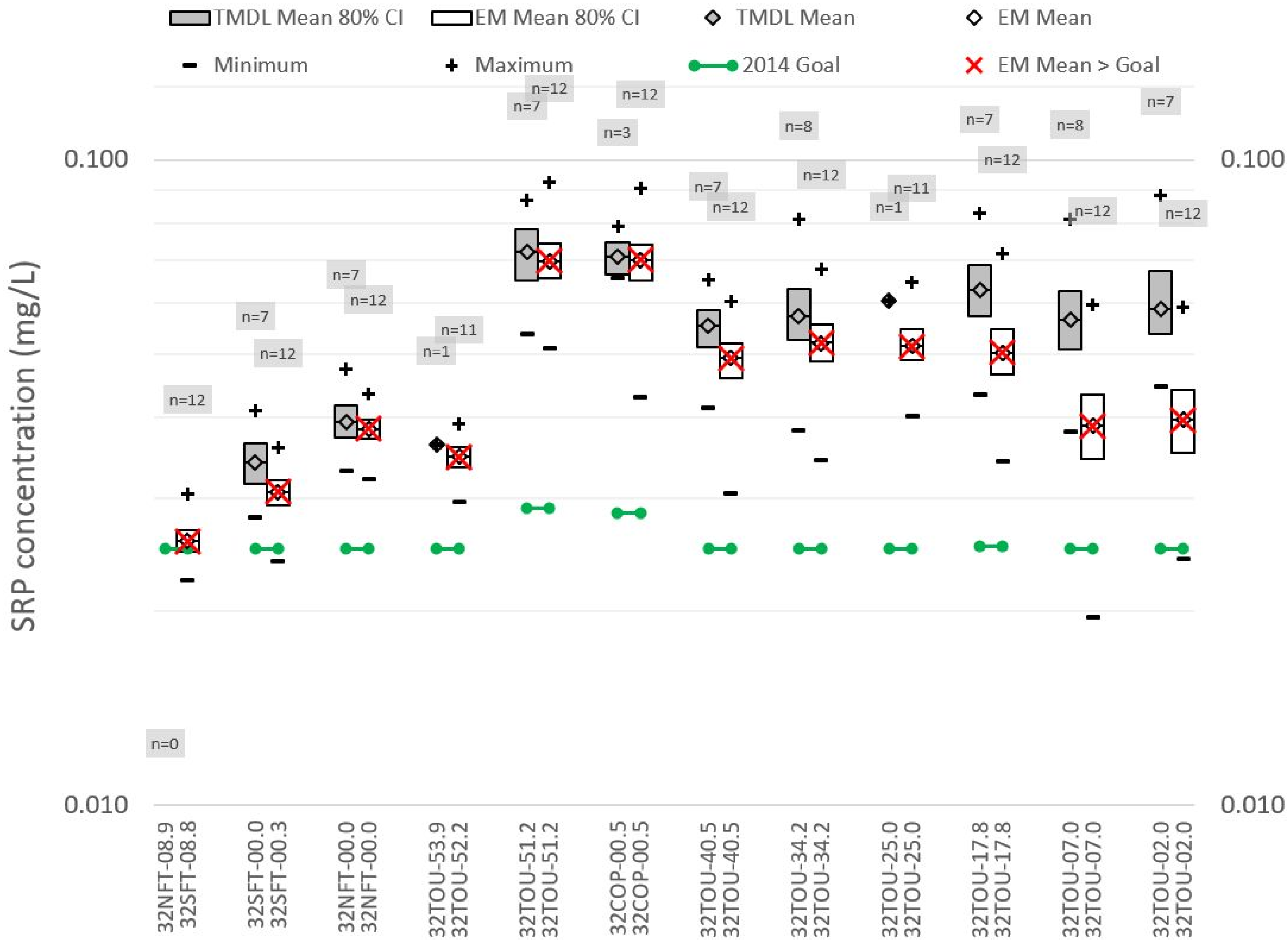


Figure 13: Low-flow TMDL and Effectiveness Monitoring boxplots of SRP concentration for Touchet River sites.

High-flow season

Table 18. Touchet River Basin changes in high-flow season SRP.

EM Site ID	EM Site Name	Target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	2014 EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32SFT-08.8	SF Touchet R @ Rainwater	0.025	0	NA	NA	5	***0.023***	[0.022, 0.024]	NA
32SFT-00.3	SF Touchet R @ Magill Rd	0.025	2	***0.025***	[0.024, 0.025]	5	***0.022***	[0.020, 0.023]	-10%
32NFT-00.0	NF Touchet R near mouth	0.025	2	0.029	[0.028, 0.029]	5	0.035	[0.034, 0.037]	24% (increase)
32TOU-52.2	Touchet R above Dayton STP	0.025	4	0.036	[0.031, 0.039]	5	0.035	[0.034, 0.036]	-4%
32TOU-51.2	Touchet R @ Ward Rd	0.025	2	0.039	[0.036, 0.042]	5	0.045	[0.043, 0.046]	15% (increase)
32COP-00.5	Coppei Creek @ Hwy 124	0.025	2	0.045	[0.023, 0.068]	5	0.038	[0.033, 0.042]	-17%
32TOU-40.5	Touchet R @ Bolles Rd	0.025	2	0.033	[0.032, 0.034]	5	0.043	[0.040, 0.045]	31% (increase)
32TOU-34.2	Touchet R @ Hwy 125	0.025	6	0.044	[0.037, 0.051]	5	0.043	[0.040, 0.045]	-2%
32TOU-25.0	Touchet R @ Lamar	0.025	0	NA	NA	5	0.042	[0.037, 0.045]	NA
32TOU-17.8	Touchet R @ Luckenbill Rd	0.025	2	0.027	[0.025, 0.029]	5	0.044	[0.039, 0.046]	61% (increase)
32TOU-07.0	Touchet R @ Touchet N Rd	0.025	6	0.040	[0.031, 0.048]	5	0.042	[0.038, 0.045]	5% (increase)
32TOU-02.0	Touchet R @ Cummins Rd	0.025	2	***0.022***	[0.014, 0.031]	5	0.042	[0.037, 0.046]	89% (increase)

1. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
2. 80% CI = Two-sided 80 percent confidence intervals (CI) on the ArMn in the format [lower CI, upper CI].

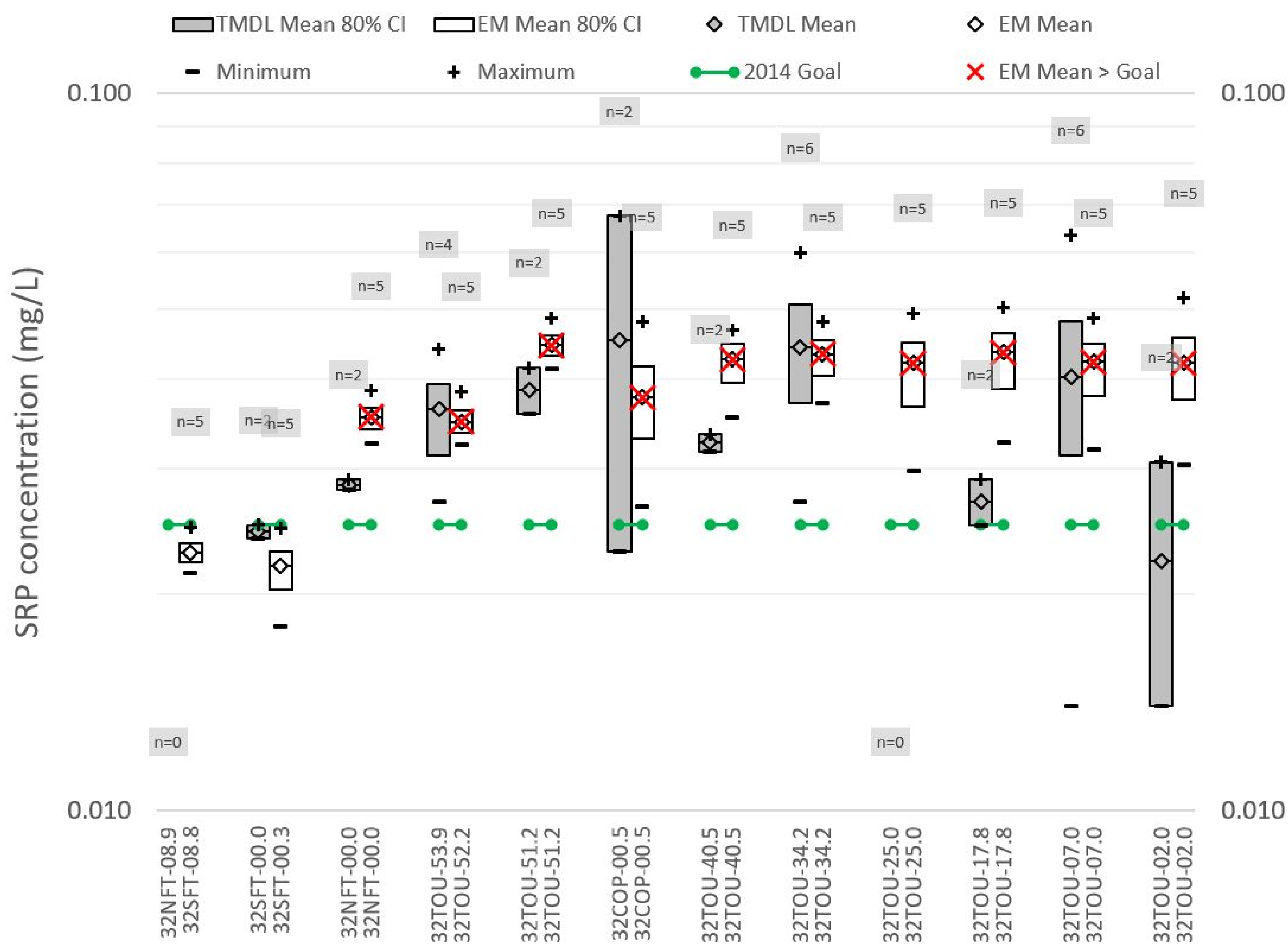


Figure 14: High-flow TMDL and Effectiveness Monitoring boxplots of SRP concentration for Touchet River sites.

Dissolved Inorganic Nitrogen (DIN) in the Touchet River Basin

Low-flow season

Table 19. Touchet River Basin changes in low-flow season DIN.

EM Site ID	EM Site Name	Target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32SFT-08.8	SF Touchet R @ Rainwater	0.055	0	NA	NA	12	***0.027***	[0.021, 0.034]	NA
32SFT-00.3	SF Touchet R @ Magill Rd	0.120	7	0.301	[0.244, 0.346]	12	***0.106***	[0.084, 0.154]	***-65%***
32NFT-00.0	NF Touchet R near mouth	0.055	7	***0.050***	[0.041, 0.061]	12	0.068	[0.059, 0.076]	35% (increase)
32TOU-52.2	Touchet R above Dayton STP	0.055	1	***0.031***	NA	11	***0.055***	[0.046, 0.066]	77% (increase)
32TOU-51.2	Touchet R @ Ward Rd	0.108	7	0.270	[0.245, 0.292]	12	0.131	[0.118, 0.144]	-51%
32COP-00.5	Coppei Creek @ Hwy 124	0.243	3	0.606	[0.484, 0.725]	12	0.318	[0.277, 0.360]	-48%
32TOU-40.5	Touchet R @ Bolles Rd	0.058	7	0.144	[0.127, 0.162]	12	0.071	[0.048, 0.099]	-51%
32TOU-34.2	Touchet R @ Hwy 125	0.055	8	0.068	[0.055, 0.084]	12	***0.048***	[0.031, 0.080]	-29%
32TOU-25.0	Touchet R @ Lamar	0.055	1	***0.010***	NA	11	***0.029***	[0.019, 0.044]	187% (increase)
32TOU-17.8	Touchet R @ Luckenbill Rd	0.055	7	***0.015***	[0.011, 0.022]	12	***0.019***	[0.016, 0.025]	31% (increase)
32TOU-07.0	Touchet R @ Touchet N Rd	0.055	8	***0.012***	[0.013, 0.019]	12	***0.017***	[0.015, 0.019]	39% (increase)
32TOU-02.0	Touchet R @ Cummins Rd	0.055	7	0.072	[0.058, 0.093]	12	***0.031***	[0.026, 0.038]	-56%

1. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
2. 80% CI = Two-sided 80 percent confidence intervals (CI) on the ArMn in the format [lower CI, upper CI].

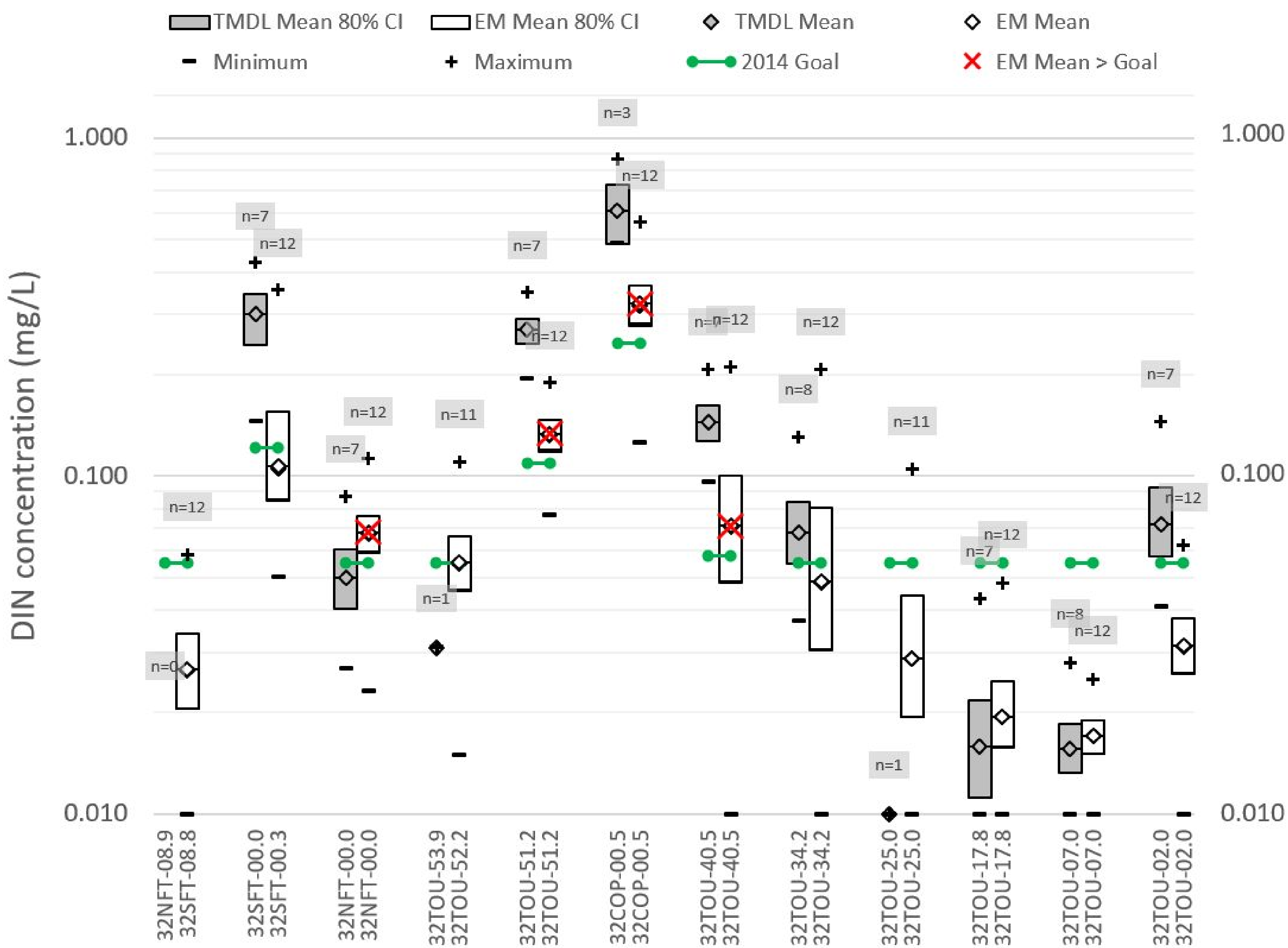


Figure 15: Low-flow TMDL and EM arithmetic mean and 80% confidence intervals on DIN concentration for Touchet River sites.

High-flow season

Table 20. Touchet River Basin changes in high-flow season DIN.

EM Site ID	EM Site Name	Target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32SFT-08.8	SF Touchet R @ Rainwater	0.055	0	NA	NA	5	***0.051***	[0.040, 0.061]	NA
32SFT-00.3	SF Touchet R @ Magill Rd	0.055	2	0.104	[0.061, 0.146]	5	0.063	[0.046, 0.074]	-39%
32NFT-00.0	NF Touchet R near mouth	0.055	2	0.062	[0.010, 0.114]	5	0.136	[0.104, 0.153]	129% (increase)
32TOU-52.2	Touchet R above Dayton STP	0.059	4	0.148	[0.086, 0.180]	5	0.164	[0.138, 0.184]	11% (increase)
32TOU-51.2	Touchet R @ Ward Rd	0.059	2	0.149	[0.128, 0.169]	5	0.215	[0.176, 0.238]	45% (increase)
32COP-00.5	Coppei Creek @ Hwy 124	0.557	2	1.393	[1.365, 1.420]	5	***0.470***	[0.387, 0.526]	***-66%***
32TOU-40.5	Touchet R @ Bolles Rd	0.138	2	0.345	[0.277, 0.414]	5	0.273	[0.231, 0.315]	-21%
32TOU-34.2	Touchet R @ Hwy 125	0.175	6	0.438	[0.338, 0.522]	5	0.265	[0.213, 0.313]	-39%
32TOU-25.0	Touchet R @ Lamar	0.055	0	NA	NA	5	0.254	[0.199, 0.297]	#N/A
32TOU-17.8	Touchet R @ Luckenbill Rd	0.089	2	0.223	[0.142, 0.304]	5	0.239	[0.167, 0.284]	7% (increase)
32TOU-07.0	Touchet R @ Touchet N Rd	0.133	6	0.332	[0.195, 0.465]	5	0.230	[0.154, 0.277]	-31%
32TOU-02.0	Touchet R @ Cummins Rd	0.055	2	0.135	[0.024, 0.245]	5	0.239	[0.155, 0.295]	78% (increase)

1. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
2. 80% CI = Two-sided 80 percent confidence intervals (CI) on the ArMn in the format [lower CI, upper CI].

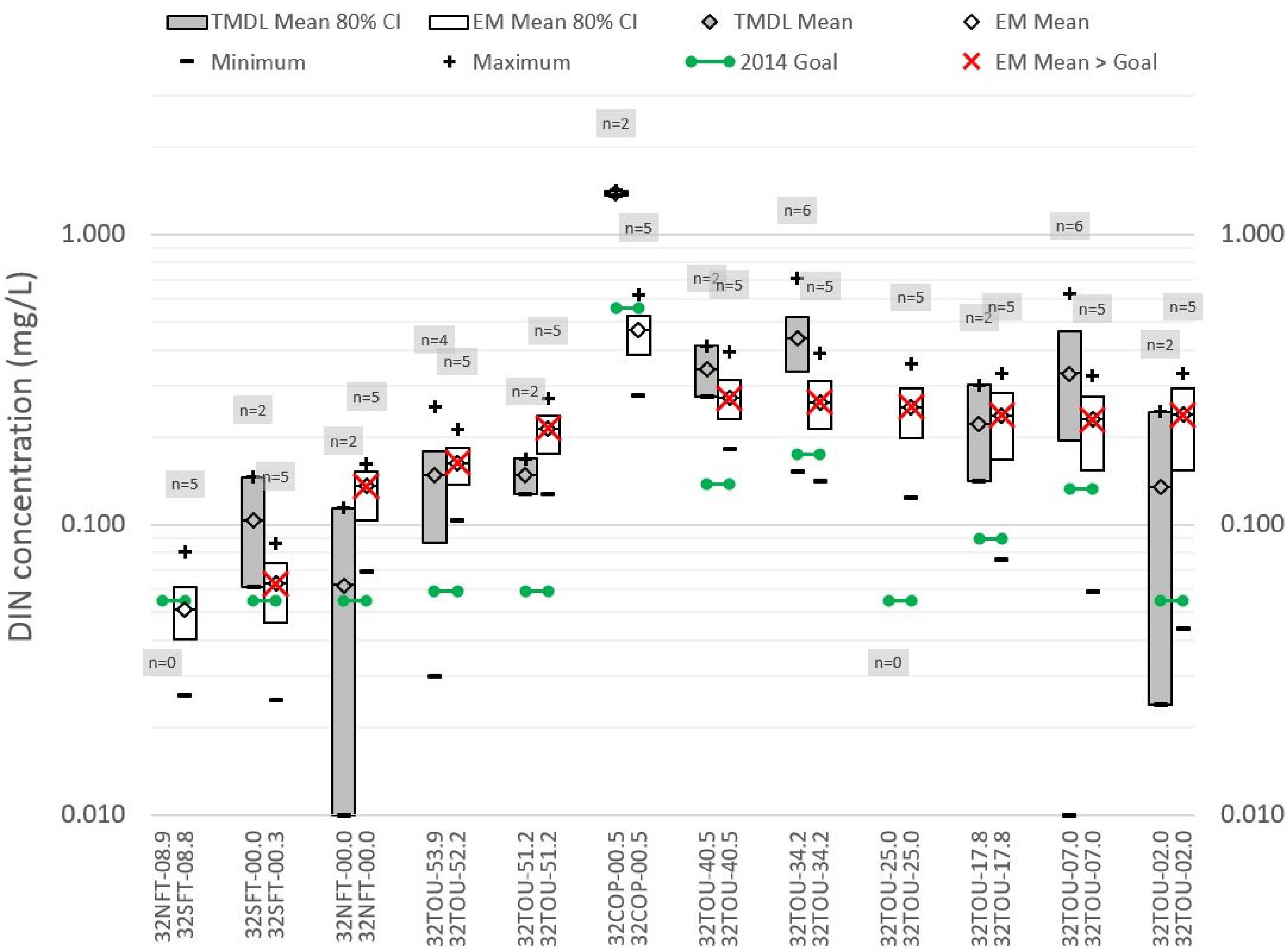


Figure 16: High-flow TMDL and EM arithmetic mean and 80% confidence intervals on DIN concentration for Touchet River sites.

Organic phosphorus in the Touchet River Basin

Low-flow season

Table 21. Touchet River Basin changes in low-flow season organic phosphorus.

