Mid-Yakima River Basin Fecal Coliform Bacteria Total Maximum Daily Load

Water Quality Study Findings

September 2012
Publication No. 12-03-047

DEPARTMENT OF
ECOLOGY
State of Washington

Publication and Contact Information

This Water Quality Improvement report is published in two parts:

1. Water Quality Improvement Report and Implementation Plan.
   The Department of Ecology's Water Quality Program will publish this at a later date.
2. Study Findings (this report):
   https://fortress.wa.gov/ecy/publications/SummaryPages/1203047.html

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Cover photo: Wide Hollow Creek in Yakima, Washington.

Project Codes and 1996 303(d) Water-Body ID Numbers

Data for this project are available at Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search User Study ID, YUTTMDL.

Activity Tracker Code (Environmental Assessment Program) is 04-001.

TMDL Study Code (Water Quality Program) is YakC37FC.

Water-body Numbers: WA-38-1015, WA-38-1016, WA-38-1017, WA-37-1048, WA-37-1047.

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Water Quality Study Findings

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Abstract

Three Yakima area creeks (Cowiche Creek, Wide Hollow Creek, and Moxee Drain) are listed on the federal Clean Water Act 303(d) list as impaired for fecal coliform bacteria. This total maximum daily load (TMDL) report includes a study of the bacteria impairment, indicates how much the bacteria needs to be reduced to meet Washington State water quality standards, and describes activities to achieve those reductions.

The Washington State Department of Ecology collected bacteria and streamflow data from 76 sites throughout the study area during 2004-06 and 2010. These data were analyzed to determine the level of bacteria reduction needed to meet the water quality standards.

Cowiche Creek, Wide Hollow Creek, Moxee Drain, and their tributaries are required to have a geometric mean of less than 100 colony forming units/100 milliliters (100 cfu/100 mL), and not more than 10% of the samples used to calculate the geometric mean can exceed 200 cfu/100 mL.

Compliance with this TMDL will be based on meeting the water quality standards.

Acknowledgements

The authors of this report thank the following people for their contribution to this report:

- Rod Ensign and Lou Ann Leitch, Selah-Moxee Irrigation District
- John Dickman, Yakima-Tieton Irrigation District
- Matt Durkee, Yakima County Public Services
- Shelley Willson, City of Yakima
- Robert Smoot, Yakima Valley Canal Company
- Washington State Department of Ecology staff, Environmental Assessment Program
    - Nuri Mathieu, Western Operations Section
    - Jenna Durkee, Joe Joy, and Andy Albrecht, Eastern Operations Section
    - Dean Momohara, Nancy Rosenbower, Nancy Jensen, and Leon Weiks, Manchester Environmental Laboratory
    - Joan LeTourneau and Diana Olegre for formatting and editing the final report.

Why is Ecology Conducting a TMDL Study in This Watershed?

Overview of the TMDL process

The Clean Water Act (CWA) establishes a process to identify and clean up polluted waters. Under the CWA, each state is required to have its own water quality standards designed to protect, restore, and preserve water quality.

Every two years, states are required to prepare a list of water bodies – lakes, rivers, streams, or marine waters – that do not meet water quality standards. This list is called the 303(d) list. The CWA states that every water body on the 303(d) list must have a total maximum daily load (TMDL) or other appropriate water quality improvement plan developed.

What is a TMDL

A TMDL identifies how much pollution needs to be reduced or eliminated to achieve clean water. The goal of a TMDL is to ensure that impaired water will attain water quality standards. By definition, a TMDL is the sum of the allocations, which must not exceed the loading capacity. The sum of the wasteload and load allocations, the margin of safety, and any reserve capacity must be equal to or less than the loading capacity.

TMDL = Loading Capacity = sum of all wasteload allocations + sum of all load allocations + margin of safety

For more information on TMDLs, see *Mid-Yakima Basin Bacteria TMDL: Water Quality Improvement Report and Implementation Plan*. This will be published by the Department of Ecology's Water Quality Program at a later date.