EM Site ID	EM Site Name	Target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	2014 EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32SFT-08.8	SF Touchet R @ Rainwater	0.018	0	NA	NA	12	***0.008***	[0.005, 0.010]	NA
32SFT-00.3	SF Touchet R @ Magill Rd	0.018	7	***0.013***	[0.010, 0.016]	12	***0.006***	[0.005, 0.007]	-53%
32NFT-00.0	NF Touchet R near mouth	0.018	7	***0.017***	[0.015, 0.021]	12	***0.005***	[0.005, 0.005] [3]	***-71%***
32TOU-52.2	Touchet R above Dayton STP	0.018	1	0.032	NA	11	***0.005***	[0.005, 0.005] [3]	***-84%***
32TOU-51.2	Touchet R @ Ward Rd	0.018	7	0.020	[0.018, 0.024]	12	***0.005***	[0.005, 0.005] [3]	***-75%***
32COP-00.5	Coppei Creek @ Hwy 124	0.018	3	0.040	[0.024, 0.045]	12	0.025	[0.020, 0.029]	-37%
32TOU-40.5	Touchet R @ Bolles Rd	0.018	7	0.021	[0.019, 0.023]	12	***0.007***	[0.006, 0.008]	***-68%***
32TOU-34.2	Touchet R @ Hwy 125	0.018	8	0.020	[0.016, 0.023]	12	***0.007***	[0.006, 0.008]	***-67%***
32TOU-25.0	Touchet R @ Lamar	0.018	1	0.024	NA	11	***0.007***	[0.006, 0.008]	***-72%***
32TOU-17.8	Touchet R @ Luckenbill Rd	0.018	7	0.023	[0.019, 0.025]	12	***0.009***	[0.007, 0.012]	-59%
32TOU-07.0	Touchet R @ Touchet N Rd	0.018	8	0.024	[0.022, 0.026]	12	***0.009***	[0.007, 0.011]	***-64%***
32TOU-02.0	Touchet R @ Cummins Rd	0.018	7	0.024	[0.022, 0.026]	12	***0.009***	[0.007, 0.011]	***-62%***

1. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
2. 80% CI = Two-sided 80 percent confidence intervals (CI) on the ArMn in the format [lower CI, upper CI].
3. All calculated concentrations were at or below 0.005 mg/L and assigned a value of 0.005 mg/L as non-detect values.

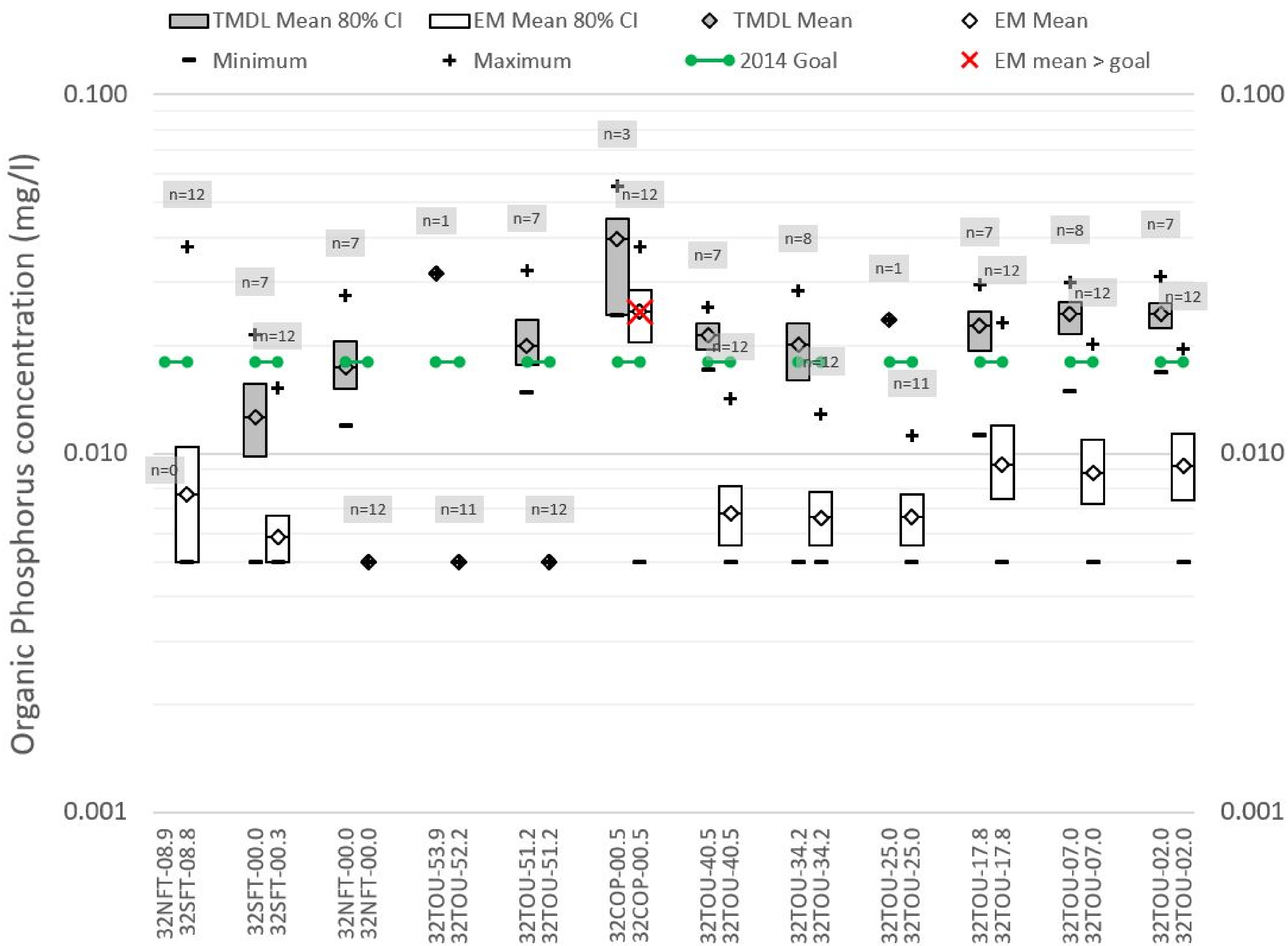


Figure 17: **Low-flow TMDL and Effectiveness Monitoring boxplots of organic phosphorus concentration for Touchet River sites**.

High-flow season

Table 22. Touchet River Basin changes in high-flow season organic phosphorus.

EM Site ID	EM Site Name	Target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32SFT-08.8	SF Touchet R @ Rainwater	0.018	0	NA	NA	5	***0.005***	[0.005, 0.005] [3]	NA
32SFT-00.3	SF Touchet R @ Magill Rd	0.018	2	0.032	[0.025, 0.038]	5	***0.005***	[0.005, 0.005] [3]	***-84%***
32NFT-00.0	NF Touchet R near mouth	0.018	2	0.038	[0.029, 0.047]	5	***0.005***	[0.005, 0.005] [3]	***-87%***
32TOU-52.2	Touchet R above Dayton STP	0.018	4	0.046	[0.027, 0.065]	5	***0.005***	[0.005, 0.005] [3]	***-89%***
32TOU-51.2	Touchet R @ Ward Rd	0.018	2	0.038	[0.030, 0.047]	5	***0.005***	[0.005, 0.005] [3]	***-87%***
32COP-00.5	Coppei Creek @ Hwy 124	0.046	2	0.116	[0.055, 0.176]	5	***0.020***	[0.014, 0.025]	***-82%***
32TOU-40.5	Touchet R @ Bolles Rd	0.018	2	0.041	[0.034, 0.048]	5	***0.007***	[0.005, 0.007]	***-83%***
32TOU-34.2	Touchet R @ Hwy 125	0.037	6	0.093	[0.039, 0.199]	5	***0.006***	[0.005, 0.006]	***-93%***
32TOU-25.0	Touchet R @ Lamar	0.018	0	NA	NA	5	***0.010***	[0.007, 0.013]	NA
32TOU-17.8	Touchet R @ Luckenbill Rd	0.018	2	0.046	[0.045, 0.046]	5	***0.013***	[0.010, 0.016]	***-72%***
32TOU-07.0	Touchet R @ Touchet N Rd	0.077	6	0.192	[0.049, 0.474]	5	***0.015***	[0.012, 0.019]	***-92%***
32TOU-02.0	Touchet R @ Cummins Rd	0.018	2	0.046	[0.045, 0.047]	5	***0.015***	[0.014, 0.015]	***-68%***

1. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
2. 80% CI = Two-sided 80 percent confidence intervals (CI) on the ArMn in the format [lower CI, upper CI].
3. All calculated concentrations were at or below 0.005 mg/L and assigned a value of 0.005 mg/L as non-detect values.

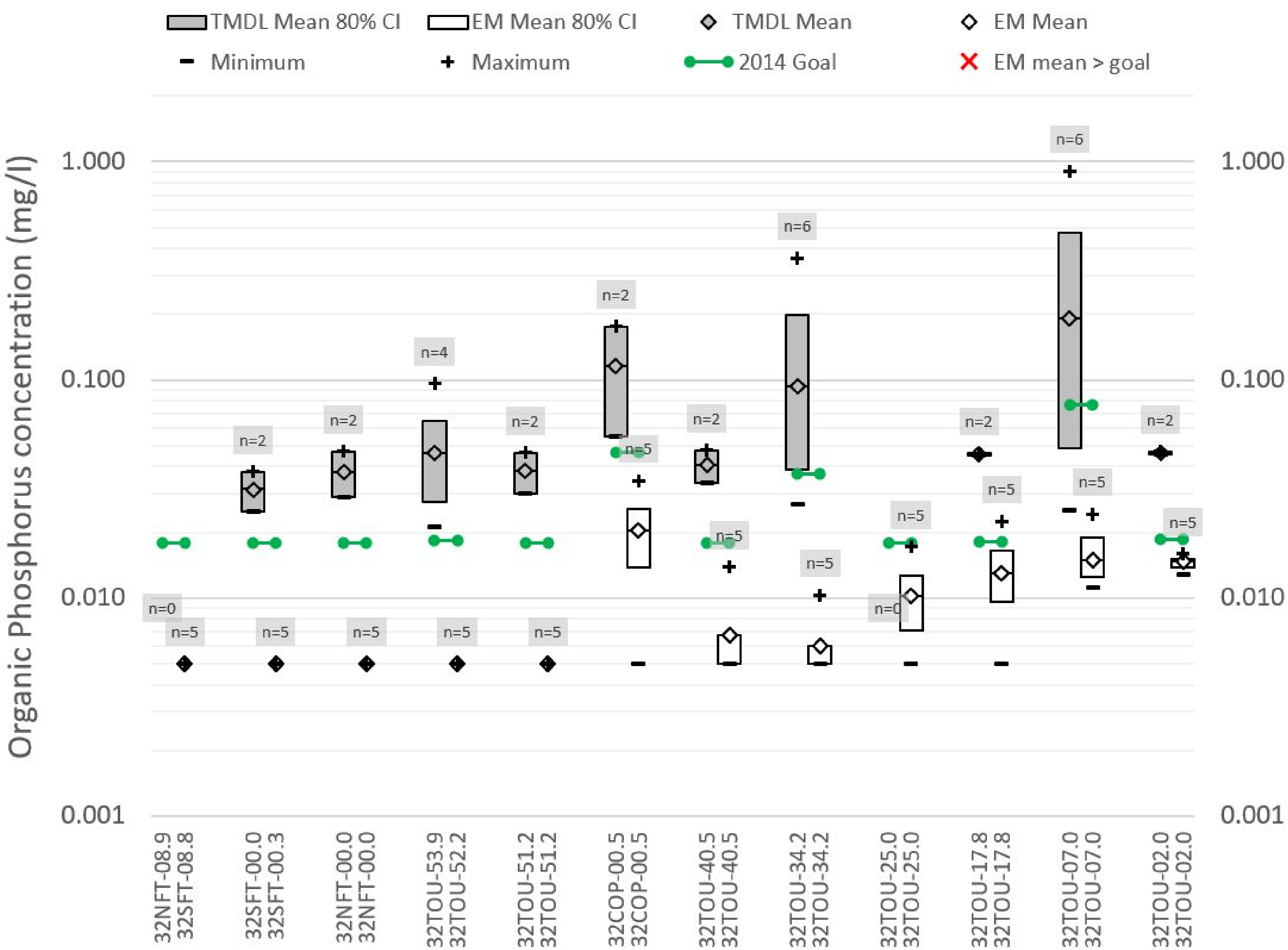


Figure 18: High-flow TMDL and Effectiveness Monitoring boxplots of organic phosphorus concentration for Touchet River sites.

Organic nitrogen in the Touchet River Basin

Low-flow season

Table 23. Touchet River Basin changes in low-flow season organic nitrogen.

EM Site ID	EM Site Name	TMDL target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	2014 EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32SFT-08.8	SF Touchet R @ Rainwater	0.039	0	NA	NA	12	0.057	[0.043, 0.082]	NA
32SFT-00.3	SF Touchet R @ Magill Rd	0.039	6	0.061	[0.051, 0.068]	12	0.046	[0.042, 0.052]	-24%
32NFT-00.0	NF Touchet R near mouth	0.039	6	0.045	[0.038, 0.052]	12	0.046	[0.037, 0.063]	0%
32TOU-52.2	Touchet R above Dayton STP	0.039	1	***0.013***	NA	11	0.051	[0.047, 0.056]	293% (increase)
32TOU-51.2	Touchet R @ Ward Rd	0.039	7	0.082	[0.068, 0.090]	12	0.053	[0.048, 0.057]	-36%
32COP-00.5	Coppei Creek @ Hwy 124	0.063	3	0.158	[0.139, 0.173]	12	0.127	[0.114, 0.140]	-20%
32TOU-40.5	Touchet R @ Bolles Rd	0.043	7	0.109	[0.101, 0.117]	12	0.081	[0.074, 0.088]	-25%
32TOU-34.2	Touchet R @ Hwy 125	0.045	8	0.112	[0.094, 0.125]	12	0.088	[0.081, 0.095]	-21%
32TOU-25.0	Touchet R @ Lamar	0.045	1	0.113	NA	11	0.098	[0.089, 0.106]	-14%
32TOU-17.8	Touchet R @ Luckenbill Rd	0.058	7	0.146	[0.136, 0.155]	12	0.136	[0.118, 0.155]	-7%
32TOU-07.0	Touchet R @ Touchet N Rd	0.061	8	0.153	[0.128, 0.167]	12	0.164	[0.141, 0.193]	8% (increase)
32TOU-02.0	Touchet R @ Cummins Rd	0.068	7	0.171	[0.160, 0.180]	12	0.182	[0.156, 0.215]	6% (increase)

1. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
2. 80% CI = Two-sided 80 percent confidence intervals (CI) on the ArMn in the format [lower CI, upper CI].

Figure 19: Low-flow TMDL and EM arithmetic mean and 80% confidence intervals on OrgN concentration for Touchet River sites.

High-flow season

Table 24. Touchet River Basin changes in high-flow season organic nitrogen.

EM Site ID	EM Site Name	TMDL target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32SFT-08.8	SF Touchet R @ Rainwater	0.039	0	NA	NA	5	0.051	[0.045, 0.059]	NA
32SFT-00.3	SF Touchet R @ Magill Rd	0.039	2	0.055	[0.049, 0.060]	5	0.054	[0.049, 0.060]	-1%
32NFT-00.0	NF Touchet R near mouth	0.039	2	0.053	[0.041, 0.064]	5	***0.036***	[0.026, 0.041]	-32%
32TOU-52.2	Touchet R above Dayton STP	0.039	4	0.058	[0.043, 0.070]	5	0.048	[0.041, 0.052]	-18%
32TOU-51.2	Touchet R @ Ward Rd	0.039	2	0.058	[0.052, 0.064]	5	0.046	[0.040, 0.052]	-20%
32COP-00.5	Coppei Creek @ Hwy 124	0.055	2	0.138	[0.125, 0.150]	5	0.089	[0.079, 0.095]	-35%
32TOU-40.5	Touchet R @ Bolles Rd	0.039	2	0.088	[0.066, 0.110]	5	0.060	[0.047, 0.068]	-32%
32TOU-34.2	Touchet R @ Hwy 125	0.040	6	0.099	[0.084, 0.126]	5	0.057	[0.041, 0.067]	-42%
32TOU-25.0	Touchet R @ Lamar	0.039	0	NA	NA	5	0.063	[0.054, 0.068]	NA
32TOU-17.8	Touchet R @ Luckenbill Rd	0.039	2	0.086	[0.081, 0.091]	5	0.074	[0.067, 0.078]	-14%
32TOU-07.0	Touchet R @ Touchet N Rd	0.039	6	0.093	[0.073, 0.118]	5	0.065	[0.051, 0.076]	-30%
32TOU-02.0	Touchet R @ Cummins Rd	0.043	2	0.108	[0.086, 0.130]	5	0.064	[0.049, 0.074]	-40%

1. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
2. 80% CI = Two-sided 80 percent confidence intervals (CI) on the ArMn in the format [lower CI, upper CI].

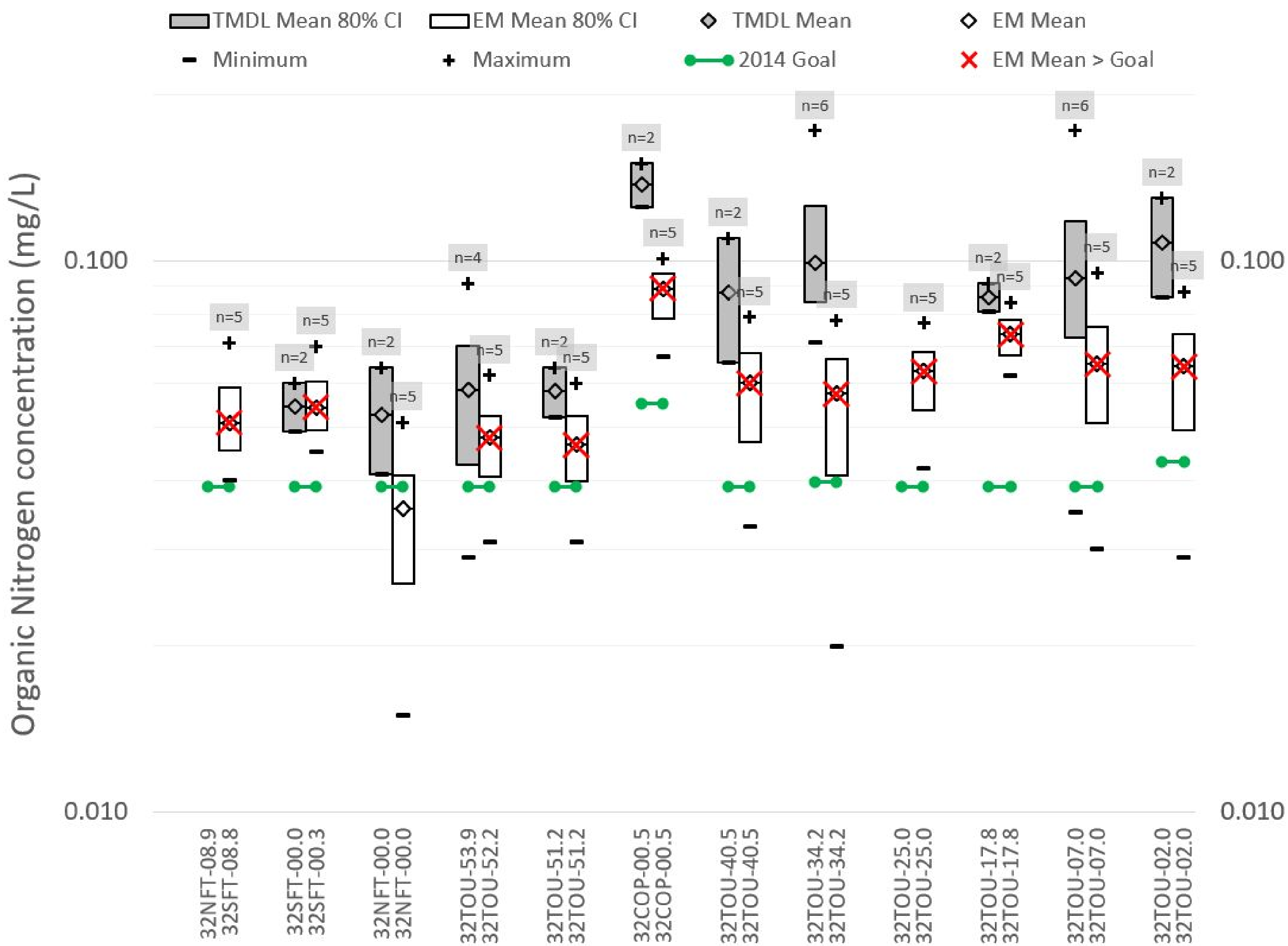


Figure 20: **High-flow TMDL and EM arithmetic mean and 80% confidence intervals on OrgN concentration for Touchet River sites**.

Reach-specific nutrient load and concentration changes for the Touchet River Basin

Tables 25 to 28 show reach-specific nutrient load changes calculated between our sampling sites in the Touchet River Basin. These unspecified loads include nonpoint load sources in most cases. In the reach between the Touchet River at RM 52.2 and RM 51.2, these loads probably came from the Dayton WWTP NPDES permitted point source at RM 52.1.

Table 25: Touchet River low-flow (May-Oct) reach-specific changes to SRP concentrations versus TMDL targets

Upstream Sites	Downstream Sites	Load Changes (lbs. SRP/day)	Flow Changes (cfs)	Upstream to downstream change in mean concentration (mg SRP/L)	10 year nonpoint targets (mg SRP/L)	Concentration Changes (mg SRP/L) [1,2]
32NFT-00.0, 32SFT-00.3 [3,4]	32TOU-52.2 [3]	+1.27	+10.61	-0.002	0.050	***-0.022***
32TOU-52.2 [3,5]	32TOU-51.2 [3,5]	+12.26	+0.26	+0.033	NA[5]	8.604
32TOU-51.2 [3] 32COP-00.5	32TOU-40.5	-11.49	-15.52	-0.020	0.050	***-0.137***
32TOU-40.5	32TOU-34.2 [3]	-1.16	-5.41	+0.001	0.050	***0.040***
32TOU-34.2 [3]	32TOU-02.0	-4.61	-13.29	-0.006	0.050	***-0.064***

Table 26: Touchet River high-flow (Nov-Apr) reach-specific changes to SRP concentrations versus TMDL targets.

Upstream Sites	Downstream Sites	Load Changes (lbs. SRP/day)	Flow Changes (cfs)	Upstream to downstream change in mean concentration (mg SRP/L)	10 year nonpoint targets (mg SRP/L)	Concentration Changes (mg SRP/L) [1,2]
32NFT-00.0, 32SFT-00.3 [3,4]	32TOU-52.2 [3]	+13.81	+50.19	+0.004	0.050	0.051
32TOU-52.2 [3,5]	32TOU-51.2 [3,5]	+13.52	+0.45	+0.009	NA[5]	5.581
32TOU-51.2 [3] 32COP-00.5	32TOU-40.5	-5.14	-12.98	-0.001	0.050	***-0.073***
32TOU-40.5	32TOU-34.2 [3]	+9.21	+34.03	+0.001	0.050	0.050
32TOU-34.2 [3]	32TOU-02.0	-10.30	-38.47	-0.001	0.050	***-0.050***

1. Negative results show an upstream to downstream decrease in the nutrient water concentration.
2. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
3. This station's result uses estimated flow data from a neighboring station.
4. Due to a lack of continuous flow data, we adjusted this mean seasonal load estimate using continuous flows from a neighboring station.
5. The large positive loads in this reach likely come from the Dayton WWTP point source instead of nonpoint sources. Nonpoint TMDL targets do not apply to this result because the WWTP point source results cannot be disentangled from the nonpoint source results.

Table 27: Touchet River low-flow (May-Oct) reach-specific changes to DIN concentrations versus TMDL targets.

Upstream Sites	Downstream Sites	Load Changes (lbs. DIN/ day)	Flow Changes (cfs)	Upstream to downstream change in mean concentration (mg DIN/L)	10 year nonpoint targets (mg DIN/L)	Concentration Changes (mg DIN/L) [1,2]
32NFT-00.0, 32SFT-00.3 [3,4]	32TOU-52.2 [3]	+0.50	+10.61	-0.010	0.205	***-0.009***
32TOU-52.2 [3,5]	32TOU-51.2 [3,5]	+27.55	+0.26	+0.075	NA[5]	19.335
32TOU-51.2 [3] 32COP-00.5	32TOU-40.5	-27.75	-15.52	-0.054	0.205	***-0.331***
32TOU-40.5	32TOU-34.2 [3]	-5.49	-5.41	-0.011	0.205	***-0.188***
32TOU-34.2 [3]	32TOU-02.0	-15.33	-13.29	-0.050	0.205	***-0.214***

Table 28: Touchet River high-flow (Nov-Apr) reach-specific changes to DIN concentrations versus TMDL targets.