Background

Ecology conducted a TMDL study in these watersheds because historical data have shown that Cowiche Creek, Wide Hollow Creek, and Moxee Drain (Figure 1) are impaired by elevated levels of fecal coliform (FC) bacteria (Joy, 2005). These water bodies do not meet *Primary Contact Recreation* beneficial use standards. North Fork (NF) Cowiche Creek, South Fork (SF) Cowiche Creek, Cowiche Creek, Wide Hollow Creek, Cottonwood Creek, Congdon Canal, Shaw Creek, Randall Park Pond, East Spring Creek, Moxee Drain, Drainage Improvement District (DID) #11, and Hubbard Canal were included on Washington State's 2008 303(d) list of impaired water bodies for FC bacteria impairments.

FC bacteria are used as indicators of fecal contamination and the presence of other disease-causing (pathogenic) organisms. High FC bacteria numbers in waterways may pose an increased risk of infection from pathogens associated with fecal waste. This report includes a technical analysis of the FC loading in the watershed.

Study area

The study area for this TMDL consists of the Cowiche Creek, Wide Hollow Creek, and Moxee Drain sub-watersheds. These sub-watersheds are within the Yakima River and Naches River watersheds within Washington State (Figure 1). These two watersheds are known as the Water Resource Inventory Areas (WRIAs) 37 and 38.

Ecology sampled sites on Cowiche Creek, Wide Hollow Creek, and Moxee Drain near their respective headwaters to their mouths. Many tributaries and irrigation returns were also sampled: NF Cowiche Creek, SF Cowiche Creek, Cottonwood Creek, Congdon Canal, Shaw Creek, Randall Park Pond, East Spring Creek, DID #11, and Hubbard Canal. The tributaries and irrigation returns were sampled as near as access would allow to their confluence with Cowiche Creek, Wide Hollow Creek, or Moxee Drain. Multiple sites were sampled along NF Cowiche Creek, SF Cowiche Creek, Cottonwood Creek, Randall Park Pond, and DID #11 in order to address impaired reaches.

The study area (Figure 1) was determined by selecting Hydrologic Unit Code Level 6 basins in Geographic Information System (GIS) that encompassed Cowiche Creek, Wide Hollow Creek, and Moxee Drain including the impaired tributaries.

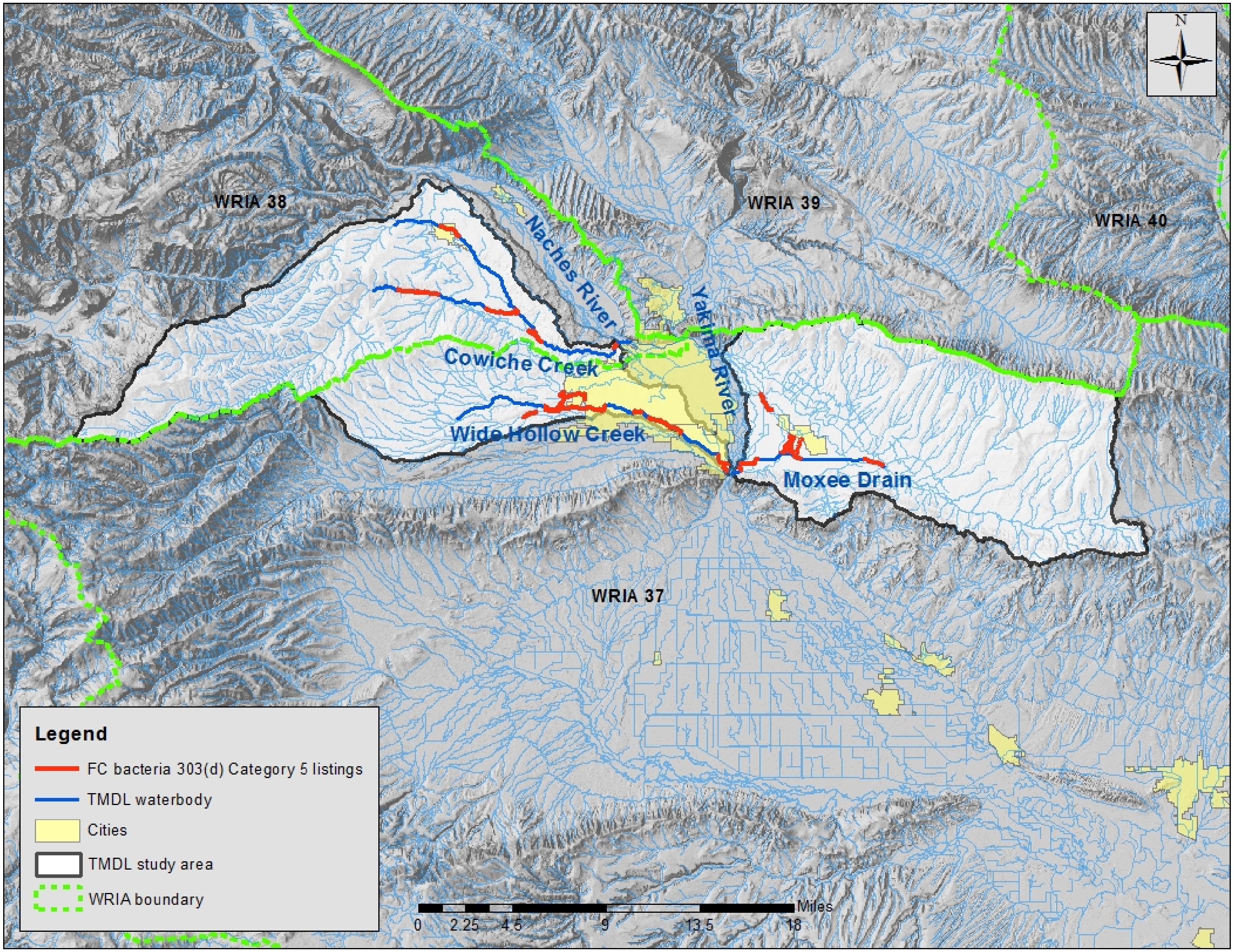


Figure 1. Map of the TMDL study area and the FC bacteria 303(d) Category 5 listings.

Impairments addressed by this TMDL

Pollutant loading must be decreased so that FC bacteria will comply with water quality standards in the water body.

Table 1. Study area water bodies on the 2008 303(d) list for Fecal Coliform.

Water Body	Listing ID	Township	Range	Section
NF Cowiche Creek	8322	14N	17E	18
	8323	13N	17E	3
SF Cowiche Creek	8326	14N	16E	35
	8327	13N	17E	3
	46346	14N	16E	36
	46633	13N	17E	4
Cowiche Creek	8319	13N	17E	11
	45115	13N	18E	9
	45886	13N	17E	11
Wide Hollow Creek	6717	12N	19E	7
	6718	13N	18E	35
	8306	12N	19E	8
	16804	13N	18E	27
	45081	13N	18E	29
	45161	13N	17E	25
	45219	13N	18E	36
	46645	13N	18E	30
Cottonwood Creek	45210	13N	17E	25
	46164	13N	17E	35
Congdon Canal	45875	13N	17E	25
Shaw Creek	45869	13N	18E	30
Randall Park Pond	46628	13N	18E	27
East Spring Creek	45541	12N	19E	8
Moxee Drain	45122	12N	19E	9
	45717	12N	19E	9
	46167	12N	19E	11
	46168	12N	20E	9
	46355	12N	19E	3
Moxee Canal	45313	12N	19E	2
DID #11	45114	12N	19E	2
	45703	12N	19E	3
Hubbard Canal	46548	12N	19E	2
	46673	13N	19E	27

Applicable water quality standards for bacteria

Bacteria criteria are set to protect people who work and play in and on the water from waterborne illnesses. In Washington State, the Department of Ecology's (Ecology) water quality standards use FC as an indicator bacteria for the state's freshwaters (e.g., lakes and streams). FC in water indicates the presence of waste from humans and other warm-blooded animals. Waste from warm-blooded animals is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals. The FC criteria are set at levels that are shown to maintain low rates of serious intestinal illness (gastroenteritis) in people.