Upstream Sites	Downstream Sites	Load Changes (lbs. DIN/ day)	Flow Changes (cfs)	Upstream to downstream change in mean concentration (mg DIN/L)	10 year nonpoint targets (mg DIN/L)	Concentration Changes (mg DIN/L) [1,2]
32NFT-00.0, 32SFT-00.3 [3,4]	32TOU-52.2 [3]	+97.40	+50.19	+0.047	0.205	0.360
32TOU-52.2 [3,5]	32TOU-51.2 [3,5]	+69.09	+0.45	+0.048	NA[5]	28.520
32TOU-51.2 [3] 32COP-00.5	32TOU-40.5	+26.71	-12.98	+0.029	0.205	0.382
32TOU-40.5	32TOU-34.2 [3]	+33.82	+34.03	-0.008	0.205	***-0.184***
32TOU-34.2 [3]	32TOU-02.0	-73.35	-38.47	-0.015	0.205	***-0.354***

1. Negative results show an upstream to downstream decrease in the nutrient water concentration.
2. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
3. This station's result uses estimated flow data from a neighboring station.
4. Due to a lack of continuous flow data, we adjusted this mean seasonal load estimate using continuous flows from a neighboring station.
5. The large positive loads in this reach likely come from the Dayton WWTP point source instead of nonpoint sources. Nonpoint TMDL targets do not apply to this result.

Status and changes for the Touchet River Basin

Fecal coliform bacteria (FC) concentrations exceeded TMDL reduction targets in low- and high-flow seasons at intermittent locations throughout the Touchet River Basin. The largest target exceedances appear to come from sources near incorporated and unincorporated towns, including the following sites:

- 32TOU-51.2, downstream of Dayton, WA
- 32COP-00.5: downstream of Waitsburg, WA
- 32TOU-34.2: downstream of Prescott, WA
- 32TOU-02.0: near unincorporated Touchet, WA (low-flow season only)

In the low-flow season, all Touchet River reaches, except the Dayton WWTP reach, showed upstream to downstream nutrient load reduction, probably through algal uptake (Tables 17 and 19 and Figures 13 and 15). The corresponding increase of the organic nutrient concentrations (for OrgP and OrgN) in the same reaches probably resulted from algal uptake converting the soluble, and biologically available, inorganic nutrients to organic forms (Figures 19 and 21).

In the high-flow season, when algal uptake was reduced, nutrient loads entered the Touchet River downstream of the urban areas of Dayton and Waitsburg (Tables 26 and 28).

Most Touchet River Basin sites had lower concentrations in 2015 than in 2002 and met targets in the low-flow season. Notable exceptions, where FC increased in 2015 versus 2002, occurred near the confluence of the SF Touchet River, and in the Touchet River and Coppei Creek near Dayton and Waitsburg. Across all Touchet River Basin sites, most high-flow season nutrient samples and low-flow season SRP and OrgN did not meet the 60% nutrient reduction target.

Above Dayton, Joy et al. (2007) estimated only a one-third reduction in nutrient loads was possible after mitigating all development and nonpoint sources. Throughout the year, the South Fork Touchet River near its confluence (32SFT-00.3) met this reduction estimate for DIN. SRP concentrations at the confluence remained near the reference conditions at 32SFT-08.8. DIN concentrations in the North Fork Touchet River were higher in 2015 than in 2002 and may indicate new nitrogen sources upstream.

Most nutrients in Coppei Creek showed some reduction. However, Coppei Creek continued to show high FC and nutrient concentrations, which may contribute sufficient loads during the low-flow season to affect the Touchet River downstream.

Dayton WWTP reach (RM 52.2 to RM 51.2)

In this reach, sources include the NPDES permitted Dayton WWTP at River Mile (RM) 52.1 and rural nonpoint sources common to the Walla Walla River Basin (Appendix F, Figure F1). The following water quality data summary evaluates correlation between downstream water quality and water quality data reported by the Dayton WWTP only, and does not evaluate potential nonpoint sources due to the lack of data.

Dayton WWTP effluent flows were a small fraction of the Touchet River (receiving water) flows throughout the year (Figure F2).

FC concentrations increased greatly in the Touchet River between 32TOU-52.2, just above the Dayton WWTP, and 32TOU-51.2 at Ward Road, below the WWTP. Throughout the year, the Touchet River's increase in FC load between RM 52.2 and RM 51.2 ranged from six to 2200 times the WWTP loads reported in the same week.

Peaks in FC loads entering this reach occurred in July and August 2014, January 2015, and March to June 2015 (Figure F3). In the summer of 2014, Dayton reported equipment problems with their UV disinfection system that would have directly affected FC counts. In January of 2015, Dayton reported significant equipment failure with the trickling filter pumps that led to additional downgradient equipment failures and resulted in emergency bypass to the Touchet River (Ecology 2015b). Dayton also reported equipment problems with their UV disinfection system in April and May of 2015 (Ecology 2015c).

In a WWTP compliance inspection in April 2015, Ecology described the emergency effluent-treatment bypass that occurred in January 2015 due to equipment failure at the trickling filter system (Ecology 2015b). The Discharge Monitoring Report (DMR) noted a corresponding FC "Too Many to Count" (TMTC) result on January 11, 2015. During our study, other Dayton DMRs also noted FC TMTC results on August 3 and 4, 2014 (Figure F3). In a 2009 supplemental TMDL study (Tarbutton 2010), Ecology noted earlier Dayton WWTP treatment bypasses and found effluent FC concentrations far above the permit limits.

To evaluate WWTP effluent effects on FC loads in the Touchet River, we did linear regressions on the calculated instream FC load changes and the WWTP reported FC loads from the same week (Figure F3). Increases in FC loads were strongly correlated with increases in FC load from the Dayton WWTP between January and June 2015 (R^2=0.9582; correlation equation y=2319x-853; where y=the instream load difference between downstream at RM 51.2 and upstream at RM 52.2 and x = the Dayton WWTP load). Between July and December 2014 the correlation equation was y=52.14x-9.06 (R^2=0.6105). For the entire study period the correlation was less tight (R^2=0.5373; equation y=1437x-620).

Mill Creek and other Walla Walla urban-area tributaries

This section summarizes the TMDL and Effectiveness Monitoring study results from sampling sites on Mill Creek and other streams that intersect the Walla Walla urban area. These streams flow through an engineered distributary irrigation network that services the cities of Walla Walla and College Place and surrounding areas (Figure 21).

Walla Walla and College Place each have NPDES permitted wastewater treatment facilities (Figure 21), discharging to their respective receiving waters, Mill Creek and Garrison Creek.

We compare these facilities' effluent loads and concentrations with this study's adjacent instream loads and concentrations in Appendix F.

We present the Mill Creek and other tributaries of the Walla Walla urban-area FC and nutrient results and TMDL target comparisons in Tables 29 to 38 and Figures 22 to 29.

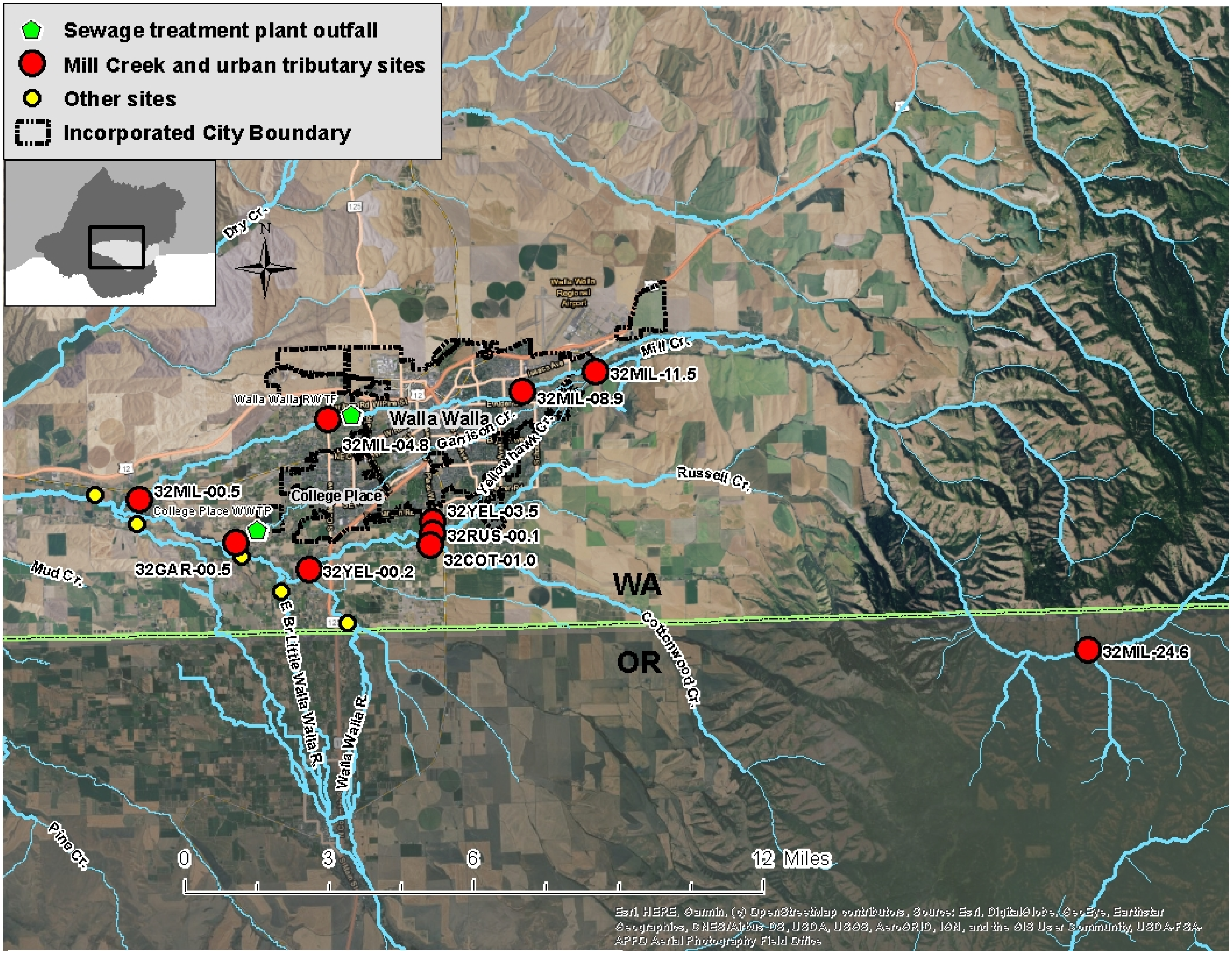


Figure 21. Mill Creek and urban-area tributary sites.

FC results in Mill Creek and other Walla Walla urban-area tributaries

Low-flow season

Table 29: Mill Creek and urban tributary sites change in low-flow season FC concentrations and targets

EM Site ID	EM Site Name	GM targets[1]	TMDL count	TMDL GM[2]	TMDL GM, 80% CI[3]	EM sample count	EM GM[2]	EM GM, 80% CI[3]	% Change in GM[2]	10% NTEV targets[1]	TMDL % of samples above 10% NTEV[2]	EM % of samples above 10% NTEV[2]
32MIL-24.6	Mill Creek @ Tiger Cr Rd	100	9	***9***	[5, 13]	12	***14***	[7, 25]	+52% (increase)	200	***0%***	***8%***
32MIL-11.5	Mill Cr @ Yellowhawk/ Garrison Diversion	100	8	***15***	[12, 22]	12	***52***	[36, 71]	+245% (increase)	200	***0%***	***8%***
32MIL-08.9	Mill Creek @ Wilbur St	206	2	502	[360, 700]	12	***113***	[80, 167]	***-78%***	180	100%	33%
32YEL-03.5	Yellowhawk Creek @ Plaza Rd	100	1	150	NA	12	136	[101, 172]	-9%	183	0%	33%
32RUS-00.1	Russell Creek @ Plaza Rd	181	3	441	[410, 464]	7	418	[297, 589]	-5%	189	100%	86%
32COT-01.0	Cottonwood Creek @ Plaza Rd	24	3	60	[21, 110]	8	80	[60, 104]	+35% (increase)	200	33%	13%
32MIL-04.8	Mill Creek @ Gose Street	100	9	***14***	[9, 22]	12	***23***	[16, 31]	+67% (increase)	200	***0%***	***0%***
32YEL-00.2	Yellowhawk Creek @ Old Milton Rd	100	9	176	[147, 202]	12	260	[167, 387]	+48% (increase)	183	56%	58%
32GAR-00.5	Garrison Creek @ Mission Rd	138	9	335	[238, 461]	12	***129***	[94, 174]	***-62%***	200	67%	42%
32MIL-00.5	Mill Creek @ Sweagle Rd	181	9	441	[359, 548]	12	***67***	[50, 88]	***-85%***	200	89%	***8%***

1. Targets below the state standards were calculated using statistical rollback to meet reductions at both the geometric mean (GM) and the 10% NTEV.
2. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
3. 80% CI = Two-sided 80 percent confidence intervals (CI) on the GM in the format [lower CI, upper CI].

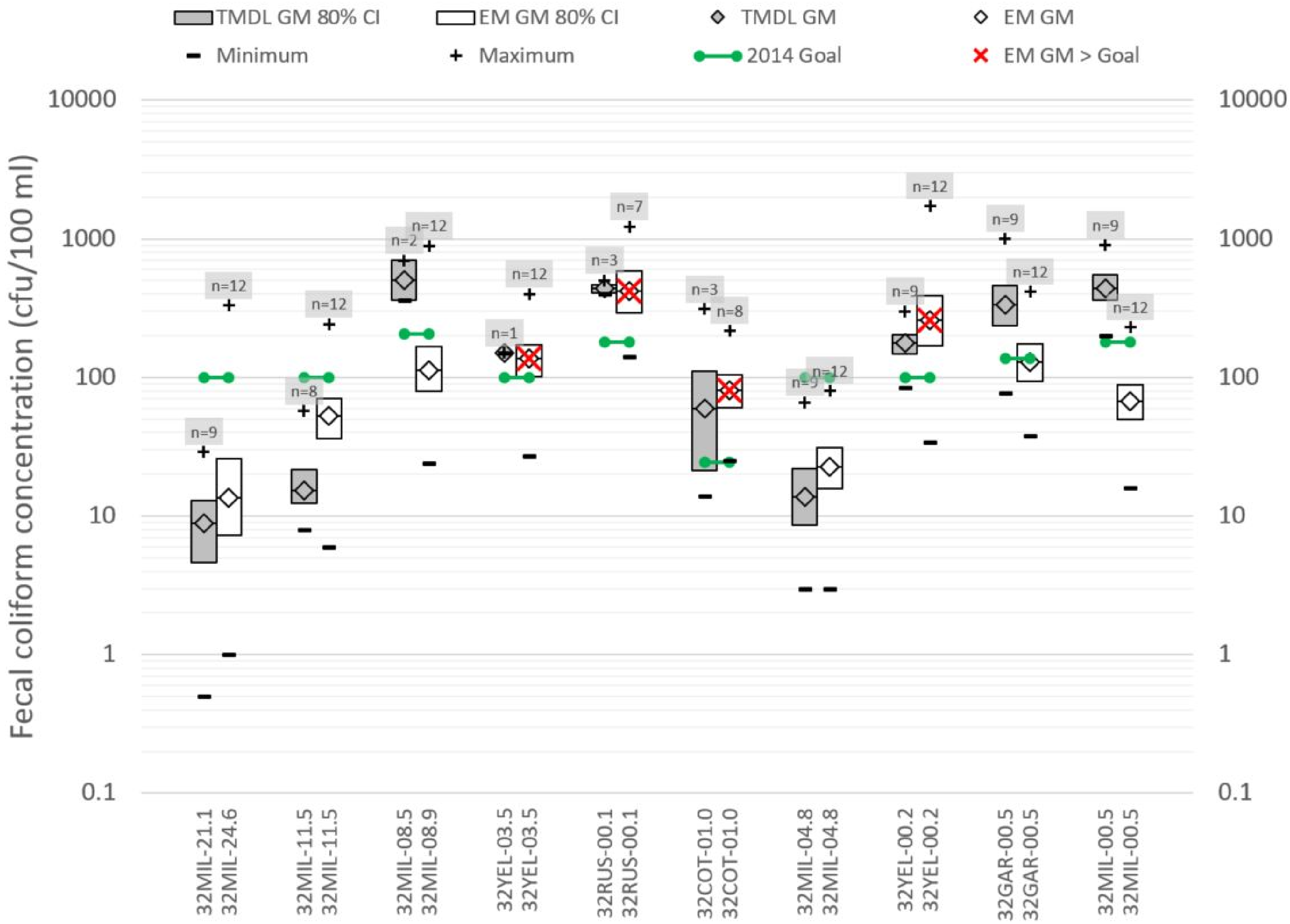


Figure 22: Low-flow Mill Creek and urban tributary site GM and 10% NTEV targets versus FC concentrations in 2002-3 vs. 2014-15.

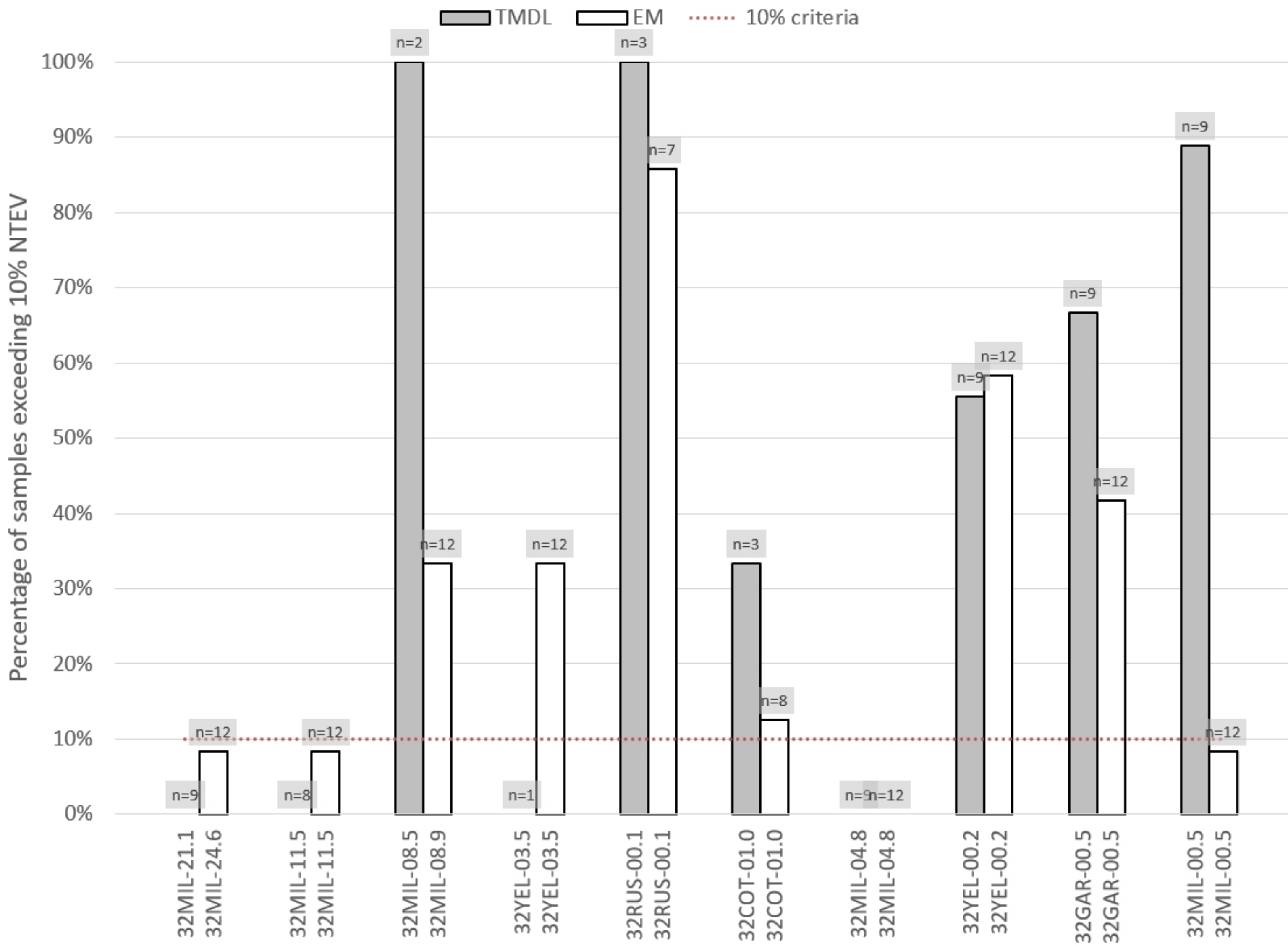


Figure 23: Low-flow season Mill Creek and urban tributary percentage of FC samples above the 10% Not to Exceed Value (NTEV) during the 2002-2003 TMDL and the 2014-2015 Effectiveness Monitoring (EM).

High-flow season

Table 30: Mill Creek and urban tributary sites change in high-flow season FC concentrations and targets

EM Site ID	EM Site Name	GM targets[1]	TMDL count	TMDL GM[2]	TMDL GM, 80% CI[3]	EM count	EM GM[2]	EM GM, 80% CI[3]	% Change in GM[2]	10% NTEV targets[1]	TMDL % of samples above 10% NTEV[2]	EM % of samples above 10% NTEV[2]
32MIL-24.6	Mill Creek @ Tiger Cr Rd	100	7	***1.6***	[1.1, 2.4]	5	***1.8***	[0.9, 4.2]	+10% (increase)	200	***0%***	***0%***
32MIL-11.5	Mill Cr @ Yellowhawk/ Garrison Diversion	100	7	***3***	[2, 4]	5	***11***	[7, 14]	+287% (increase)	200	***0%***	***0%***
32MIL-08.9	Mill Creek @ Wilbur St	100	2	148	[76, 290]	5	120	[53, 231]	-19%	180	50%	40%
32YEL-03.5	Yellowhawk Creek @ Plaza Rd	100	0	NA	NA	5	***87***	[57, 115]	NA	183	NA	***0%***
32RUS-00.1	Russell Creek @ Plaza Rd	100	2	190	[150, 240]	5	152	[108, 247]	-20%	189	50%	20%
32COT-01.0	Cottonwood Creek @ Plaza Rd	18	2	***10***	[2, 47]	4	30	[19, 43]	+206% (increase)	200	***0%***	***0%***
32MIL-04.8	Mill Creek @ Gose Street	100	7	***54***	[29, 82]	5	***85***	[59, 154]	+57% (increase)	200	***0%***	20%
32YEL-00.2	Yellowhawk Creek @ Old Milton Rd	100	7	165	[117, 205]	5	156	[103, 245]	-6%	183	71%	40%
32GAR-00.5	Garrison Creek @ Mission Rd	45	6	109	[51, 260]	5	101	[58, 215]	-7%	200	33%	20%
32MIL-00.5	Mill Creek @ Sweagle Rd	100	7	***35***	[30, 42]	5	***28***	[10, 51]	-20%	200	***0%***	***0%***

1. Targets below the state standards were calculated using statistical rollback to meet reductions at both the geometric mean (GM) and the 10% NTEV.
2. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
3. 80% CI = Two-sided 80 percent confidence intervals (CI) on the GM in the format [lower CI, upper CI].

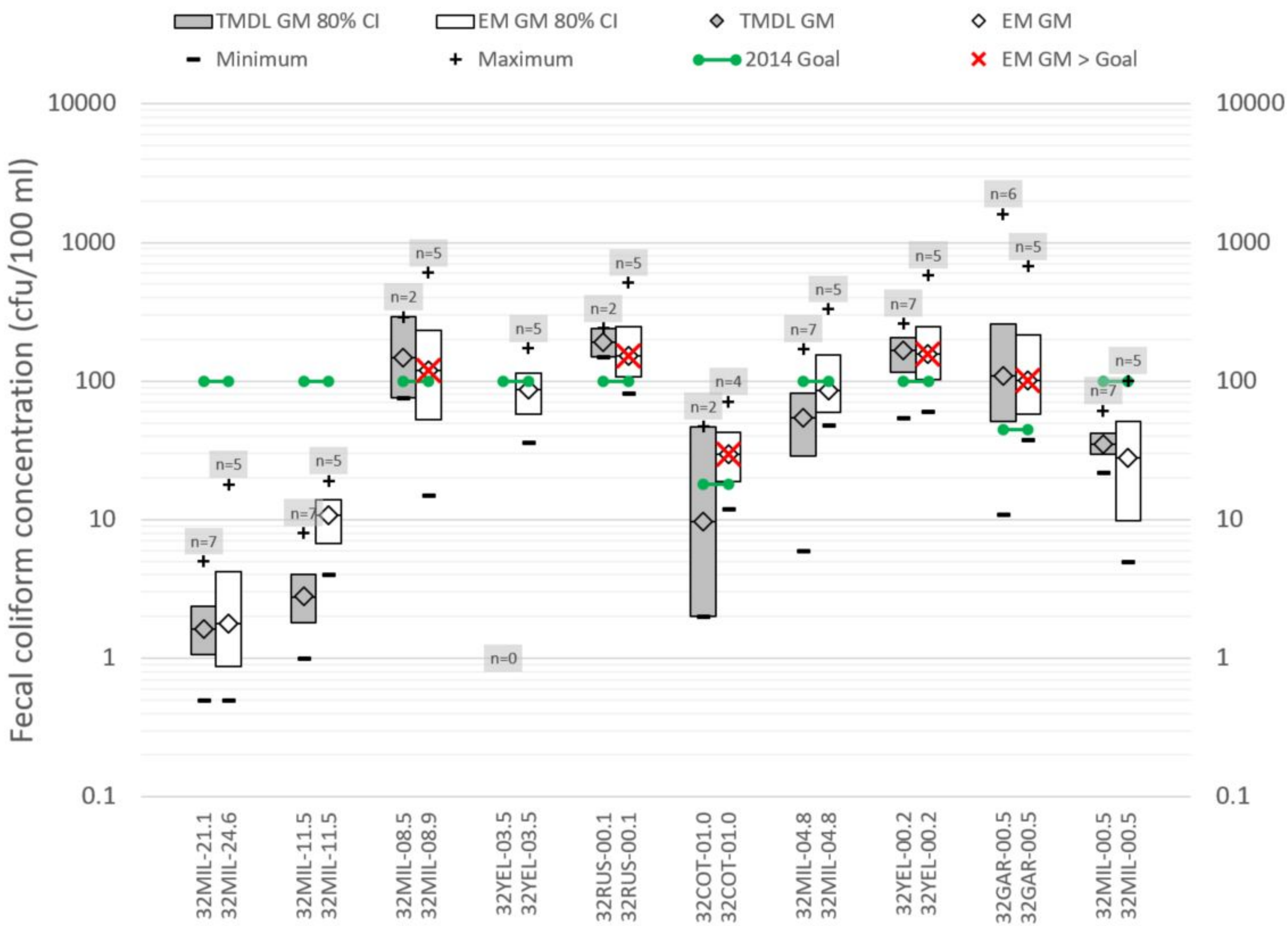


Figure 24: High-flow Mill Creek and urban tributary site GM and 10% NTEV targets vs. FC concentrations in 2002-3 vs. 2014-15.

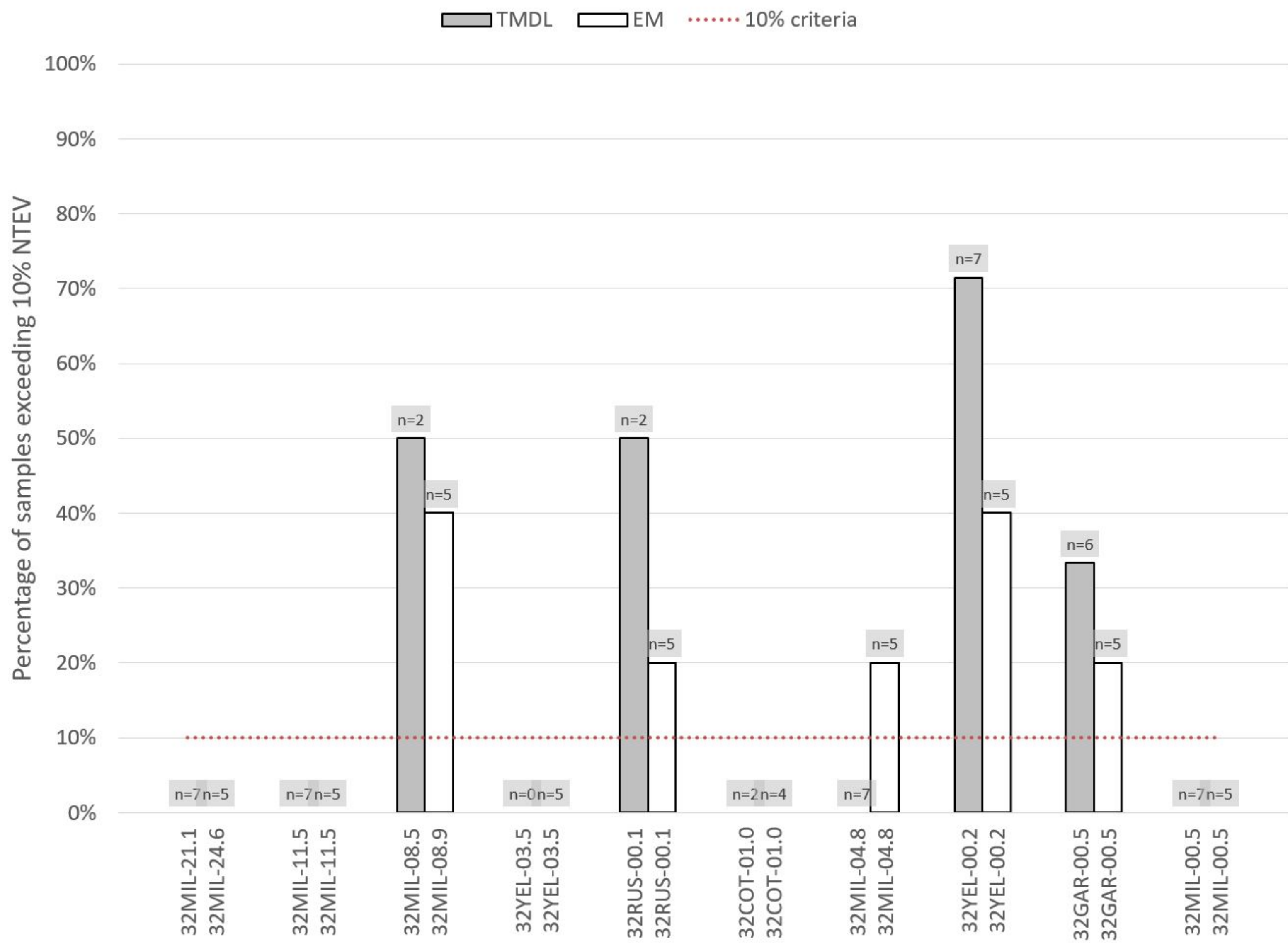


Figure 25: **High-flow Mill Creek and urban tributary percentage of FC samples above the 10% Not to Exceed Value (NTEV) during the 2002-2003 TMDL and the 2014-2015 Effectiveness Monitoring (EM).**

Soluble Reactive Phosphorus (SRP) results in Mill Creek and other Walla Walla urban-area tributaries

Low-flow season

Table 31. Mill Creek and urban tributary sites change in low-flow season SRP.

EM Site ID	EM Site Name	2014 target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32MIL-24.6	Mill Creek @ Tiger Cr Rd	0.047	8	***0.047***	[0.045, 0.049]	12	0.049	[0.048, 0.051]	5% (increase)
32MIL-11.5	Mill Cr @ Yellowhawk/ Garrison Diversion	0.047	8	***0.031***	[0.029, 0.033]	12	***0.026***	[0.025, 0.028]	-16%
32MIL-08.9	Mill Creek @ Wilbur St	0.047	1	***0.021***	NA	12	***0.017***	[0.015, 0.020]	-21%
32YEL-03.5	Yellowhawk Creek @ Plaza Rd	0.047	0	NA	NA	12	***0.032***	[0.030, 0.035]	NA
32RUS-00.1	Russell Creek @ Plaza Rd	0.052	1	0.131	NA	7	0.162	[0.140, 0.205]	24% (increase)
32COT-01.0	Cottonwood Creek @ Plaza Rd	0.047	0	NA	NA	8	0.056	[0.055, 0.058]	NA
32MIL-04.8	Mill Creek @ Gose Street	0.214	7	0.534	[0.486, 0.563]	12	***0.071***	[0.052, 0.102]	***-87%***
32YEL-00.2	Yellowhawk Creek @ Old Milton Rd	0.047	7	0.049	[0.046, 0.053]	12	0.053	[0.048, 0.060]	9% (increase)
32GAR-00.5	Garrison Creek @ Mission Rd	1.064	7	2.660	[2.051, 3.366]	12	***0.663***	[0.533, 0.859]	***-75%***
32MIL-00.5	Mill Creek @ Sweagle Rd	0.057	8	0.143	[0.131, 0.152]	12	0.110	[0.100, 0.121]	-23%

1. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
2. 80% CI = Two-sided 80 percent confidence intervals (CI) on the ArMn in the format [lower CI, upper CI].

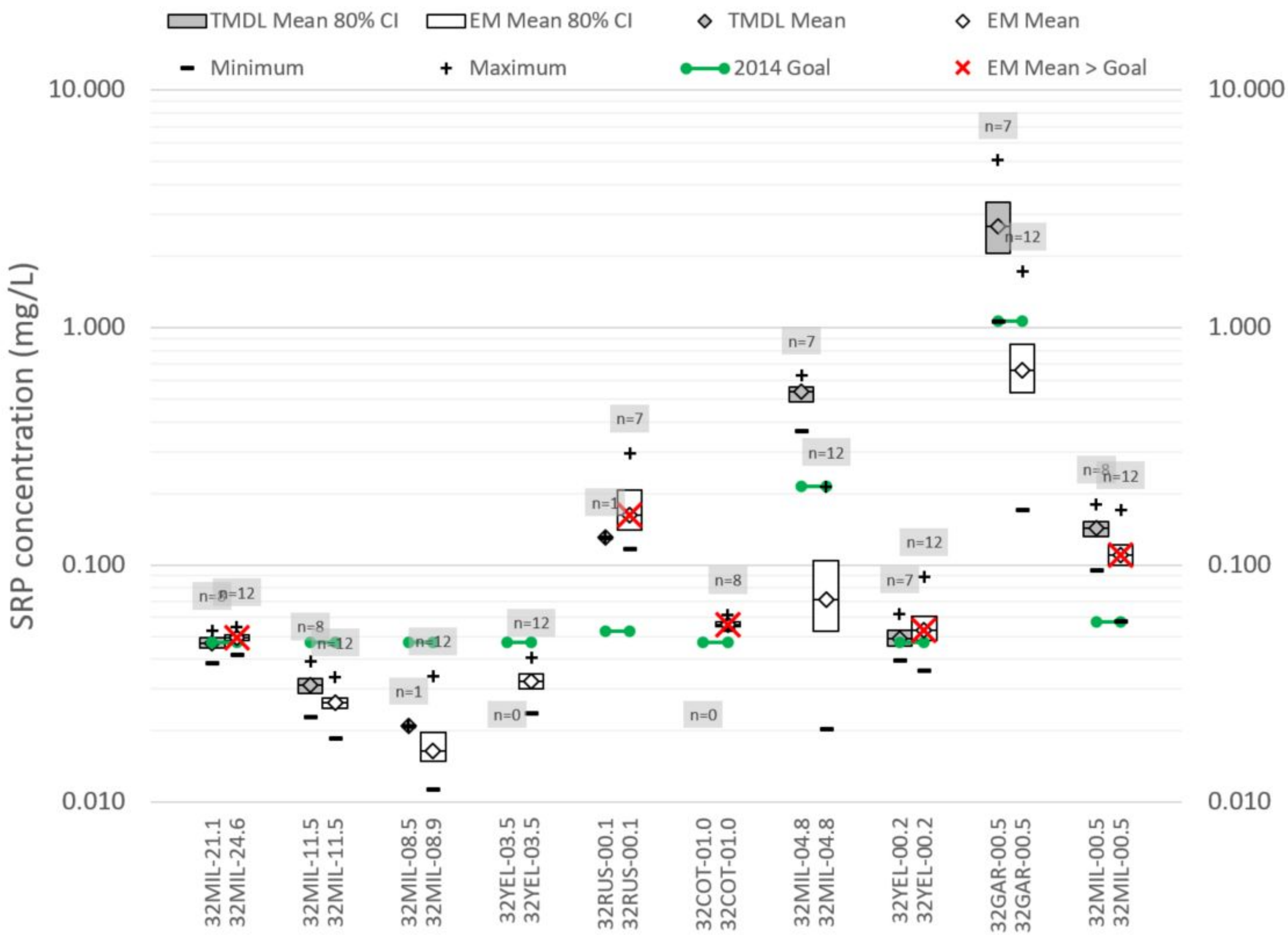


Figure 26: Low-flow TMDL and EM arithmetic mean and 80% confidence intervals on SRP concentration for Mill Creek and urban tributary sites.

High-flow season

Table 32. Mill Creek and urban tributary sites change in high-flow season SRP.

EM Site ID	EM Site Name	TMDL target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32MIL-24.6	Mill Creek @ Tiger Cr Rd	0.047	6	***0.036***	[0.033, 0.040]	5	***0.043***	[0.041, 0.045]	18% (increase)
32MIL-11.5	Mill Cr @ Yellowhawk/ Garrison Diversion	0.047	6	***0.031***	[0.028, 0.034]	5	***0.032***	[0.028, 0.035]	4% (increase)
32MIL-08.9	Mill Creek @ Wilbur St	0.047	2	***0.022***	[0.020, 0.024]	5	***0.027***	[0.023, 0.031]	25% (increase)
32YEL-03.5	Yellowhawk Creek @ Plaza Rd	0.047	0	NA	NA	5	***0.030***	[0.025, 0.034]	NA
32RUS-00.1	Russell Creek @ Plaza Rd	0.047	0	NA	NA	5	0.100	[0.089, 0.109]	NA
32COT-01.0	Cottonwood Creek @ Plaza Rd	0.047	0	NA	NA	4	***0.038***	[0.032, 0.044]	NA
32MIL-04.8	Mill Creek @ Gose Street	0.056	6	0.139	[0.112, 0.173]	5	0.075	[0.054, 0.099]	-46%
32YEL-00.2	Yellowhawk Creek @ Old Milton Rd	0.047	2	***0.043***	[0.037, 0.050]	5	***0.041***	[0.037, 0.045]	-4%
32GAR-00.5	Garrison Creek @ Mission Rd	0.290	5	0.724	[0.466, 1.195]	5	1.523	[0.918, 2.558]	110% (increase)
32MIL-00.5	Mill Creek @ Sweagle Rd	0.083	6	0.207	[0.150, 0.297]	5	0.105	[0.086, 0.127]	-49%

1. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
2. 80% CI = Two-sided 80 percent confidence intervals (CI) on the ArMn in the format [lower CI, upper CI].

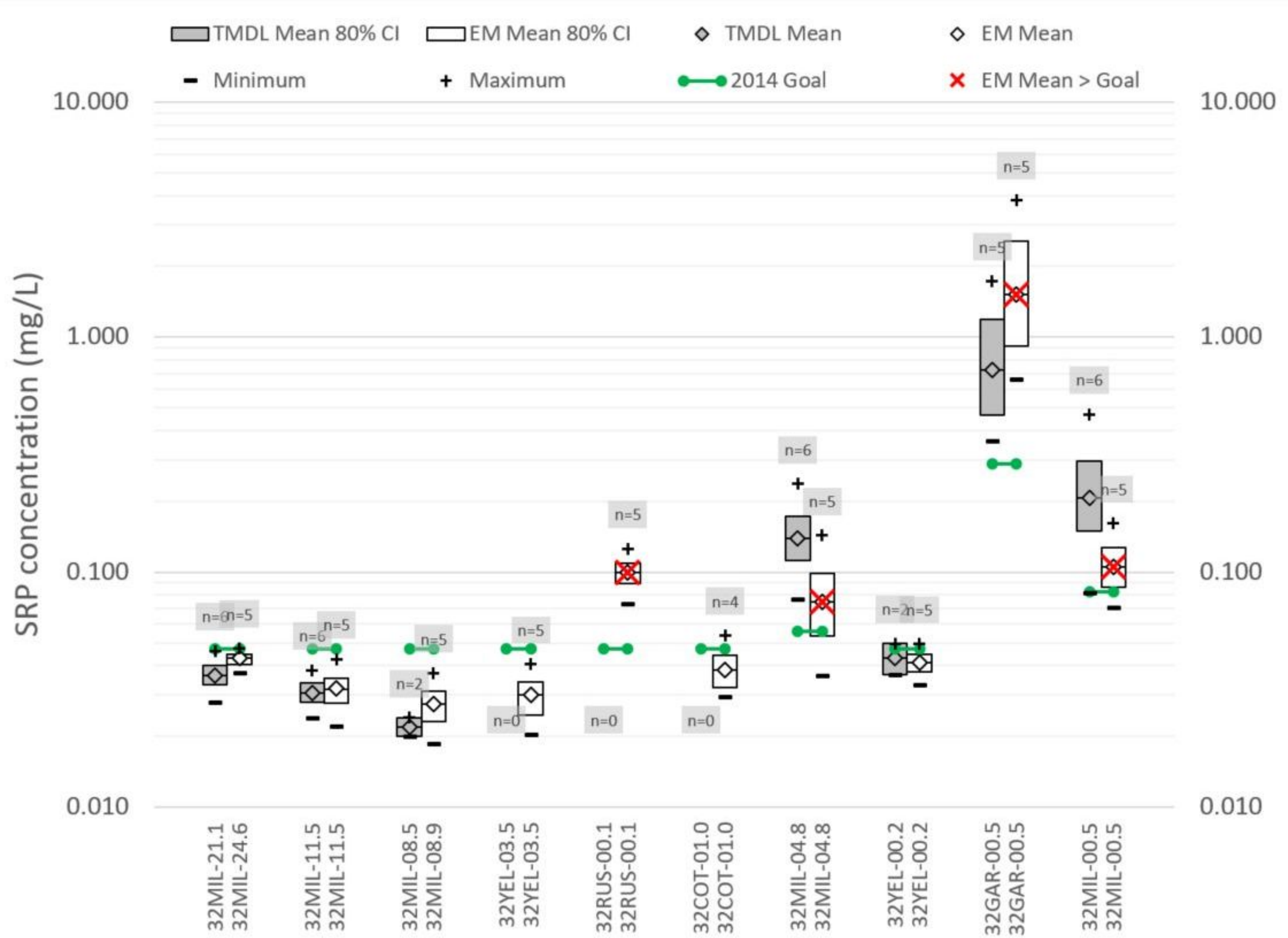


Figure 27: High-flow TMDL and EM arithmetic mean and 80% confidence intervals on SRP concentration for Mill Creek and urban tributary sites.

Dissolved Inorganic Nitrogen (DIN) results in Mill Creek and other Walla Walla urban-area tributaries

Low-flow season

Table 33. Mill Creek and urban tributary changes in low-flow season DIN.

EM Site ID	EM Site Name	EM target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32MIL-24.6	Mill Creek @ Tiger Cr Rd	0.076	8	***0.067***	[0.060, 0.072]	12	0.132	[0.128, 0.137]	99% (increase)
32MIL-11.5	Mill Cr @ Yellowhawk/ Garrison Diversion	0.076	7	***0.010***	[0.010, 0.011]	12	***0.029***	[0.023, 0.039]	194% (increase)
32MIL-08.9	Mill Creek @ Wilbur St	0.076	1	***0.010***	NA	12	***0.022***	[0.016, 0.032]	123% (increase)
32YEL-03.5	Yellowhawk Creek @ Plaza Rd	0.076	0	NA	NA	12	0.099	[0.078, 0.121]	NA
32RUS-00.1	Russell Creek @ Plaza Rd	0.978	1	2.445	NA	7	4.148	[3.535, 4.476]	70% (increase)
32COT-01.0	Cottonwood Creek @ Plaza Rd	0.076	0	NA	NA	7	0.886	[0.816, 0.954]	NA
32MIL-04.8	Mill Creek @ Gose Street	0.768	7	1.919	[1.489, 2.371]	12	***0.486***	[0.422, 0.546]	***-75%***
32YEL-00.2	Yellowhawk Creek @ Old Milton Rd	0.181	7	0.452	[0.368, 0.518]	12	0.288	[0.220, 0.371]	-36%
32GAR-00.5	Garrison Creek @ Mission Rd	0.567	7	1.417	[1.260, 1.632]	12	2.048	[1.879, 2.351]	45% (increase)
32MIL-00.5	Mill Creek @ Sweagle Rd	0.557	8	1.394	[0.814, 2.024]	12	1.554	[1.408, 1.679]	11% (increase)

1. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
2. 80% CI = Two-sided 80 percent confidence intervals (CI) on the ArMn in the format [lower CI, upper CI].