The *Primary Contact* use is intended for waters "where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and waterskiing." More to the point, however, the use is designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, throat, and urogenital system. Since children are also the most sensitive group for many of the waterborne pathogens of concern, even shallow waters may warrant primary contact protection. To protect this use category: "Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies/100 mL" [WAC 173-201A-200(2)(b), 2003 edition].

Compliance is based on meeting both the geometric mean criterion and the 10% of samples (or single sample if less than ten total samples) limit. These two measures used in combination ensure that bacterial pollution in a water body will be maintained at levels that will not cause a greater risk to human health than intended. While some discretion exists for selecting sample averaging periods, compliance will be evaluated for both monthly (if five or more samples exist) and seasonal (summer versus winter) data sets.

The criteria for FC are based on allowing no more than the pre-determined risk of illness to humans that work or recreate in a water body. The criteria used in the state standards are designed to allow seven or fewer illnesses out of every 1,000 people engaged in primary contact activities. Once the concentration of FC in the water reaches the numeric criterion, human activities that would increase the concentration above the criteria are not allowed. If the criterion is exceeded, the state will require that human activities be conducted in a manner that will bring FC concentrations back into compliance with the standard.

If natural levels of FC (from wildlife) cause criteria to be exceeded, no allowance exists for human sources to measurably increase bacterial pollution. While the specific level of illness rates caused by animal versus human sources has not been quantitatively determined, warm-blooded animals (particularly those that are managed by humans and thus exposed to human-derived pathogens as well as those of animal origin) are a common source of serious waterborne illness for humans.

For more information about the water quality standards applicable to this TMDL project, see *Mid-Yakima Basin Bacteria TMDL: Water Quality Improvement Report and Implementation Plan* (in preparation). For a more general discussion about the state water quality standards, see Ecology's web site: www.ecy.wa.gov/programs/wq/swqs.

Watershed Description

Study area characteristics and maps, in addition to the ones presented below, are located in the *Quality Assurance Project Plan: Yakima Area Creeks Fecal Coliform Total Maximum Daily Load Study* (Joy, 2005).

Geographic setting

The Yakima urban area is located at the intersection of three Water Resource Inventory Areas (WRIAs) in Yakima County (Figure 1). The city of Yakima forms the urban center, with smaller nearby urban communities at Selah, Union Gap, Naches, Tieton, and Moxee City.

The area has been growing rapidly and has a unique checkerboard of industrial, urban, transportation, residential, orchard, irrigated agriculture, non-commercial farm, forest, and range land uses. The combined population in the cities of Yakima, Union Gap, Tieton, and Moxee City increased by 20,000 people between 1990 and 2000, and another 20,000 people between 2000 and 2010 (OFM, 2012). The population increase has resulted in rapid conversions of farm, orchard, and range land into commercial, industrial, and residential areas. This trend is expected to continue.

Several streams, canals, and drains transect the urban area, carrying water to or from the Naches and Yakima Rivers and from creeks emanating from the surrounding foothills. Many were formerly used for irrigation and farmland drainage when the land use was dominated by agriculture. Now they provide water for agriculture but also for a broader range of sometimes conflicting uses such as stormwater conveyance, fish habitat, and recreational opportunities.

The water quality characteristics of the streams, canals, and drains are influenced by the various uses of the water, along with wastewater additions and runoff from adjacent land. The wastewater and runoff loads can add FC bacteria, nutrients, oxygen-demanding substances, pesticides, and suspended sediment. Some reaches of these water bodies have been monitored and have contaminant concentrations that do not meet state or federal water quality standards. These reaches have been included on Washington State's 303(d) list, although only the FC bacteria listings are addressed in this study.