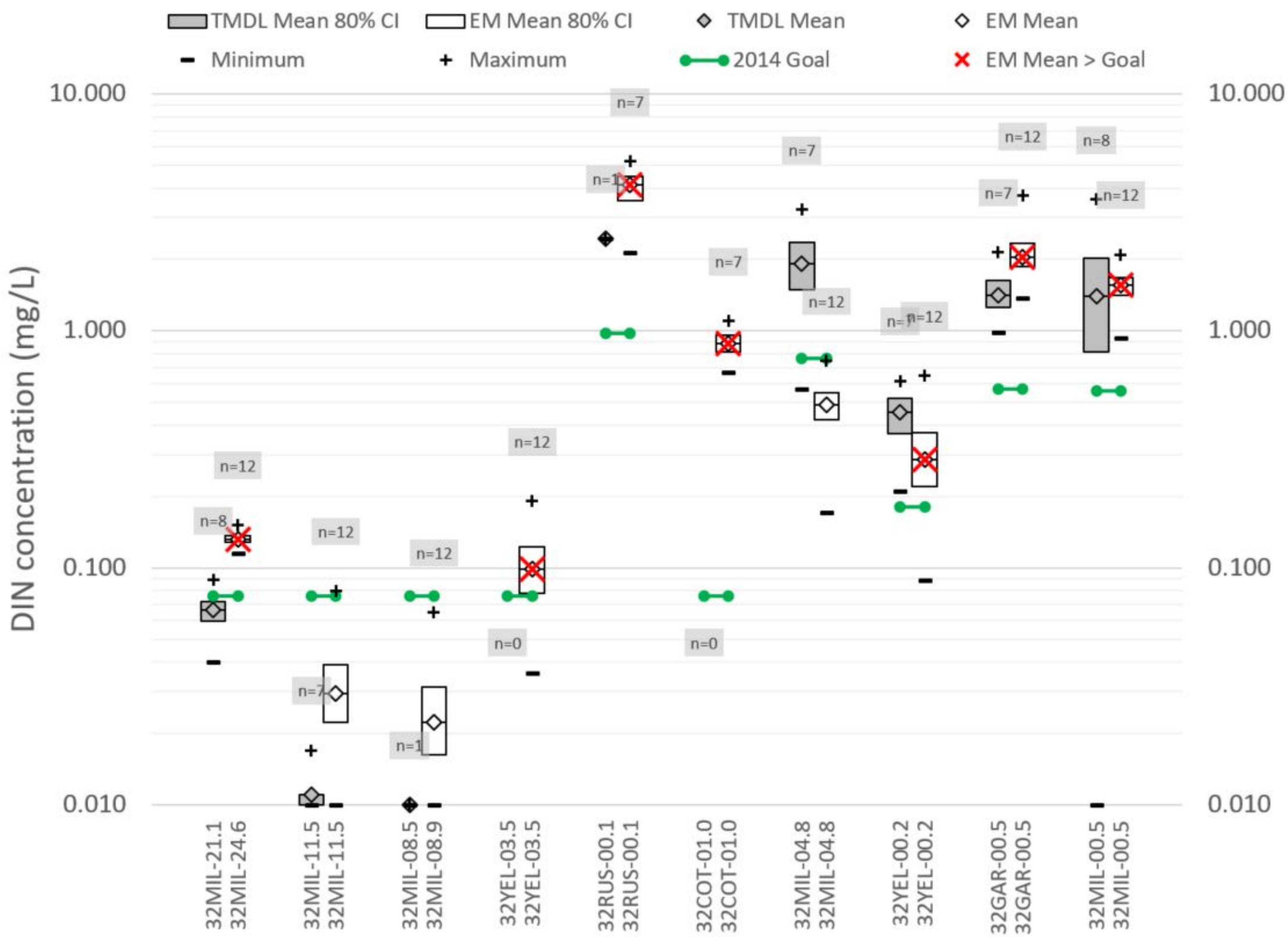


Figure 28: Low-flow TMDL and EM arithmetic mean and 80% confidence intervals on DIN concentration for Mill Creek and urban tributary sites.

High-flow season

Table 34. Mill Creek and urban tributary changes in high-flow season DIN.

EM Site ID	EM Site Name	2014 target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM sample count	EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32MIL-24.6	Mill Creek @ Tiger Cr Rd	0.076	6	***0.074***	[0.056, 0.093]	5	0.122	[0.107, 0.135]	65% (increase)
32MIL-11.5	Mill Cr @ Yellowhawk/ Garrison Diversion	0.076	6	0.142	[0.099, 0.179]	5	0.189	[0.146, 0.211]	33% (increase)
32MIL-08.9	Mill Creek @ Wilbur St	0.076	2	0.097	[0.078, 0.116]	5	0.195	[0.146, 0.220]	101% (increase)
32YEL-03.5	Yellowhawk Creek @ Plaza Rd	0.076	0	NA	NA	5	0.328	[0.265, 0.377]	NA
32RUS-00.1	Russell Creek @ Plaza Rd	0.076	0	NA	NA	5	3.324	[2.833, 3.834]	NA
32COT-01.0	Cottonwood Creek @ Plaza Rd	0.076	0	NA	NA	4	0.827	[0.649, 0.981]	NA
32MIL-04.8	Mill Creek @ Gose Street	0.264	6	0.661	[0.481, 0.868]	5	0.447	[0.345, 0.531]	-32%
32YEL-00.2	Yellowhawk Creek @ Old Milton Rd	0.408	2	1.021	[0.987, 1.055]	5	0.957	[0.737, 1.079]	-6%
32GAR-00.5	Garrison Creek @ Mission Rd	0.838	5	2.094	[1.574, 2.760]	5	3.780	[3.400, 4.049]	80% (increase)
32MIL-00.5	Mill Creek @ Sweagle Rd	0.555	6	1.388	[0.831, 2.397]	5	0.734	[0.590, 0.851]	-47%

1. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.

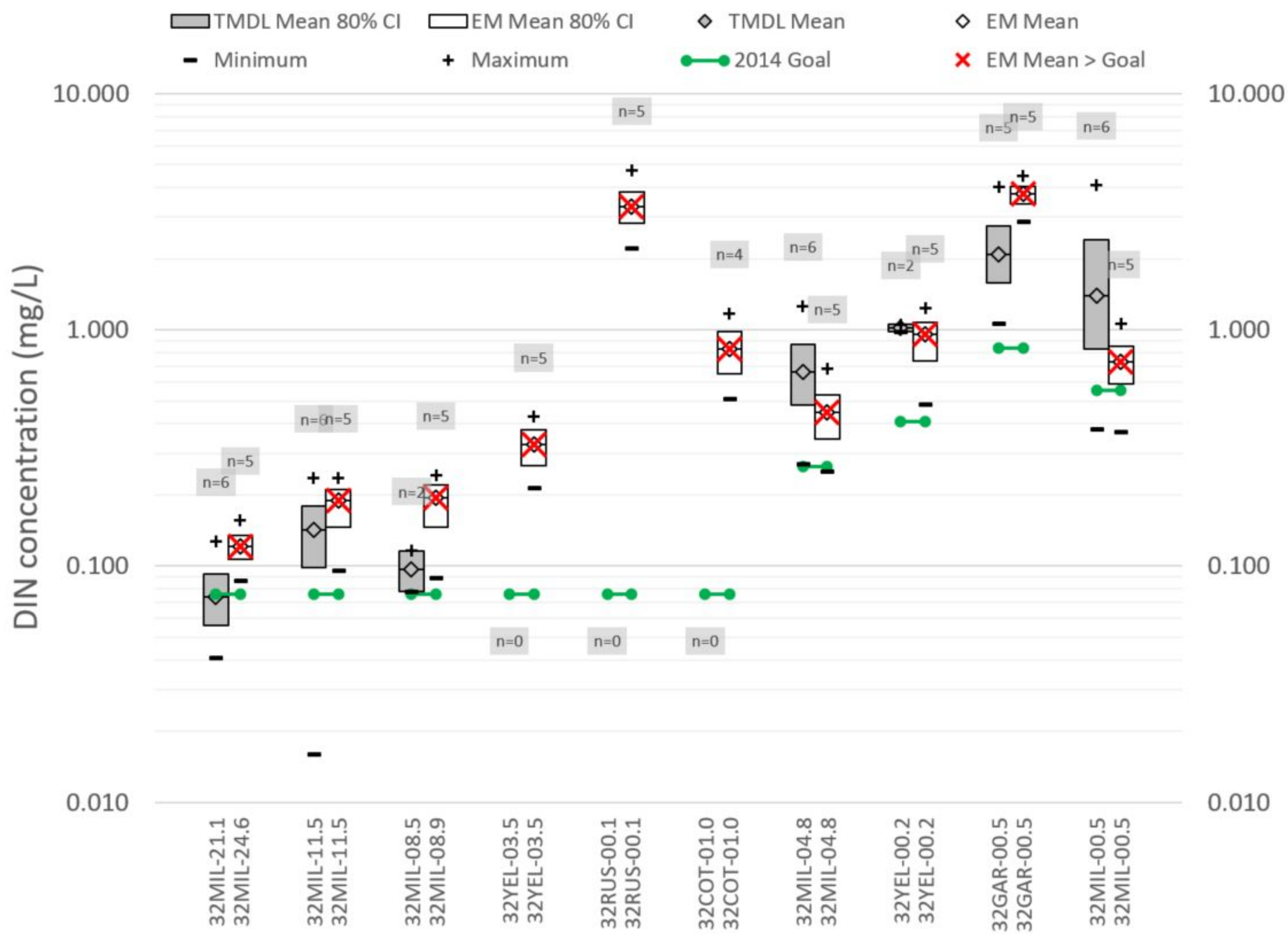


Figure 29: High-flow TMDL and EM arithmetic mean and 80% confidence intervals on DIN concentration for Mill Creek and urban tributary sites.

Reach-specific nutrient load and concentration changes for Mill Creek and other Walla Walla urban-area tributaries

Tables 35 to 38 show reach-specific nutrient load changes calculated between our sampling sites in Mill Creek and other creeks intersecting the Walla Walla urban area. Loads at these sites may come from both urban and rural nonpoint sources.

Table 35: Year 6 low-flow (May-Oct) reach-specific changes to SRP concentrations versus TMDL targets.

Upstream Sites	Downstream Sites	Load Changes (lbs SRP/ day)	Flow Changes (cfs)	Upstream to downstream change in mean concentration (mg SRP/L)	10 year nonpoint targets (mg SRP/L)	Concentration Changes (mg SRP/L) [1,2]
32MIL-24.6 [3]	32MIL-11.5	-5.91	-18.35	-0.023	0.085	***-0.060***
32YEL-03.5 [3], 32RUS-00.1 [3] 32COT-01.0 [3]	32YEL-00.2	-0.31	-4.78	+0.011	0.085	***0.012***

Table 36: Year 6 high-flow (Nov-Apr) reach-specific changes to SRP concentrations versus TMDL targets.

Upstream Sites	Downstream Sites	Load Changes (lbs SRP/ day)	Flow Changes (cfs)	Upstream to downstream change in mean concentration (mg SRP/L)	10 year nonpoint targets (mg SRP/L)	Concentration Changes (mg SRP/L) [1,2]
32MIL-24.6 [3]	32MIL-11.5	-1.06	+19.45	-0.010	0.085	***-0.010***
32YEL-03.5 [3], 32RUS-00.1 [3] 32COT-01.0 [3]	32YEL-00.2	-0.63	+0.22	-0.004	0.085	***-0.535***

1. Negative results show an upstream to downstream decrease in the nutrient water concentration.
2. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
3. Due to a lack of continuous flow data, we adjusted this mean seasonal load estimate using continuous flows from a neighboring station.

Table 37: Year 6 low-flow (May-Oct) reach-specific changes to DIN concentrations versus TMDL targets.

Upstream Sites	Downstream Sites	Load Changes (lbs DIN/ day)	Flow Changes (cfs)	Upstream to downstream change in mean concentration (mg DIN/L)	10 year nonpoint targets (mg DIN/L)	Concentration Changes (mg DIN/L) [1,2]
32MIL-24.6 [3]	32MIL-11.5	-18.21	-18.35	-0.105	0.387	***-0.184***
32YEL-03.5 [3], 32RUS-00.1 [3] 32COT-01.0 [3]	32YEL-00.2	-5.73	-4.78	+0.051	0.387	***0.222***

Table 38: Year 6 high-flow (Nov-Apr) reach-specific changes to DIN concentrations versus TMDL targets.

Upstream Sites	Downstream Sites	Load Changes (lbs DIN/ day)	Flow Changes (cfs)	Upstream to downstream change in mean concentration (mg DIN/L)	10 year nonpoint targets (mg DIN/L)	Concentration Changes (mg DIN/L) [1,2]
32MIL-24.6 [3]	32MIL-11.5	+49.48	+19.45	+0.067	0.387	0.472
32YEL-03.5 [3], 32RUS-00.1 [3] 32COT-01.0 [3]	32YEL-00.2	-25.38	+0.22	-0.162	0.387	***-21.732***

1. Negative results show an upstream to downstream decrease in the nutrient water concentration.
2. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
3. Due to a lack of continuous flow data, we adjusted this mean seasonal load estimate using continuous flows from a neighboring station.

Status and trends for Mill Creek and other Walla Walla urban-area tributaries

Upstream of the Walla Walla urban area, FC and nutrients in Mill Creek remained near the low concentrations measured in the TMDL. As during the TMDL, concentrations increased slightly with distance from the headwaters.

Downstream of the Mill Creek diversion, FC and nutrient levels increased within the Walla Walla urban distributary network for Yellowhawk, Garrison, and Mill Creeks. Low-flow season samples showed a proportionally greater urban increase than high-flow season samples. All urban sites increased FC and nutrient concentrations relative to the headwaters. The largest concentrations occurred at these sites:

- 32RUS-00.1, Russell Creek at Plaza Road
- 32GAR-00.5, Garrison Creek at Mission Road
- 32YEL-00.2, Yellowhawk Creek at Old Milton Road

Russell Creek at Plaza Road (32RUS-00.1) in the low-flow season, had the highest FC concentrations and the second highest DIN and SRP concentrations in this study, approaching effluent levels. These concentrations indicate pollutant sources between Plaza Road and the Mill Creek diversion to Bennington Lake. These high concentrations appear unchanged from the single Russell Creek TMDL sample.

Between the Plaza Road sites (for Yellowhawk, Russell, and Cottonwood Creeks) and Old Milton Road, Yellowhawk Creek receives additional low-flow season nutrient loads from nonpoint sources (Tables 35 and 37). At Old Milton Road (32YEL-00.2), 2015 surface water FC concentrations were higher than in 2002, while nutrient concentrations remained about the same.

Walla Walla WWTP and Mill Creek

The Walla Walla WWTP discharges to Mill Creek at RM 5.4 from December through April (Appendix F, Figure F9). During our study, the Walla Walla WWTP Discharge Monitoring Reports (DMRs) reported effluent FC levels below the NPDES permit limits (Figures F11 and F12). We compare the Walla Walla WWTP DMR effluent results to our study's instream concentrations at 32MIL-08.9 and 32MIL-04.8 in Appendix F.

An overlay of the estimated DIN loads from the WWTP on Mill Creek loads in the effluent receiving reach shows an instream load increase between January and April 2015 that resembles the WWTP effluent loads (Figure F13). The similarity in load and timing suggests the WWTP contributes a significant portion of the Mill Creek DIN loads during the permitted high-flow season discharge period. High-flow season 2015 DIN concentrations decreased by 32% in Mill Creek below the WWTP relative to 2002. In the low-flow season, the diversion of effluent to irrigation land application successfully removed those loads from the stream.

College Place WWTP and Garrison Creek

At Garrison Creek at Mission Road (32GAR-00.5), FC concentrations reduced in all seasons, and met the low-flow season reduction target, but will require further reduction to meet GM and 10% NTEV criteria. Low-flow season SRP at Garrison Creek was 75% lower in 2015 than in 2002, but SRP remained at the highest concentrations in this study for all seasons, and was higher in

2015 than in 2002 for the high-flow season. DIN concentrations at Garrison Creek were also higher in 2015 than in 2002 for all seasons (Tables 29 to 34 and Figures 23 to 30).

The College Place WWTP discharges effluent to Garrison Creek a half-mile upstream of Mission Road (RM 1.0) from November to April, and land applies effluent from May to October. The WWTP also has effluent limits from May to October based on the potential for periodic discharge. We present figures of College Place WWTP effluent data with this study's Garrison Creek results in Appendix F.

From December 2014 to April 2015, College Place WWTP effluent flow and nutrient loads, entering at Garrison Creek RM 1.0, closely approximated the Garrison Creek flow patterns and nutrient levels at RM 0.5. In contrast, during the low-flow season, when effluent was sent to land application, Garrison Creek loads showed no persistent relationship with the WWTP effluent (Figures F15, F18, and F19).

In a 2014 internal memo, Ecology analysis of monitoring well data showed elevated groundwater nitrate concentrations upgradient of the College Place WWTP, and lower nitrate concentrations in the downgradient monitoring wells closest to Garrison Creek (Figure F14). They concluded this indicates an unknown source of groundwater nitrogen originating off-site from the WWTP (Doremus 2014b).

Mainstem Walla Walla River and rural tributary results

This section summarizes the TMDL and Effectiveness Monitoring study results from sampling sites in the mainstem Walla Walla River and rural tributaries downstream of the city of Walla Walla.

The mainstem Walla Walla River enters Washington State after exchanging flows in a distributary network around Milton-Freewater Oregon. It passes downstream of the distributary network in the cities of Walla Walla and College Place, then enters a more rural agricultural area passing the unincorporated towns of Lowden and Touchet. The river assimilates further irrigation return flows from the East and West Branch Little Walla Walla Rivers, Dry, Mud, and Pine Creeks, and finally the Touchet River (Figure 30).

The Walla Walla mainstem and rural tributary FC and nutrient results and TMDL target comparisons follow in Tables 39 to 44 and Figures 31 to 38.

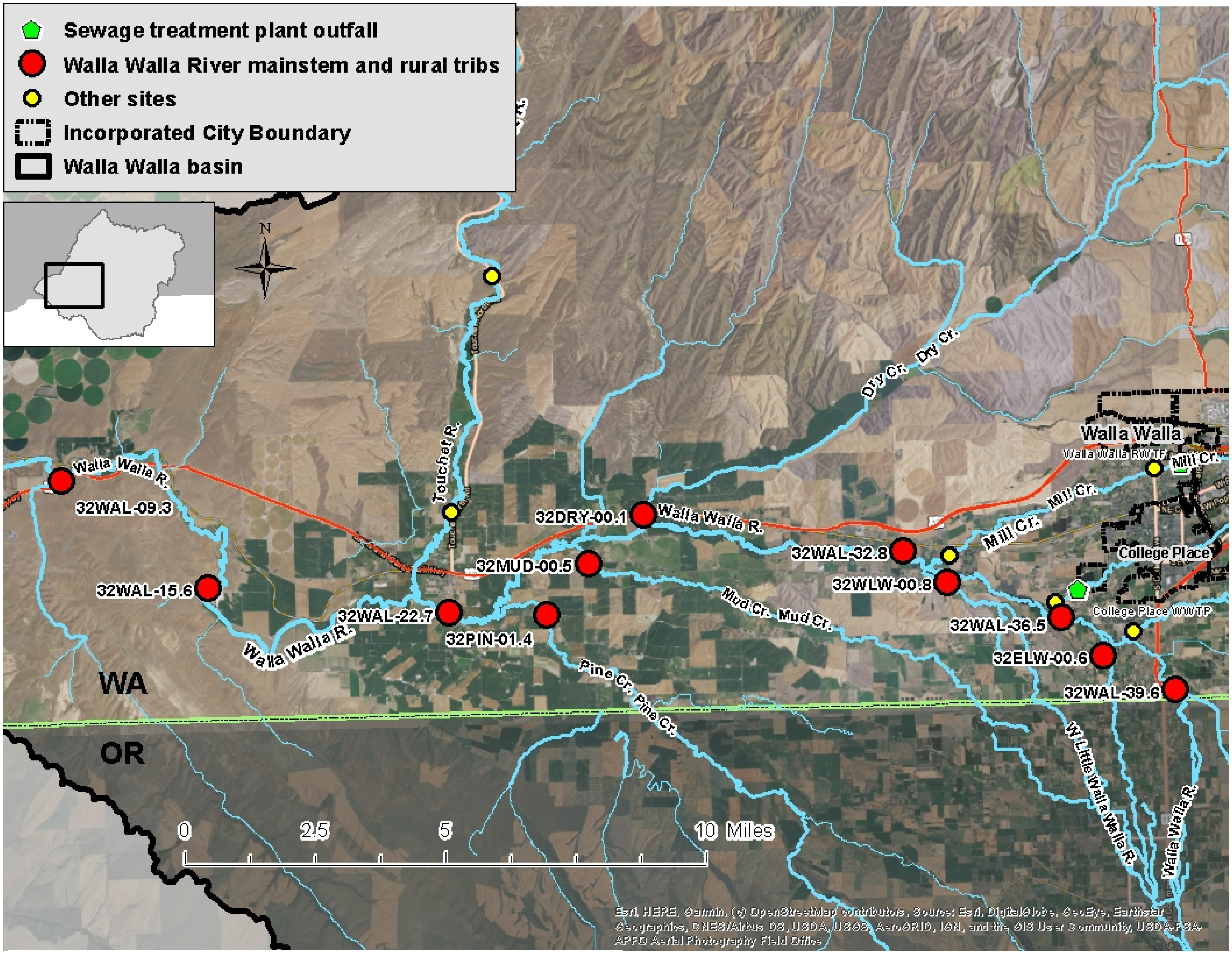


Figure 30. Walla Walla River mainstem and rural-area tributary sites.

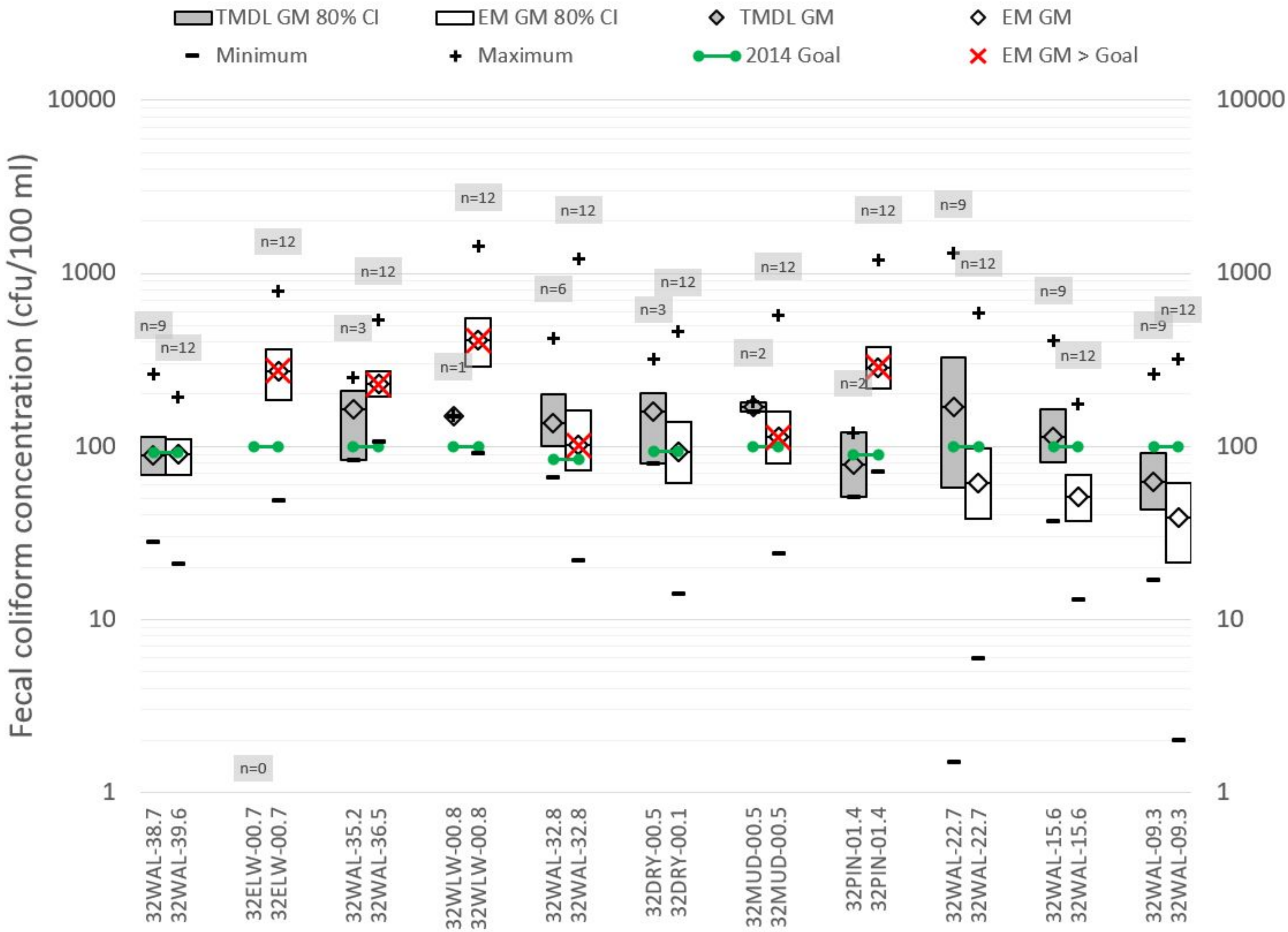
FC results for the Walla Walla River mainstem and rural-area tributary sites

Low-flow season

Table 39: Walla Walla River mainstem and rural-area tributary sites change in low-flow season FC concentrations and targets.

EM Site ID	EM Site Name	GM targets[1]	TMDL count	TMDL GM[2]	TMDL GM, 80% CI[3]	EM count	EM GM[2]	EM GM, 80% CI[3]	% Change in GM[2]	10% NTEV targets[1]	TMDL % of samples above 10% NTEV[2]	EM % of samples above 10% NTEV[2]
32WAL-39.6	Walla Walla R @ Peppers Bridge Rd	92	9	***89***	[68, 113]	12	***90***	[68, 109]	+0.3% (increase)	200	11%	***0%***
32ELW-00.7	E Br Little Walla Walla R @ Springdale Rd	100	0	NA	NA	12	274	[190, 368]	NA	200	NA	75%
32WAL-36.5	Walla Walla R @ Mojonnier (Beet) Rd	100	3	164	[84, 210]	12	230	[194, 273]	+40% (increase)	188	67%	67%
32WLW-00.8	W Br Little Walla Walla R @ Sweagle Rd	100	1	150	NA	12	408	[290, 546]	+172% (increase)	147	100%	83%
32WAL-32.8	Walla Walla R @ Detour Rd	84	6	136	[100, 200]	12	102	[72, 162]	-25%	200	33%	33%
32DRY-00.1	Dry Creek @ Dodd Ranch	93	3	160	[80, 202]	12	***92***	[62, 138]	-42%	200	33%	25%
32MUD-00.5	Mud Creek @ Barney (Borgen) Rd	100	2	170	[160, 180]	12	113	[79, 160]	-34%	180	***0%***	25%
32PIN-01.4	Pine Creek @ Sand Pit Rd	89	2	***78***	[51, 120]	12	286	[219, 376]	+265% (increase)	200	***0%***	75%
32WAL-22.7	Walla Walla R @ Touchet-Gardena Rd	100	9	170	[57, 329]	12	***61***	[38, 97]	***-64%***	200	56%	17%
32WAL-15.6	Walla Walla R @ Byerly Rd	100	9	114	[81, 163]	12	***51***	[37, 68]	-55%	200	33%	***0%***
32WAL-09.3	Walla Walla R @ Pierce's RV Park	100	9	***62***	[43, 91]	12	***39***	[21, 61]	-38%	200	11%	17%

1. Targets below the state standards were calculated using statistical rollback to meet reductions at both the geometric mean (GM) and the 10% NTEV.
2. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
3. 80% CI = Two-sided 80 percent confidence intervals (CI) on the GM in the format [lower CI, upper CI).



4.

Figure 31: Low-flow Walla Walla River mainstem and rural-area tributary sites GM and 10% NTEV targets versus FC concentrations in 2002-3 vs. 2014-15.

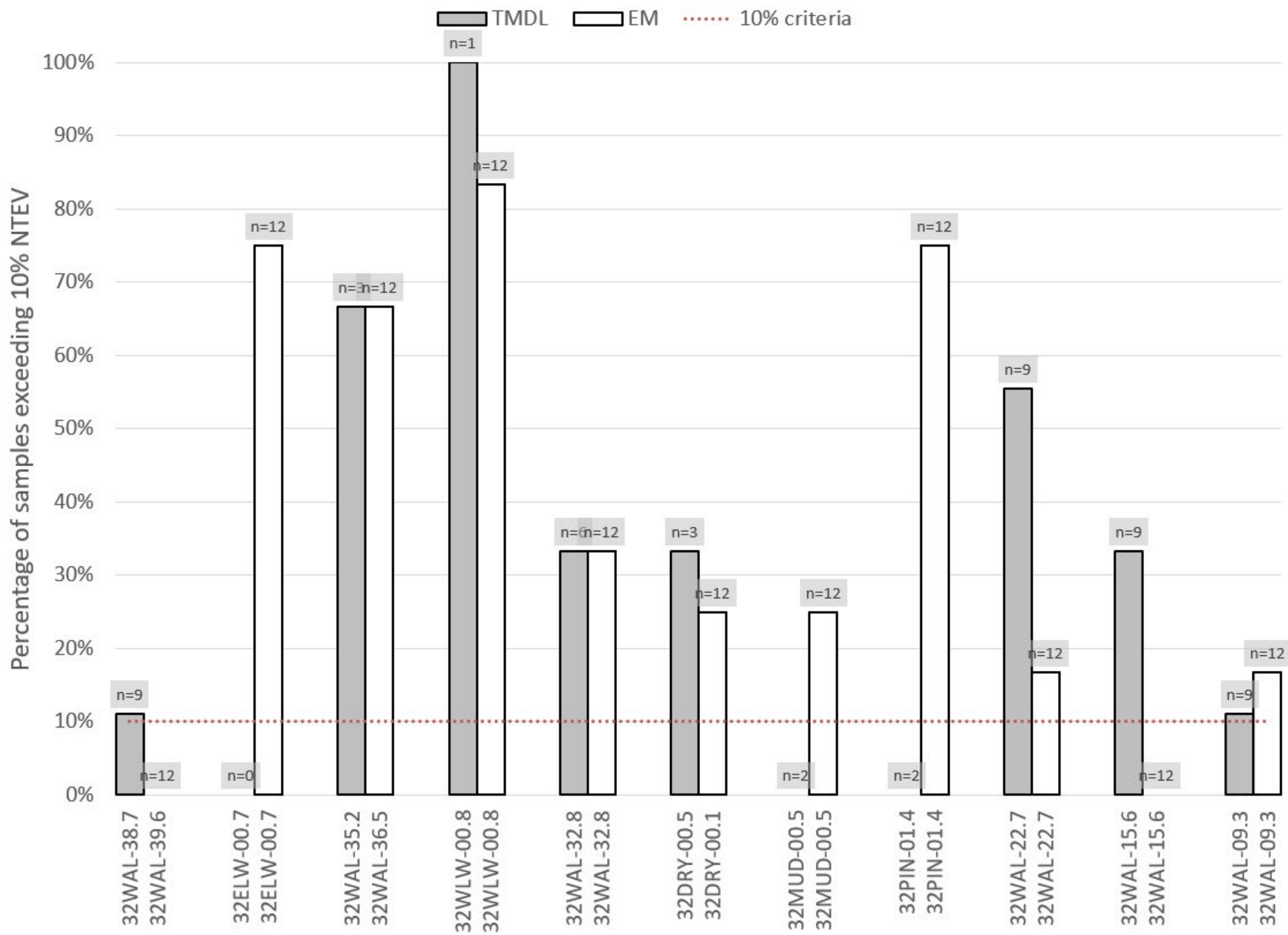


Figure 32: Low-flow season Walla Walla River mainstem and primary tributary percentage of FC samples above the 10% Not to Exceed Value (NTEV) during the 2002-2003 TMDL and the 2014-2015 Effectiveness Monitoring (EM).

High-flow season

Table 40: Walla Walla River mainstem and rural-area tributary sites change in high-flow season FC concentrations and targets

EM Site ID	EM Site Name	GM targets[1]	TMDL count	TMDL GM[2]	TMDL GM, 80% CI[3]	EM count	EM GM[2]	EM GM, 80% CI[3]	% Change in GM[2]	10% NTEV targets[1]	TMDL % of samples above 10% NTEV[2]	EM % of samples above 10% NTEV[2]
32WAL-39.6	Walla Walla R @ Peppers Bridge Rd	92	7	***26***	[20, 37]	5	***22***	[10, 38]	-14%	200	***0%***	***0%***
32ELW-00.7	E Br Little Walla Walla R @ Springdale Rd	100	0	NA	NA	5	132	[102, 161]	NA	200	NA	20%
32WAL-36.5	Walla Walla R @ Mojonnier (Beet) Rd	100	2	139	[97, 200]	5	***35***	[26, 41]	***-75%***	188	50%	***0%***
32WLW-00.8	W Br Little Walla Walla R @ Sweagle Rd	100	2	204	[160, 260]	5	***31***	[18, 67]	***-85%***	147	100%	20%
32WAL-32.8	Walla Walla R @ Detour Rd	84	7	***55***	[42, 70]	5	***31***	[15, 46]	-44%	200	***0%***	***0%***
32DRY-00.1	Dry Creek @ Dodd Ranch	93	2	190	[120, 300]	5	***31***	[24, 41]	***-84%***	200	50%	***0%***
32MUD-00.5	Mud Creek @ Barney (Borgen) Rd	150	2	367	[320, 420]	5	***26***	[18, 46]	***-93%***	180	100%	***0%***
32PIN-01.4	Pine Creek @ Sand Pit Rd	89	2	162	[110, 240]	5	123	[95, 154]	-24%	200	50%	40%
32WAL-22.7	Walla Walla R @ Touchet-Gardena Rd	100	7	***41***	[23, 58]	5	***40***	[23, 55]	-4%	200	***0%***	***0%***
32WAL-15.6	Walla Walla R @ Byerly Rd	100	6	***31***	[22, 43]	5	***54***	[43, 65]	+73% (increase)	200	***0%***	***0%***
32WAL-09.3	Walla Walla R @ Pierce's RV Park	100	7	***22***	[13, 32]	5	***48***	[34, 60]	+124% (increase)	200	***0%***	***0%***

1. Targets below the state standards were calculated using statistical rollback to meet reductions at both the geometric mean (GM) and the 10% NTEV.
2. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
3. 80% CI = Two-sided 80 percent confidence intervals (CI) on the GM in the format [lower CI, upper CI].

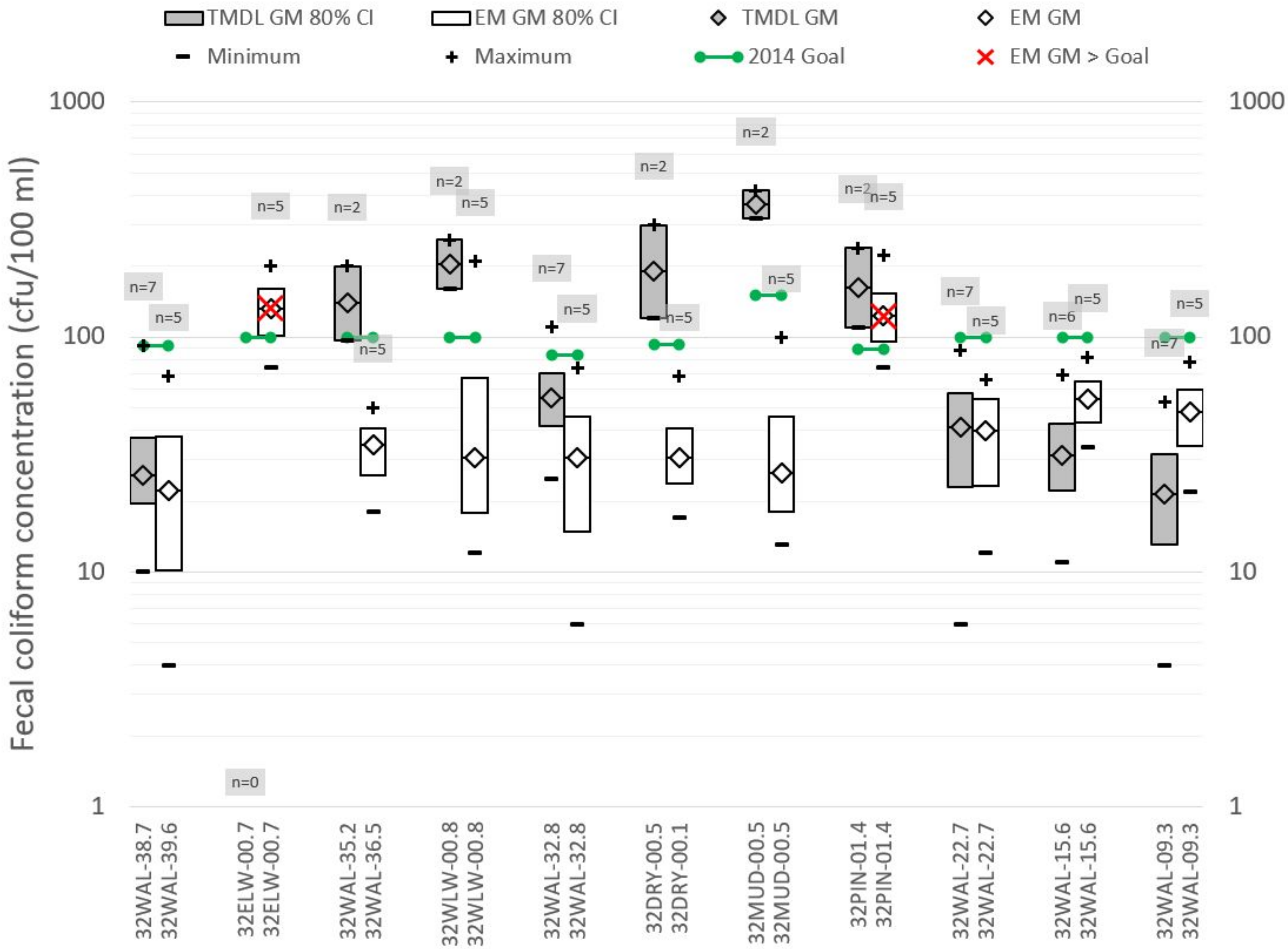


Figure 33: High-flow Walla Walla River mainstem and rural-area tributary sites GM and 10% NTEV targets versus FC concentrations in 2002-3 vs. 2014-15.

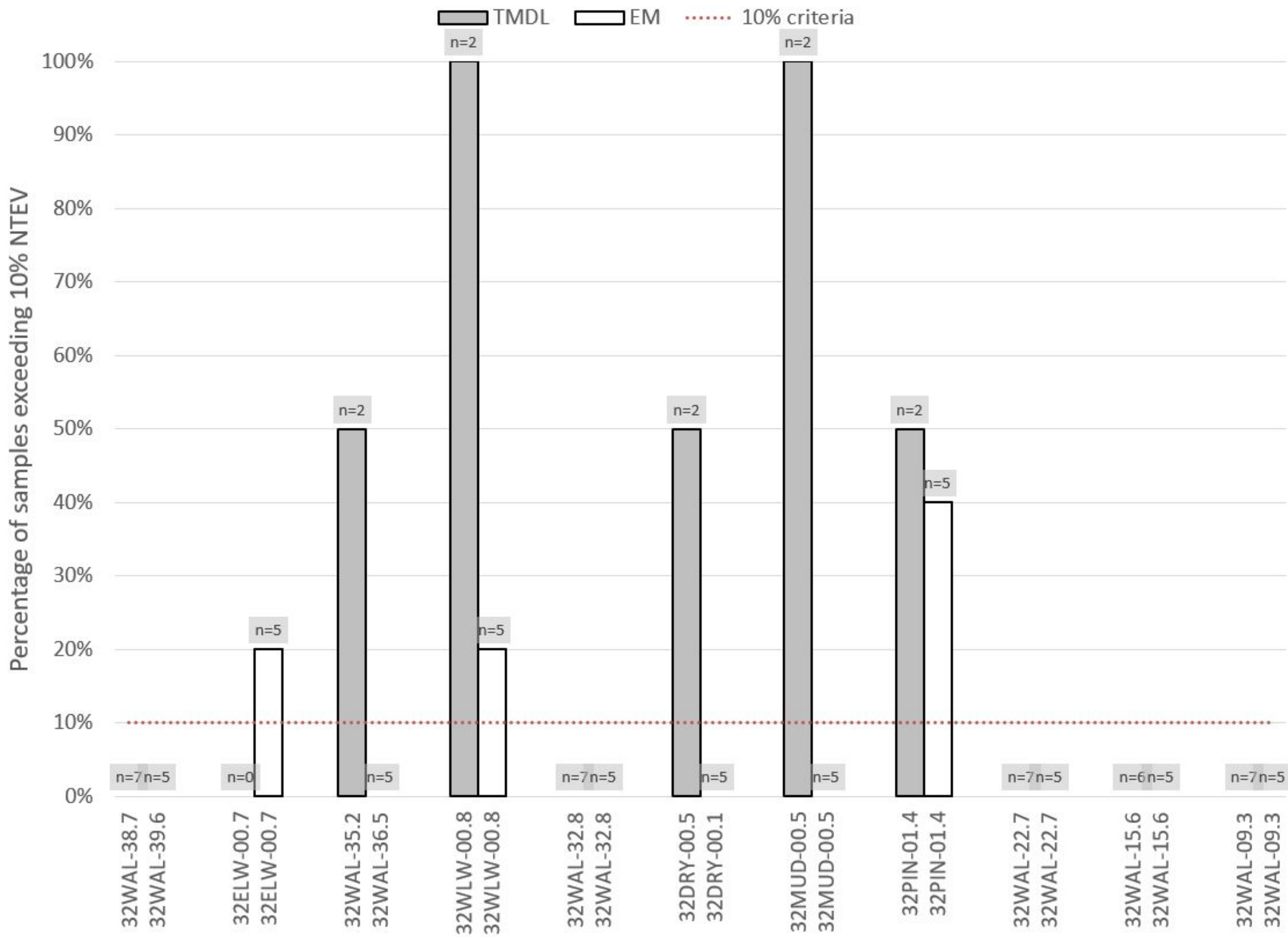


Figure 34: **High-flow Walla Walla River mainstem and primary tributary percentage of FC samples above the 10% Not to Exceed Value (NTEV) during the 2002-2003 TMDL and the 2014-2015 Effectiveness Monitoring (EM).**

Soluble Reactive Phosphorus (SRP) results for the Walla Walla River mainstem and rural-area tributary sites

Low-flow season

Table 41. Walla Walla River mainstem and rural-area tributary sites change in low-flow season SRP.

EM Site ID	EM Site Name	2014 target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32WAL-39.6	Walla Walla R @ Peppers Bridge Rd	0.040	6	***0.040***	[0.036, 0.043]	12	***0.038***	[0.037, 0.039]	-4%
32ELW-00.7	E Br Little Walla Walla R @ Springdale Rd	0.040	0	NA	NA	12	0.055	[0.053, 0.058]	NA
32WAL-36.5	Walla Walla R @ Mojonnier (Beet) Rd	0.040	2	0.063	[0.055, 0.071]	12	0.051	[0.048, 0.053]	-19%
32WLW-00.8	W Br Little Walla Walla R @ Sweagle Rd	0.040	0	NA	NA	12	0.121	[0.105, 0.151]	NA
32WAL-32.8	Walla Walla R @ Detour Rd	0.040	3	0.082	[0.072, 0.089]	12	0.077	[0.070, 0.088]	-5%
32DRY-00.1	Dry Creek @ Dodd Ranch	0.068	1	0.170	NA	12	0.124	[0.113, 0.133]	-27%
32MUD-00.5	Mud Creek @ Barney (Borgen) Rd	0.052	1	0.130	NA	12	0.137	[0.117, 0.160]	5% (increase)
32PIN-01.4	Pine Creek @ Sand Pit Rd	0.040	0	NA	NA	12	0.065	[0.055, 0.076]	NA
32WAL-22.7	Walla Walla R @ Touchet-Gardena Rd	0.046	7	0.114	[0.099, 0.132]	12	0.085	[0.076, 0.092]	-25%
32WAL-15.6	Walla Walla R @ Byerly Rd	0.040	6	0.081	[0.075, 0.091]	12	***0.036***	[0.029, 0.045]	-55%
32WAL-09.3	Walla Walla R @ Pierce's RV Park	0.040	7	0.068	[0.057, 0.08]	12	***0.035***	[0.025, 0.045]	-48%

1. Targets below the state standards were calculated using statistical rollback to meet reductions at both the geometric mean (GM) and the 10% NTEV.
2. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
3. 80% CI = Two-sided 80 percent confidence intervals (CI) on the GM in the format [lower CI, upper CI].

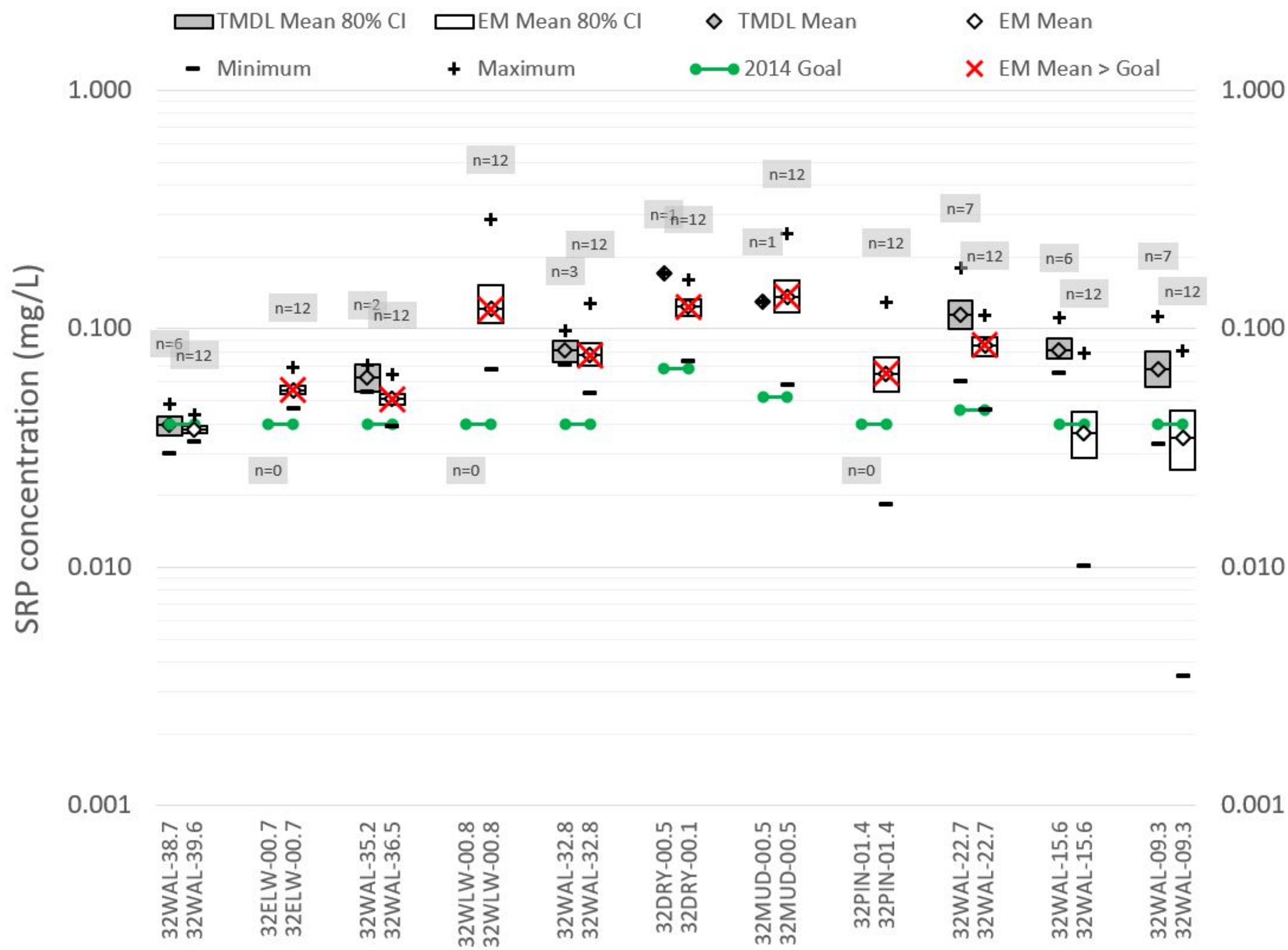


Figure 35: Low-flow TMDL and EM arithmetic mean and 80% confidence intervals on SRP concentration for Walla Walla River mainstem and rural-area tributary sites.