Basin characteristics

Climate

Moxee Drain and Wide Hollow Creek are in the Lower Yakima River Basin (WRIA 37), and Cowiche Creek is in the Naches River Basin (WRIA 38). The study area lies within parts of the Eastern Cascade Slopes and Foothills Ecoregion, and the Columbia Basin Ecoregion. The Eastern Cascade Slope area of the Cowiche and Upper Wide Hollow watersheds get more rain and snow than the Yakima Valley and Moxee watershed in the Columbia Basin Ecoregion (Joy, 2005). Temperatures are cooler in the upper reaches of the Cowiche and Wide Hollow than the lower reaches. Winter snow is common and increases with elevation (Joy, 2005).

Hydrologic characteristics

All three water bodies have seasonal hydrologic characteristics and stream networks that are characteristic of agricultural irrigation or drainage operations (e.g., high summer irrigation flows and low winter natural base flows (Figure 2) (Ecology, 2012a; USBR, 2012)). All three streams flow through:

- Primarily privately owned land.
- One or more urbanized areas as defined by the US Census Bureau (Ecology, 2002).
- Ceded lands of the Yakima Treaty of 1855 where usual and accustomed rights of the Yakama Indian Nation are retained.
- One or more irrigation and drainage districts.
- Areas where more than one public agency and industry have NPDES Phase II stormwater permit responsibilities.

Each of the three watersheds drains less than 150 square miles to the Yakima River but delivers more water than the watersheds generate naturally. During the irrigation season (April – October), the creeks carry return flows from inter-basin transfers through the irrigation network, mainly from the Yakima, Naches, and Tieton Rivers. These return flows can be highly variable because they depend on water availability, the water needs of specific crops, and operational management of the irrigation network.