High-flow season

Table 42. Walla Walla River mainstem and rural-area tributary sites change in high-flow season SRP.

EM Site ID	EM Site Name	2014 target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[2]
32WAL-39.6	Walla Walla R @ Peppers Bridge Rd	0.040	6	***0.031***	[0.028, 0.034]	5	***0.035***	[0.030, 0.037]	10% (increase)
32ELW-00.7	E Br Little Walla Walla R @ Springdale Rd	0.040	0	NA	NA	5	0.056	[0.052, 0.059]	NA
32WAL-36.5	Walla Walla R @ Mojonnier (Beet) Rd	0.040	0	NA	NA	5	***0.038***	[0.035, 0.040]	NA
32WLW-00.8	W Br Little Walla Walla R @ Sweagle Rd	0.040	0	NA	NA	5	0.059	[0.054, 0.064]	NA
32WAL-32.8	Walla Walla R @ Detour Rd	0.040	2	0.069	[0.058, 0.080]	5	0.073	[0.068, 0.081]	6% (increase)
32DRY-00.1	Dry Creek @ Dodd Ranch	0.040	0	NA	NA	5	0.071	[0.062, 0.077]	NA
32MUD-00.5	Mud Creek @ Barney (Borgen) Rd	0.040	0	NA	NA	5	0.113	[0.103, 0.121]	NA
32PIN-01.4	Pine Creek @ Sand Pit Rd	0.040	0	NA	NA	5	0.070	[0.056, 0.080]	NA
32WAL-22.7	Walla Walla R @ Touchet-Gardena Rd	0.040	6	0.082	[0.069, 0.098]	5	0.073	[0.060, 0.082]	-11%
32WAL-15.6	Walla Walla R @ Byerly Rd	0.040	2	0.053	[0.043, 0.063]	5	0.061	[0.051, 0.066]	15% (increase)
32WAL-09.3	Walla Walla R @ Pierce's RV Park	0.040	6	0.066	[0.061, 0.074]	5	0.064	[0.051, 0.072]	-4%

1. Targets below the state standards were calculated using statistical rollback to meet reductions at both the geometric mean (GM) and the 10% NTEV.
2. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
3. 80% CI = Two-sided 80 percent confidence intervals (CI) on the GM in the format [lower CI, upper CI].

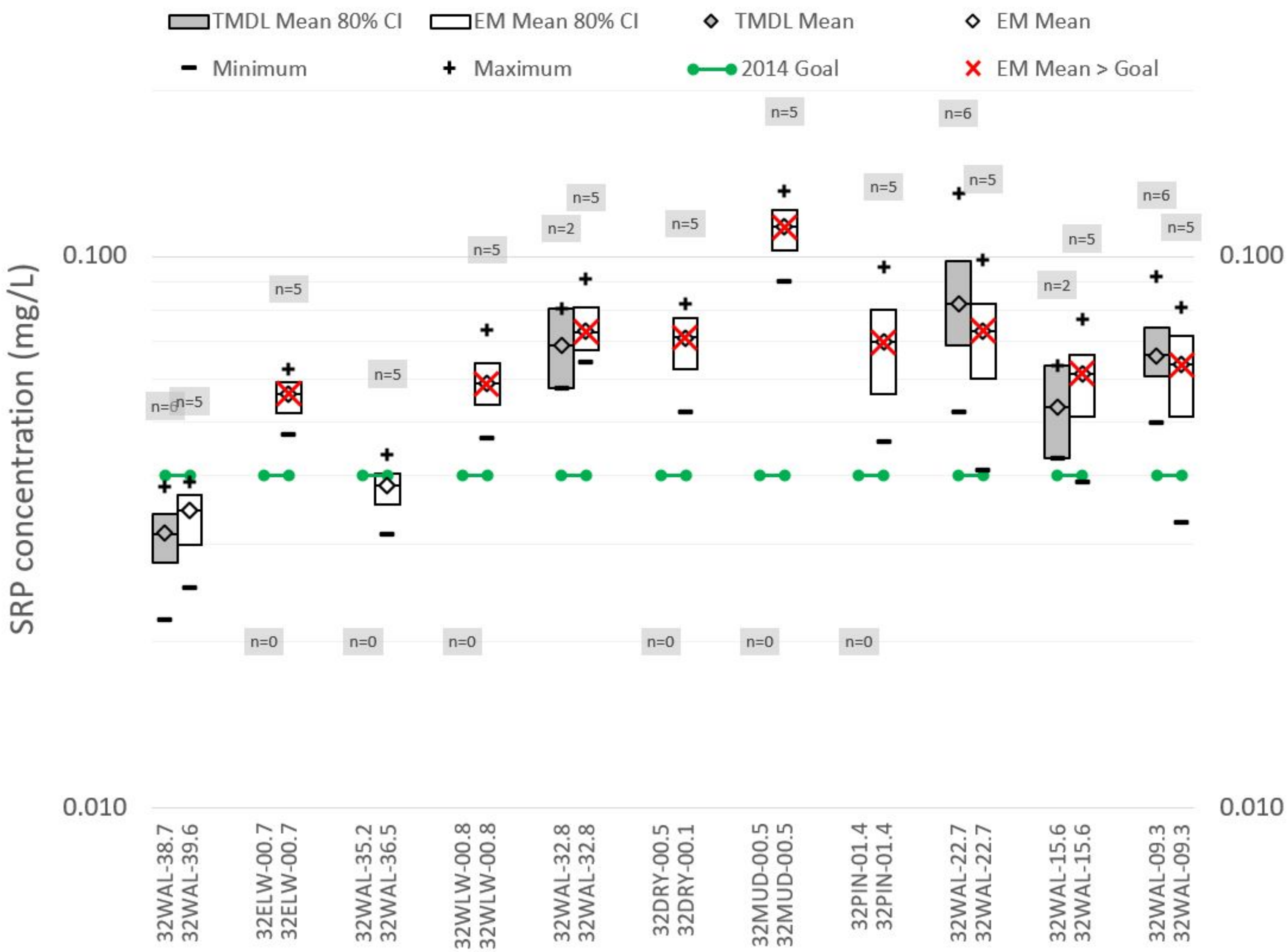


Figure 36: High-flow TMDL and EM arithmetic mean and 80% confidence intervals on SRP concentration for Walla Walla River mainstem and rural-area tributary sites.

Dissolved Inorganic Nitrogen (DIN) results for the Walla Walla River mainstem and rural-area tributary sites

Low-flow season

Table 43. Walla Walla River mainstem and rural-area tributary sites change in low-flow season DIN.

EM Site ID	EM Site Name	2014 target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32WAL-39.6	Walla Walla R @ Peppers Bridge Rd	0.200	8	0.413	[0.371, 0.478]	12	***0.173***	[0.146, 0.215]	-58%
32ELW-00.7	E Br Little Walla Walla R @ Springdale Rd	0.200	0	NA	NA	12	0.357	[0.314, 0.396]	NA
32WAL-36.5	Walla Walla R @ Mojonnier (Beet) Rd	0.200	2	0.303	[0.261, 0.345]	12	0.421	[0.357, 0.515]	39% (increase)
32WLW-00.8	W Br Little Walla Walla R @ Sweagle Rd	0.200	0	NA	NA	12	0.261	[0.215, 0.325]	NA
32WAL-32.8	Walla Walla R @ Detour Rd	0.220	4	0.549	[0.407, 0.658]	12	0.710	[0.592, 0.859]	29% (increase)
32DRY-00.1	Dry Creek @ Dodd Ranch	1.574	1	3.934	NA	12	5.238	[4.362, 6.282]	33% (increase)
32MUD-00.5	Mud Creek @ Barney (Borgen) Rd	0.200	1	***0.010***	NA	12	0.226	[0.170, 0.309]	2163% (increase)
32PIN-01.4	Pine Creek @ Sand Pit Rd	0.200	0	NA	NA	12	0.435	[0.332, 0.570]	NA
32WAL-22.7	Walla Walla R @ Touchet-Gardena Rd	0.200	8	0.240	[0.194, 0.285]	12	0.545	[0.426, 0.691]	127% (increase)
32WAL-15.6	Walla Walla R @ Byerly Rd	0.215	7	0.538	[0.447, 0.632]	12	0.452	[0.369, 0.536]	-16%
32WAL-09.3	Walla Walla R @ Pierce's RV Park	0.200	8	0.387	[0.325, 0.447]	12	0.268	[0.180, 0.378]	-31%

1. Targets below the state standards were calculated using statistical rollback to meet reductions at both the geometric mean (GM) and the 10% NTEV.
2. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
3. 80% CI = Two-sided 80 percent confidence intervals (CI) on the GM in the format [lower CI, upper CI].

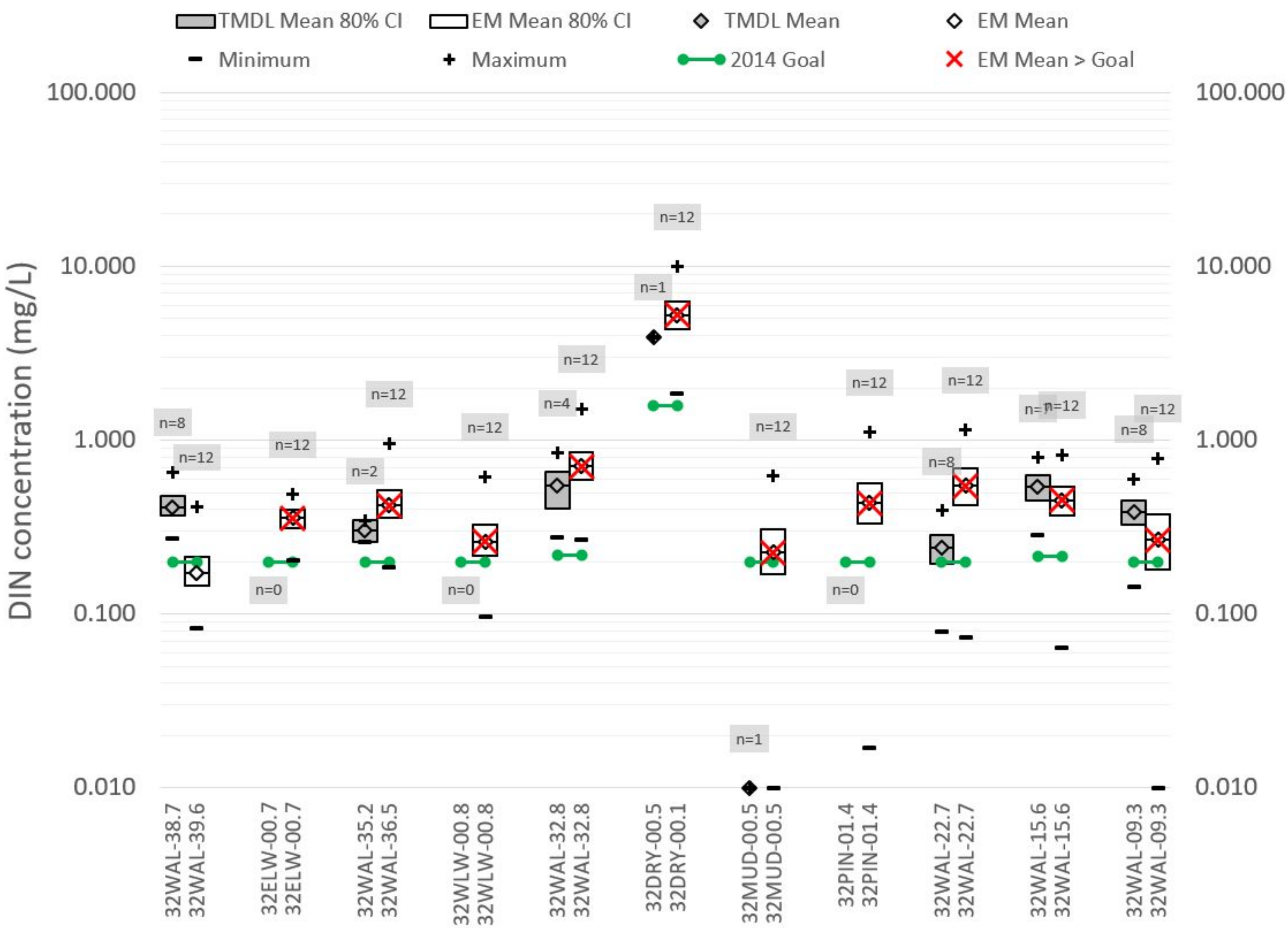


Figure 37: Low-flow TMDL and EM arithmetic mean and 80% confidence intervals on DIN concentration for the Walla Walla River mainstem and rural-area tributary sites.

High-flow season

Table 44. Walla Walla River mainstem and rural-area tributary sites change in high-flow season DIN.

EM Site ID	EM Site Name	2014 target	TMDL count	TMDL ArMn[1]	TMDL ArMn, 80% CI[2]	EM count	EM ArMn[1]	EM ArMn, 80% CI[2]	% Change in concentration observed[1]
32WAL-39.6	Walla Walla R @ Peppers Bridge Rd	0.200	6	***0.175***	[0.126, 0.252]	5	***0.177***	[0.125, 0.206]	1% (increase)
32ELW-00.7	E Br Little Walla Walla R @ Springdale Rd	0.200	0	NA	NA	5	0.540	[0.467, 0.585]	NA
32WAL-36.5	Walla Walla R @ Mojonnier (Beet) Rd	0.200	0	NA	NA	5	0.417	[0.365, 0.473]	NA
32WLW-00.8	W Br Little Walla Walla R @ Sweagle Rd	0.200	0	NA	NA	5	1.362	[1.130, 1.595]	NA
32WAL-32.8	Walla Walla R @ Detour Rd	0.207	2	0.517	[0.465, 0.568]	5	0.653	[0.559, 0.763]	27% (increase)
32DRY-00.1	Dry Creek @ Dodd Ranch	0.200	0	NA	NA	5	2.150	[1.840, 2.625]	NA
32MUD-00.5	Mud Creek @ Barney (Borgen) Rd	0.200	0	NA	NA	5	0.942	[0.664, 1.142]	NA
32PIN-01.4	Pine Creek @ Sand Pit Rd	0.200	0	NA	NA	5	1.048	[0.804, 1.209]	NA
32WAL-22.7	Walla Walla R @ Touchet-Gardena Rd	0.296	6	0.739	[0.627, 0.881]	5	0.787	[0.696, 0.932]	6% (increase)
32WAL-15.6	Walla Walla R @ Byerly Rd	0.200	2	0.415	[0.348, 0.481]	5	0.552	[0.448, 0.642]	33% (increase)
32WAL-09.3	Walla Walla R @ Pierce's RV Park	0.228	6	0.569	[0.496, 0.638]	5	0.580	[0.484, 0.678]	2% (increase)

1. Targets below the state standards were calculated using statistical rollback to meet reductions at both the geometric mean (GM) and the 10% NTEV.
2. Results in ***Bold Italic*** met 2014 arithmetic mean (ArMn) reduction targets.
3. 80% CI = Two-sided 80 percent confidence intervals (CI) on the GM in the format [lower CI, upper CI].

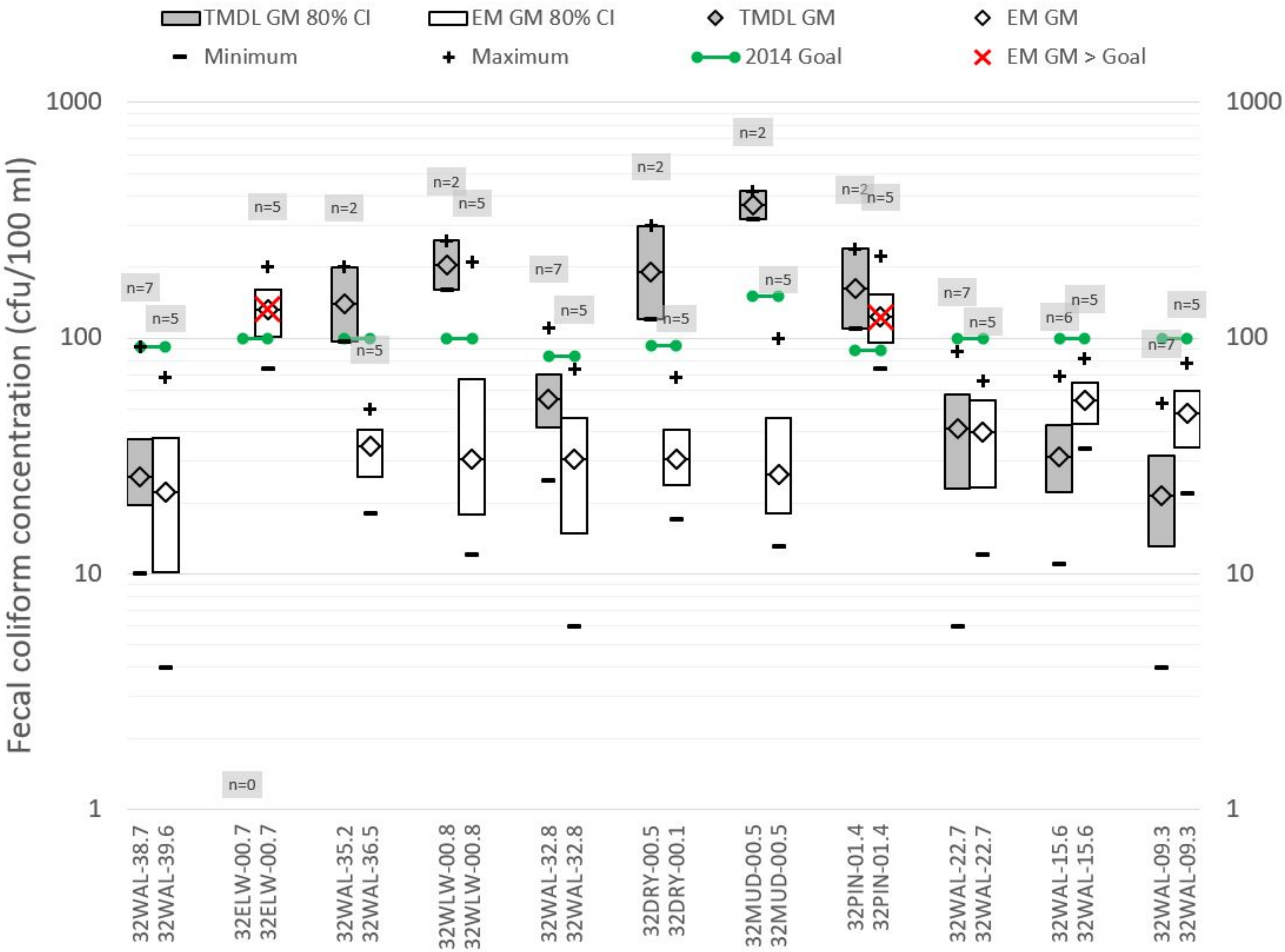


Figure 38: High-flow TMDL and Effectiveness Monitoring boxplots of DIN concentration for the Walla Walla River mainstem and rural-area tributary sites.

Status and trends for the mainstem Walla Walla River and tributary confluences

The Walla Walla River mainstem at the State Line (32WAL-39.6) met interim TMDL targets for all FC and nutrient parameters year-round during our study.

Walla Walla River FC and nutrient concentrations increased through the urban area to Detour Road at RM 32.8 (Tables 39 to 44 and Figures 31 to 38). The mainstem sites in this area (32WAL-36.5 and 32WAL-32.8) did not achieve low-flow season FC or nutrient concentration targets.

Rural tributaries downstream of RM 32.8, including Dry, Mud, and Pine Creeks and the East and West Branches of the Little Walla Walla River continued to show FC and nutrient concentrations over reduction targets. Dry Creek (32DRY-00.1) had the highest mean DIN concentrations during the study. The West Branch Little Walla Walla River (32WLW-00.8) had the second highest FC concentrations during the study.

Reach assessment summary tables

Tables 45 through 56 summarize the progress toward TMDL targets for each study parameter at each site. EM results that met TMDL targets met the least restrictive of either the 2014 interim percent reduction targets or the 2018 concentration targets. For sample means, we noted the direction of change between 2002 and 2015 if indicated by no overlap on the 80% mean confidence intervals (CIs) for TMDL and the EM studies. Gray-shaded cells in Table 45 to 54 indicate the site met the TMDL reduction target.

Table 45. Touchet River Basin low-flow season EM results versus TMDL targets[1]

EM Site ID	EM Site Name	FC GM	FC 10% NTEV	SRP	DIN	OrgP	OrgN
32SFT-08.8	SF Touchet R @ Rainwater	M	M	X	M	M	X
32SFT-00.3	SF Touchet R @ Magill Rd	M+	X	X*	M–	M–	X*
32NFT-00.0	NF Touchet R near mouth	M*	M	X*	X*	M–	X*
32TOU-52.2	Touchet R above Dayton WWTP	M*	M	X*	M+	M–	X+
32TOU-51.2	Touchet R @ Ward Rd	X+	X	X*	X–	M–	X–
32COP-00.5	Coppei Creek @ Hwy 124	X*	X	X*	X–	X*	X*
32TOU-40.5	Touchet R @ Bolles Rd	M+	X	X*	X–	M–	X–
32TOU-34.2	Touchet R @ Hwy 125	X*	X	X*	M*	M–	X*
32TOU-25.0	Touchet R @ Lamar	M*	M	X–	M+	M–	X–
32TOU-17.8	Touchet R @ Luckenbill Rd	M*	M	X–	M*	M–	X*
32TOU-07.0	Touchet R @ Touchet N Rd	M*	M	X–	M*	M–	X*
32TOU-02.0	Touchet R @ Cummins Rd	X*	X	X–	M–	M–	X*

1. M Site met the TMDL target.
X Site failed to meet the TMDL target.
+ An increase in the sample mean from 2002 to 2015 with no overlap between 80% CIs.
– A decrease in the sample mean from 2002 to 2015 with no overlap between 80% CIs.
* The 80% CIs of the 2002 and 2015 datasets overlap.

Table 46. Touchet River Basin high-flow season EM results versus TMDL targets[1]

EM Site ID	EM Site Name	FC GM	FC 10% NTEV	SRP	DIN	OrgP	OrgN
32SFT-08.8	SF Touchet R @ Rainwater	M	M	M	M	M	X
32SFT-00.3	SF Touchet R @ Magill Rd	M*	M	M–	X*	M–	X*
32NFT-00.0	NF Touchet R near mouth	M*	M	X+	X*	M–	M–
32TOU-52.2	Touchet R above Dayton WWTP	M+	M	X*	X*	M–	X*
32TOU-51.2	Touchet R @ Ward Rd	X+	X	X+	X+	M–	X–
32COP-00.5	Coppei Creek @ Hwy 124	X*	X	X*	M–	M–	X–
32TOU-40.5	Touchet R @ Bolles Rd	M+	X	X+	X*	M–	X*
32TOU-34.2	Touchet R @ Hwy 125	X*	X	X*	X–	M–	X–
32TOU-25.0	Touchet R @ Lamar	M*	X	X	X	M	X
32TOU-17.8	Touchet R @ Luckenbill Rd	M*	X	X+	X*	M–	X–
32TOU-07.0	Touchet R @ Touchet N Rd	M*	X	X*	X*	M–	X*
32TOU-02.0	Touchet R @ Cummins Rd	M–	M	X+	X*	M–	X–

Table 47. Mill Creek low-flow season EM results versus TMDL targets[1]

EM Site ID	EM Site Name	FC GM	FC 10% NTEV	SRP	DIN
32MIL-24.6	Mill Creek @ Tiger Cr Rd	M*	M	M*	X+
32MIL-11.5	Mill Cr @ Yellowhawk/Garrison Diversion	M+	M	M–	M+
32MIL-08.9	Mill Creek @ Wilbur St	M–	X	M–	M+
32MIL-04.8	Mill Creek @ Gose Street	M*	M	M–	M–
32MIL-00.5	Mill Creek @ Sweagle Rd	M–	M	X–	X*

Table 48. Mill Creek high-flow season EM results versus TMDL targets[1]

EM Site ID	EM Site Name	FC GM	FC 10% NTEV	SRP	DIN
32MIL-24.6	Mill Creek @ Tiger Cr Rd	M*	M	M+	X+
32MIL-11.5	Mill Cr @ Yellowhawk/Garrison Diversion	M+	M	M*	X*
32MIL-08.9	Mill Creek @ Wilbur St	X*	X	M*	X+
32MIL-04.8	Mill Creek @ Gose Street	M*	X	X–	X*
32MIL-00.5	Mill Creek @ Sweagle Rd	M*	M	X–	X*

1. M Site met the TMDL target.
X Site failed to meet the TMDL target.
+ An increase in the sample mean from 2002 to 2015 with no overlap between 80% CIs.
– A decrease in the sample mean from 2002 to 2015 with no overlap between 80% CIs.
* The 80% CIs of the 2002 and 2015 datasets overlap.

Table 49. Walla Walla urban-area tributaries low-flow season EM results versus TMDL targets[1]

EM Site ID	EM Site Name	FC GM	FC 10% NTEV	SRP	DIN
32YEL-03.5	Yellowhawk Creek @ Plaza Rd	X*	X	M	X
32RUS-00.1	Russell Creek @ Plaza Rd	X*	X	X+	X+
32COT-01.0	Cottonwood Creek @ Plaza Rd	X*	X	X	X
32YEL-00.2	Yellowhawk Creek @ Old Milton Rd	X*	X	X*	X*
32GAR-00.5	Garrison Creek @ Mission Rd	M–	X	M–	X+

Table 50. Walla Walla urban-area tributaries high-flow season EM results versus TMDL targets[1]

EM Site ID	EM Site Name	FC GM	FC 10% NTEV	SRP	DIN
32YEL-03.5	Yellowhawk Creek @ Plaza Rd	M	M	M	X
32RUS-00.1	Russell Creek @ Plaza Rd	X*	X	X	X
32COT-01.0	Cottonwood Creek @ Plaza Rd	X*	M	M	X
32YEL-00.2	Yellowhawk Creek @ Old Milton Rd	X*	X	M*	X*
32GAR-00.5	Garrison Creek @ Mission Rd	X*	X	X*	X+

Table 51. Walla Walla rural-area tributaries low-flow season EM results versus TMDL targets[1]

EM Site ID	EM Site Name	FC GM	FC 10% NTEV	SRP	DIN
32ELW-00.7	E Little Walla Walla R @ Springdale Rd	X	X	X	X
32WLW-00.8	W Little Walla Walla R @ Sweagle Rd	X+	X	X	X
32DRY-00.1	Dry Creek @ Dodd Ranch	M*	X	X–	X+
32MUD-00.5	Mud Creek @ Barney (Borgen) Rd	X*	X	X*	X+
32PIN-01.4	Pine Creek @ Sand Pit Rd	X+	X	X	X

1. M Site met the TMDL target.
X Site failed to meet the TMDL target.
+ An increase in the sample mean from 2002 to 2015 with no overlap between 80% CIs.
– A decrease in the sample mean from 2002 to 2015 with no overlap between 80% CIs.
* The 80% CIs of the 2002 and 2015 datasets overlap.

Table 52. Walla Walla rural-area tributaries high-flow season EM results versus TMDL targets[1]

EM Site ID	EM Site Name	FC GM	FC 10% NTEV	SRP	DIN
32ELW-00.7	E Little Walla Walla R @ Springdale Rd	X	X	X	X
32WLW-00.8	W Little Walla Walla R @ Sweagle Rd	M–	X	X	X
32DRY-00.1	Dry Creek @ Dodd Ranch	M–	M	X	X
32MUD-00.5	Mud Creek @ Barney (Borgen) Rd	M–	M	X	X
32PIN-01.4	Pine Creek @ Sand Pit Rd	X*	X	X	X

Table 53. Walla Walla River mainstem low-flow season EM results versus TMDL targets[1]

EM Site ID	EM Site Name	FC GM	FC 10% NTEV	SRP	DIN
32WAL-39.6	Walla Walla R @ Peppers Bridge Rd	M*	M	M*	M–
32WAL-36.5	Walla Walla R @ Mojonnier (Beet) Rd	X*	X	X–	X+
32WAL-32.8	Walla Walla R @ Detour Rd	X*	X	X*	X*
32WAL-22.7	Walla Walla R @ Touchet-Gardena Rd	M*	X	X–	X+
32WAL-15.6	Walla Walla R @ Byerly Rd	M–	M	M–	X*
32WAL-09.3	Walla Walla R @ Pierce's RV Park	M*	X	M–	X*

Table 54. Walla Walla River mainstem high-flow season EM results versus TMDL targets[1]

EM Site ID	EM Site Name	FC GM	FC 10% NTEV	SRP	DIN
32WAL-39.6	Walla Walla R @ Peppers Bridge Rd	M*	X	M*	M*
32WAL-36.5	Walla Walla R @ Mojonnier (Beet) Rd	M–	M	M	X
32WAL-32.8	Walla Walla R @ Detour Rd	M*	X	X*	X*
32WAL-22.7	Walla Walla R @ Touchet-Gardena Rd	M*	M	X*	X*
32WAL-15.6	Walla Walla R @ Byerly Rd	M*	M	X*	X*
32WAL-09.3	Walla Walla R @ Pierce's RV Park	M+	M	X*	X*

1. M Site met the TMDL target.
X Site failed to meet the TMDL target.
\+ An increase in the sample mean from 2002 to 2015 with no overlap between 80% CIs.
– A decrease in the sample mean from 2002 to 2015 with no overlap between 80% CIs.
* The 80% CIs of the 2002 and 2015 datasets overlap.

Tables 55 and 56 show the percentages of sites per parameter meeting TMDL targets and the percentage showing an increase, decrease, or no change outside confidence intervals in 2015 versus 2002.

Overall, most sites showed little change in 2015 relative to 2002. Near equal percentages of sites increased or decreased FC, and two-thirds of sites did not change outside confidence intervals. In the low-flow critical period, SRP decreased across more sites than increased, and DIN increased across more sites than decreased.

Table 55. Low-flow season summary of site changes per parameter.

Code[1]	Status in 2015 versus 2002	FC GM	FC 10% NTEV	SRP	DIN	OrgP[2]	OrgN[2]
M	Site met the TMDL target.	19 (58%)	12 (36%)	9 (27%)	12 (36%)	11 (92%)	0 (0%)
X	Site did not meet the TMDL target.	14 (42%)	21 (64%)	24 (73%)	21 (64%)	1 (8%)	12 (100%)
+	The EM 80% confidence intervals (CIs) are above the TMDL 80% CIs.	6 (19%)	NA	1 (4%)	11 (41%)	0 (0%)	1 (9%)
*	The TMDL and EM 80% CIs overlap.	21 (68%)	NA	12 (44%)	9 (33%)	1 (9%)	7 (64%)
–	The EM 80% CIs are below the TMDL 80% CIs.	4 (13%)	NA	14 (52%)	7 (26%)	10 (91%)	3 (27%)

Table 56. High-flow season summary of site changes per parameter.

Code[1]	Status in 2015 versus 2002	FC GM	FC 10% NTEV	SRP	DIN	OrgP[2]	OrgN[2]
M	Site met the TMDL target.	23 (70%)	16 (48%)	10 (30%)	3 (9%)	12 (100%)	1 (8%)
X	Site did not meet the TMDL target.	10 (30%)	17 (52%)	23 (70%)	30 (91%)	0 (0%)	11 (92%)
+	The EM 80% confidence intervals (CIs) are above the TMDL 80% CIs.	5 (17%)	NA	6 (27%)	4 (18%)	0 (0%)	0 (0%)
*	The TMDL and EM 80% CIs overlap	20 (67%)	NA	13 (59%)	16 (73%)	0 (0%)	4 (40%)
–	The EM 80% CIs are below the TMDL 80% CIs.	5 (17%)	NA	3 (14%)	2 (9%)	10 (100%)	6 (60%)

1. Parameter change codes from the EM site summary Tables 45 to 54 above.
2. Organic phosphorus and organic nitrogen were collected only for Touchet River Basin sites.

Trend results for the Walla Walla River at Byerly Road (32WAL-15.6)

The Walla Walla River at Byerly Road (32WAL-15.6) is monitored monthly by Ecology to represent aggregate water quality at the Walla Walla River Basin pour point. It is the only station in the basin with long-term monitoring records for both monthly nutrient and bacteria samples, and continuous flow monitoring. This combined data set provided the opportunity to compare our discrete TMDL and EM study results to a trend analysis that included monthly data collected over the full span of the two studies.

We conducted a Seasonal Kendall Trend test on monthly discrete FC and nutrient data from Ecology's Ambient Water Quality Monitoring station (32A070), at the same location as our Byerly Road study station, 32WAL-15.6. We also used daily average flow data from USGS station ID 14018500 at RM 18.2. There are no major flow inputs or withdrawals between the USGS station and Byerly Road. We analyzed both the June 2002 through June 2015 TMDL to EM study period, and the full period of available data (1989 to 2019).

Both the Ecology and USGS data sets had few missing data for the full trend period. The Seasonal Kendall test is robust for small amounts of missing data as occurred in the ambient data set (Hirsch and Slack 1984). When the flow data set lacked continuous records of more than a day we used the USGS's calculated daily average flow estimates.

Relative to the discrete data collected for this study, the trend tests assess a much larger data set, including monthly seasonal load data for the full trend period, and accounting for flow differences. The trend analysis is thus much more capable of accounting for drought year influences, as occurred in spring 2015, than our EM study discrete data set.

The 1989 to 2019 analysis showed more changing trends than the 2002 to 2015 comparison (Tables 57 and 58). However, the lower significance of changes in that period may relate to fewer samples, which would give a larger variance and potentially hide seasonal trends (Hirsch and Slack 1984). Trend analysis guidance suggests a minimum 10-year period for reliable trend results, and the 12-year period between the TMDL and EM studies may not be sufficient to reveal all trends.

Flows in both the low-flow and high-flow seasons did not show a significant change since the TMDL or since 1989. A slight positive trend for both the 1989 to 2019 and 2002 to 2015 data sets may indicate a gradual increase in flows over time (Tables 57 and 58).

Trends showed stronger evidence of DIN reduction in high-flow than during the low-flow season (Tables 57 and 58). This may occur because during the low-flow season, DIN, the limiting nutrient, is quickly absorbed through algal uptake. With reduced algal uptake and shorter travel times, high-flow season samples are more likely than low-flow samples to detect nutrient load reductions from upstream sources. Therefore, high-flow season DIN reductions at this basin pour-point may also indicate further upstream reductions in nitrogen sources.

Table 57. Low-flow Seasonal Kendall trend test results for the Walla Walla River at river mile (RM) 15.6 (32WAL-15.6)

Parameter	Period	Tau	Theil-Sen's slope	Estimated total % change	p-value [1,2]
Flow	1989-10 to 2019-07	0.109	0.510	+38%	0.245
Flow	2002-06 to 2015-06	0.082	0.7	+22%	0.576
FC	1989-10 to 2019-07	-0.202	-1.5	-63%	***1.1E-04***
FC	2002-06 to 2015-06	-0.025	-0.25	-5%	0.305
SRP	1989-10 to 2019-07	-0.204	-8.12E-04	-47%	***0.005***
SRP	2002-06 to 2015-06	-0.228	-0.002	-48%	**0.061**
DIN	1989-10 to 2019-07	-0.049	-0.003	-14%	0.601
DIN	2002-06 to 2015-06	-0.025	-1.86E-03	-4%	0.990

Table 58. High-flow Seasonal Kendall trend test results for the Walla Walla River at river mile (RM) 15.6 (32WAL-15.6)

Parameter	Period	Tau	Theil-Sen's slope	Estimated total % change	p-value [1,2]
Flow	1989-10 to 2019-07	0.122	5.917	+24%	**0.074**
Flow	2002-06 to 2015-06	0.037	4.45	+7%	0.744
FC	1989-10 to 2019-07	-0.180	-1.071	-65%	***5.1E-05***
FC	2002-06 to 2015-06	-0.052	-0.739	-22%	0.476
SRP	1989-10 to 2019-07	-0.141	-3.71E-04	-17%	***0.039***
SRP	2002-06 to 2015-06	-0.057	-3.27E-04	-7%	0.566
DIN	1989-10 to 2019-07	-0.146	-5.86E-03	-24%	**0.059**
DIN	2002-06 to 2015-06	-0.213	-0.016	-32%	**0.084**

1. P-values in ***Bold Italic*** are significant at $\alpha \leq 0.05$. P-values in **Bold** are significant at $\alpha \leq 0.10$.
2. We adjusted all p-values for the monthly seasonal block. We also adjusted FC and nutrient p-values for the flow covariate.

The low-flow season trends generally agreed with our discrete study results. Low-flow season trends (Table 57) and our EM results (Tables 39, 41, and 43) both show nutrient and FC concentrations decreased. Both our trend analysis and our low-flow season EM confidence interval (CI) comparison indicated a low-flow season reduction in FC and SRP. The slight low-flow DIN reduction trend was not meaningfully different from no change, which corresponds to the slight reduction with overlapping CIs for discrete FC and DIN.

Unlike the low-flow season, our high-flow season EM study results (Tables 40, 42, and 44) disagreed with the reducing trends, showing increases to FC, DIN, and SRP (Table 58).

Our trend results suggest our discrete comparison may miss or exaggerate some marginal parameter changes, especially during the high-flow period where lower sample sizes reduced our result certainty, and drought conditions caused an early reduction in flows.

Generally, we should expect some minor errors in change estimates due to the lack of long-term seasonal data for most of our sites. Our small sample size discrete high-flow season results carry greater potential for error. However, the similarity at this site between the Seasonal Kendall trend and our discrete comparison of TMDL and EM CIs suggest we were still able to detect most changes with our available comparison data, especially during the low-flow season.

Summary of water quality status during the EM study versus the TMDL study

During our 2014-2015 EM study, water quality appeared relatively unchanged since the 2002-2003 TMDL study. We observed improvements to bacteria, nutrients, dissolved oxygen (DO), and pH at some sites. However, at many sites we observed conditions equivalent to or worse than 2002-2003.

Most sites within and downstream of urban areas, and some rural lower basin tributaries, showed elevated fecal coliform bacteria (FC) and nutrients relative to our headwater and State Line reference sites. The year-round increase in pollutants within these reaches are likely related to both point source loads and nonpoint stormwater, irrigation, or groundwater sources. Mill Creek, the Touchet River, and the Walla Walla mainstem below the Touchet River confluence met FC and nutrient targets more frequently than other sites. Distance from upstream sources in urban areas appeared to relate to reduced concentrations, suggesting instream metabolism.

As noted during the TMDL, in the absence of additional sources, low-flow season DIN and SRP concentrations would be expected to decrease downstream due to uptake by periphyton and other instream primary producers (Joy et al. 2007). Throughout the Walla Walla River Basin, algal uptake probably masked low-flow season nutrient sources. Lack of shade, high water temperatures, and low flows contributed to low-flow season algal uptake of nutrients, and probably contributed to the large diel swings observed for instream pH and DO. Low-flow season algal growth in the Walla Walla River Basin is typically nitrogen limited (Joy et al. 2007). Reducing instream eutrophic conditions that negatively affect pH and DO may require further nitrogen source reductions.

During the cooler and wetter high-flow season, when reduced sun exposure and lower temperatures correspondingly reduced algal uptake rates, we observed nutrient concentrations increase from upstream to downstream. This upstream to downstream increase most likely came from both point sources, including municipal WWTPs, and nonpoint nutrient sources such as runoff and sediment erosion from urban and rural residential, agricultural, and industrial areas.

Geologic sources of both phosphorus and nitrogen may also contribute to instream nutrient loads throughout the year. This study indicates that most sample sites have not yet achieved the potential nutrient load reductions calculated for the TMDL, which include these natural background nutrient sources. Further reductions are likely possible for much of the basin. However, due to natural nutrient sources it is likely pH and DO will still have wide diel ranges in parts of the Touchet and Walla Walla river basins and not be in compliance with applicable criteria. (Joy et al. 2007)

The large percentage of sites which increased in low-flow season DIN concentrations may indicate both drought year effects and the nitrogen sources. Trend tests at Walla Walla RM 15.6 showed that despite the apparent discrete nutrient increase in 2015 versus 2002, basin-wide nutrient concentrations actually decreased when accounting for inter-annual seasonal variation in nutrient and flow levels. This suggests that other sites may have decreased in nutrient loads more greatly than indicated by the discrete 2002 and 2015 concentrations. However, the increase in nutrients observed from upstream to downstream through most of the basin probably indicates continued inputs from external nutrient sources.

Due to a lack of information on best management practices (BMPs) implemented in the Walla Walla River Basin between 2002 and 2015, we do not assess BMP effectiveness in this report. During this project, we noted several BMP implementations including floodplain and flow restoration, riparian plantings, irrigation system upgrades, no-till farming, wastewater processing improvements, illicit discharge tracking and reporting, and public information campaigns. BMPs were implemented by several Walla Walla River Basin stakeholders including cities, counties, conservation districts, community groups, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), USACE, WWBWC, Ecology, and others. However, we do not have full documentation of BMP quantity, locations, types, costs, responsible entities, or completion status. Ecology will continue to work with stakeholders to collect and share implementation data to understand BMP effectiveness and adaptively manage water quality within the Walla Walla River Basin.

Conclusions

- Despite some reductions, high fecal coliform bacteria (FC) and nutrient concentrations from both point and nonpoint sources continued to occur in most of the Walla Walla River Basin. Sites near to, and downstream of, cities and towns and some lower basin rural tributaries had elevated FC and nutrient concentrations relative to headwater and State Line water quality. Specific sites had concentrations near effluent levels.
- Seasonal Kendall trend tests on monthly ambient monitoring data from the Walla Walla River at river mile (RM) 15.6 showed declining FC and nutrient loads over the TMDL to EM study period and since 1989. The high-flow season trend revealed probable FC and nutrient load reductions upstream, which may relate to the effectiveness of nutrient and bacteria BMPs. Trends agreed with this study's discrete sampling results in the low-flow season. Small high-flow season sample sizes in this study did not provide enough information to consistently observe the same changes as the trend analyses.
- Wastewater treatment plants (WWTPs) in the Walla Walla River Basin may still be impacting downstream water quality. In particular, Touchet River FC loads in the reach including the Dayton WWTP were much higher than expected, given the reported loads.
- From 2002 through 2015, many best management practices (BMPs) were implemented to reduce point and nonpoint nutrient and bacteria sources. However, specific information on the groups conducting this work, and the extent of these efforts, was not available.

Recommendations

- Stakeholders should continue BMP implementation oriented towards reducing instream nutrients and bacteria contributions.
- Stakeholders should work with Ecology to conduct source tracking of elevated bacteria and nutrients upstream of sites with elevated bacteria and nutrient levels.
- Walla Walla River Basin WWTPs should continue efforts to meet the wasteload allocations set in the TMDL.
- The City of Dayton should work with Ecology to address excess bacteria loads to the Touchet River.
- Stakeholders should collect BMP records from organizations that engaged in BMP tasks for the TMDL and organize it for comparison to water quality monitoring results.

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Glossary, acronyms, and abbreviations

Glossary

Anthropogenic: Human-caused.

Avulse (Avulsion): A sudden cutting-off of land by flood, currents, or change in course of a body of water.

Char: Fish (genus *Salvelinus*) that are distinguished from trout and salmon by the absence of teeth in the roof of the mouth, presence of light colored spots on a dark background, absence of spots on the dorsal fin, small scales, and differences in the structure of their skeleton. (Trout and salmon have dark spots on a lighter background.)

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Distributary: A distributary, or a distributary channel, is a stream that branches off and flows away from a main stream channel.

Effluent: An outflowing of water from a natural body of water or from a man-made structure. For example, the treated outflow from a wastewater treatment plant.

Eutrophication: (or hypertrophication), is when a body of water becomes overly enriched with minerals and nutrients which induce excessive growth of algae.

Geometric mean (GM): A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10- to 10,000-fold over a given period. The calculation is performed by either:
(1) taking the n^{th} root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites where more than 5 acres of land have been cleared.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare; (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses; or (3) livestock, wild animals, birds, fish, or other aquatic life.

Riparian: Relating to the banks along a natural course of water.

Salmonid: Fish that belong to the family *Salmonidae*. Species of salmon, trout, or char.

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

Total Maximum Daily Load (TMDL): Water cleanup plan. A distribution of a substance in a waterbody designed to protect it from not meeting water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector, such as a stream, river, or lake at a lower elevation.

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

90th percentile: A statistical number obtained from a distribution of a data set, above which 10% of the data exists and below which 90% of the data exists.

Acronyms and Abbreviations

ArMn	arithmetic mean
BMP	best management practice
DIN	dissolved inorganic nitrogen
DMR	Discharge Monitoring Report
DO	dissolved oxygen
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EM	effectiveness monitoring
FC	fecal coliform bacteria
GIS	Geographic Information System software
GM	geometric mean
MEL	Manchester Environmental Laboratory
NH_3	ammonia
NO_2NO_3	nitrites plus nitrates
NPDES	National Pollutant Discharge Elimination System (see glossary)
NTEV	Not to Exceed Value
OrgN	organic nitrogen
OrgP	organic phosphorus
RM	river mile
RSD	relative standard deviation
SOP	standard operating procedures
SRP	soluble reactive phosphorus
TMDL	Total Maximum Daily Load (see glossary)
TN	total nitrogen
TP	total phosphorus
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WQIP	Water Quality Implementation Plan
WRIA	Water Resource Inventory Area
WWBWC	Walla Walla Basin Watershed Council
WWRWTS	Walla Walla Regional Water Testing Services
WWTP	wastewater treatment plant

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
ft	feet
g	gram, a unit of mass
m	meter
mg	milligram
mgd	million gallons per day
mg/L	milligrams per liter (parts per million)
mL	milliliters
s.u.	standard units
µS/cm	microsiemens per centimeter, a unit of conductivity