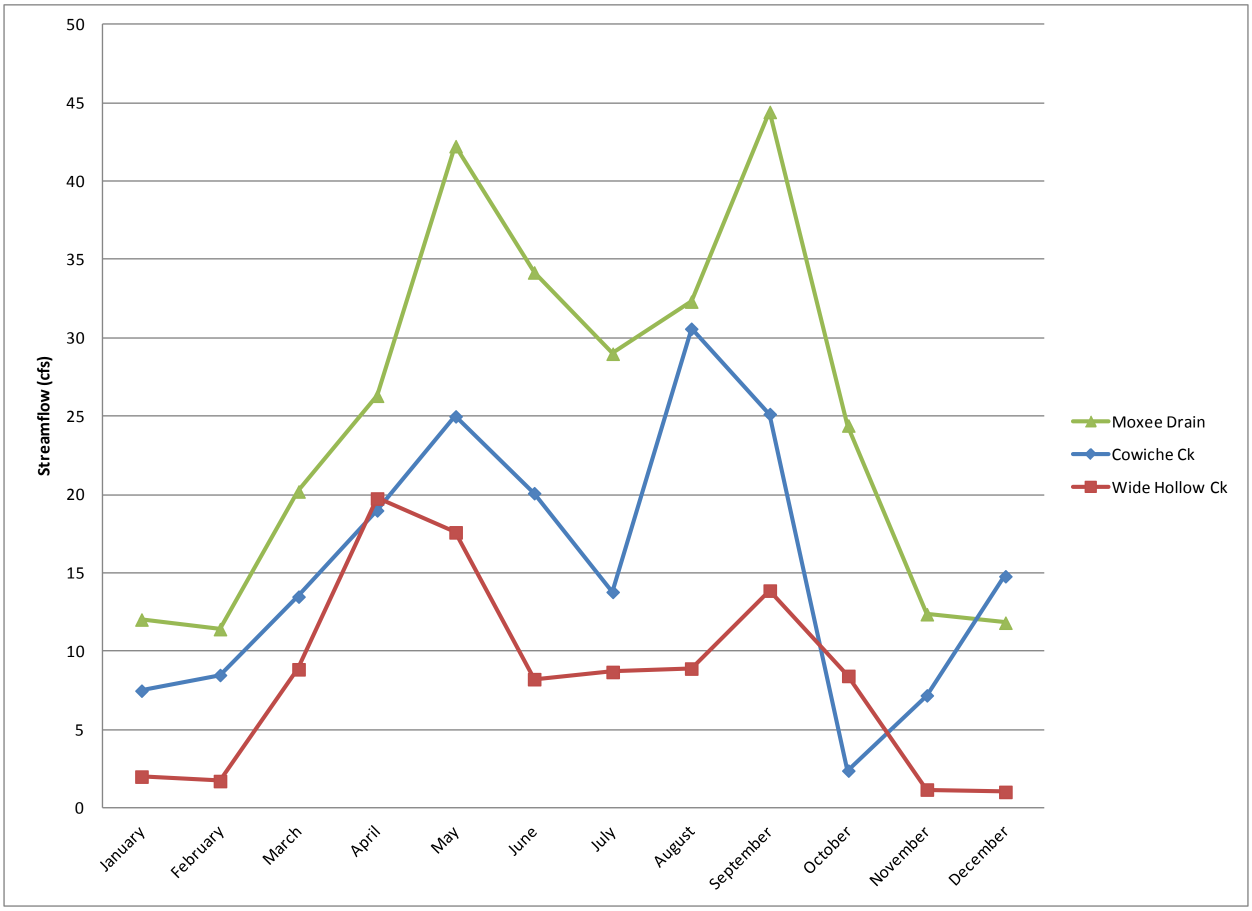


Figure 2. Historical mean monthly streamflows illustrating the seasonal hydrologic characteristics associated with agriculture irrigation and drainage operations in Cowiche Creek (2001 data from Ecology gage 38G120), Wide Hollow Creek (2005 data from Ecology gage 37E120), and Moxee Drain (2005 data from Bureau of Reclamation gage BICW).

Cowiche Creek

Cowiche Creek drains approximately 120 square miles north and east of the city of Yakima in the Naches Basin (Joy, 2005). The watershed is separated from the Naches River by Naches Heights along the northeast and from the Tieton River by Divide Ridge to the northwest. Wide Hollow Creek and Ahtanum Creek are separated from the South Fork (SF) Cowiche Creek by Cowiche Mountain to the south.

The upper SF and North Fork (NF) areas of the watershed are forested. The middle part of the SF is bounded by rangeland, and the lower SF and NF through the mainstem is primarily surrounded with agricultural uses. Orchard fruit and forage crops are grown in the areas served by the Yakima-Tieton Irrigation District.

The upper branches of the Cowiche begin in national and state forestlands. Other public lands are found downstream. For example, the Cowiche Wildlife Area occupies 4,526 acres along SF Cowiche Creek from river mile (RM) 4.2 to RM 7.7 (Joy, 2005). The area provides the

Cowiche elk sub-herd with habitat for winter range. The Cowiche Canyon Conservancy occupies three miles on an abandoned railroad grade along the mainstem Cowiche Creek from RM 2.8 to RM 5.8. Also, the Yakima-Tieton Irrigation District operates a reservoir along NF Cowiche Creek at RM 8.0 at French Road.

The developed areas around Tieton, Cowiche, and near the mouth at the city of Yakima's northwestern boundary constitute only 6% of the watershed area. Prior to 2002, the Tieton publicly owned treatment works (POTW) had a lagoon system that discharged to NF Cowiche Creek at RM 4.9, and Cowiche had a wastewater treatment plant that discharged to the NF at RM 2.0. In 2002, these two systems were consolidated into one regional facility that discharges to the NF at RM 2.0. Several fruit packing plants also are located in the Tieton/Cowiche area.

The two forks join at RM 7.5 below Cowiche and enter the Cowiche Canyon one mile downstream of the confluence. The canyon begins fairly narrow and sparsely populated, but in the last few miles opens into a wider valley that allows more room for homes and small orchards. A small commercial area is located just before the creek crosses under Highway 12 and enters the Naches River at RM 2.8.

Wide Hollow Creek

Wide Hollow Creek drains 65 square miles south and east of Yakima (Joy, 2005). The creek begins in Cowiche Mountain near Oak Spring. The upper watershed is mainly rangeland, some of which is managed by the Washington Department of Natural Resources. The transition to pasture, orchards, and cropland occurs in the valley bottom where irrigation canals convey water from the Naches and Tieton Rivers. The underlying groundwater is part of the greater Ahtanum Valley that includes areas to the south and east under Ahtanum Creek (Sinclair, 2003).

The West Valley area, downstream of where Cottonwood Creek meets Wide Hollow Creek and the Congdon Canal, is experiencing rapid urbanization from Yakima. The Wide Hollow Creek watershed has the largest percentage of urban land use (28%) of the three creeks in the study area (YVCOG, 1995). Several return drains, diversions from drainage and irrigation districts, and smaller spring-fed tributaries also are present in the lower portions of the valley. Wide Hollow Creek continues to be bordered by orchard; livestock pasture; and residential, commercial, and light industrial land usage all the way to Union Gap. At one time treated wastewater from Union Gap was discharged into Wide Hollow Creek, but for the past 30 years it has been sent to the Yakima POTW. Wide Hollow Creek enters the Yakima River at RM 107.4 after crossing under Interstate 82 and being joined by Spring Creek from the north.

Moxee Drain

Moxee Drain is a 136-square-mile watershed in the Lower Yakima Basin (Joy, 2005). Moxee Drain begins as an intermittent natural stream in the Upper Moxee Valley between the Yakima Ridge and Rattlesnake Hills. Most of the upper watershed is rangeland, parts of which are in the Yakima Training Center, an area used by the U.S. Army for live fire and maneuvering training. The open drain parallels State Highway 24 down the valley. Agricultural uses predominate as irrigation water is available from several canals routing water from the Yakima River into the watershed.

Water from the Roza, Union Gap, Moxee, Hubbard, and Selah-Moxee Canals influence the quantity and quality of water in the Moxee Drain. Many of the canals cross by way of underdrains, but others have direct or indirect inputs into Moxee Drain. Irrigated fields using water from the canals discharge tail water into the laterals or directly into Moxee Drain. Spill and overflow water from canal operations may also enter laterals or directly into Moxee Drain.

The city of Moxee lies north of the drain. Prior to June 2008, the Moxee POTW discharged to DID #11, one of many lateral drains to the lower reaches of Moxee Drain. After June 2008, the wastewater has been discharging to the Yakima POTW. Residential developments and non-commercial farms have been established in recent years in the unincorporated county around Moxee City. The urban/residential use comprises approximately 2% of the watershed area (YVCOG, 1995). The U.S. Bureau of Reclamation operates a continuous stream gaging station at Birchfield Road (BICW). Moxee Drain enters the Yakima River at RM 107.3.

Pollution sources

The following are potential sources of FC bacteria in the study area.

Point sources / permit holders

FC bacteria can be present in a wide variety of municipal and industrial wastewater and stormwater sources. No feasible treatment method is 100% effective at removing FC bacteria all of the time, so FC bacteria can enter the receiving waters from these sources. FC bacteria and other potential contaminants from industrial and municipal sources are regulated by various National Pollutant Discharge Elimination System (NPDES) individual and general permits issued by Ecology.

Wastewater

The study area receives wastewater from Cowiche POTW (NF Cowiche Creek), a secondary treatment facility regulated under a NPDES permit. The study area also received wastewater from the Moxee POTW (DID #11) prior to June 2008. This facility was also regulated under a NPDES permit during this time (Table 2).

The Cowiche POTW consists of sequencing batch reactors with extended aeration and activated sludge, constructed wetlands, and ultraviolet disinfection. The effluent is discharged from the facility into a 500-foot long cooling channel where it is joined by subsurface water intercepted by curtain drains around the facility and by non-contact cooling water from a local fresh fruit packer. The cooling channel enters the NF Cowiche Creek at about RM 2 (Ecology, 2007a). The POTW is currently operated by the city of Tieton.

The Moxee POTW consisted of an oxidation ditch, secondary clarification, and ultraviolet disinfection. Prior to June 2008, the Moxee POTW effluent was discharged from the facility through a 0.5 miles long pipe to DID #11 (Ecology, 2002).

Several fresh fruit packing plants and warehouses are located in the study area. Many of these are covered under a NPDES wastewater discharge general permit (Table 2). The permit authorizes treatment and disposal methods for wastewater, cooling water, stormwater, and solid waste. FC bacteria limits are not included in these permits, but they could be added if elevated counts in the wastewater or stormwater discharge are found.

One dairy is located near the head of the Moxee Drain. The Devries Family Farm has a certified Dairy Nutrient Management Plan for wastes generated by approximately 2700 cows. Manure and other wastes are managed to prevent their discharge to enter the creek from the dairy facility.

Stormwater

During precipitation events, rainwater washes over the surface of the landscape, pavement, rooftops, and other impervious surfaces. This stormwater runoff can accumulate and transport fecal matter via stormwater drains to receiving waters and potentially degrade water quality (Lubliner et al., 2006).

In 1987, Congress changed the federal Clean Water Act by declaring the discharge of stormwater from certain industries and municipalities to be a point (discrete) source of pollution. Due to this change, certain stormwater discharges now require a NPDES water quality discharge permit.

Elevated FC counts would not necessarily be expected in stormwater from fresh fruit packing warehouses. However, stormwater from industrial and commercial properties often can have surprisingly high FC counts from such diverse sources as misconnected sanitary lines to roosting birds on roofs (Schueler, 1999).

Two facilities on Wide Hollow Creek have individual industrial NPDES stormwater permits. The Del Monte plant discharges stormwater to the city of Yakima stormwater system. The stormwater drain discharges to Wide Hollow Creek 2.5 miles to the south. Western Recreational Vehicles had three stormwater discharges to Wide Hollow Creek near RM 6.2 (Table 2).

Yakima, Union Gap, and urbanized portions of Yakima County hold NPDES Phase II municipal separate storm sewer systems (MS4) permits. Washington Department of Transportation (WSDOT) highways and facilities are also required to be covered under a MS4 permit (Table 2). WSDOT owns and manages the major roads and highways through the urbanized areas (e.g., U.S. Highways 97 and 12, Interstate 82, and State Route 24). There is also a WSDOT Road Maintenance Facility at Union Gap on Spring Creek, a tributary to Wide Hollow Creek.

Table 2. List of NPDES and State Individual and General Wastewater or Stormwater Permit Holders in the study area.

Permit Holder	Receiving Water	Permit Number	Permit Type
Columbia Valley Fruit	Wide Hollow Creek	WAG435176B	Fruit
Borton and Sons	Wide Hollow Creek via Lateral T	WAG435131B	Fruit
Eakin Fruit Company	Wide Hollow Creek via Stormwater Pipe	WAG435031B	Fruit
LF Holdings	Cowiche Creek	WAG435070B	Fruit
Cowiche Growers, Inc.	North Fork Cowiche Creek	WAG435046B	Fruit
Strand Apples	North Fork Cowiche Creek	WAG435144B	Fruit
Strand Apples	North Fork Cowiche Creek via Unnamed County Ditch	WAG435036B	Fruit
Roy Farms, Inc.	Moxee Drain via Roza Drain Ditch	WAG435221B	Fruit
City of Moxee[1]	Lateral to Moxee Drain	WA0022501C	Municipal
Cowiche and Tieton	North Fork Cowiche Creek	WA0052396A	Municipal
Del Monte Foods 125	Wide Hollow Creek	SO3000215D	Industrial SW
Western Recreational Vehicles[2]	Wide Hollow Creek	SO3004527B	Industrial SW
Far West Fabricators[2]	Moxee Drain via Drain	SO3001307D	Industrial SW
Yakima County	All creeks and drains in urbanized areas	WAR046014	Phase II SW
City of Yakima	Wide Hollow Creek	WAR046013	Phase II SW
City of Union Gap	Wide Hollow Creek	WAR046010	Phase II SW
Yakima Valley Community College	Wide Hollow Creek	WAR046201	Phase II SW
Washington Dept. of Transportation	Wide Hollow Creek, Cowiche Creek, and Moxee Drain	WAR043000	Phase II SW

[1]Facility began discharging to Yakima POTW in June 2008. Permit canceled in August 2008.
[2]Facility does not currently discharge to surface water.
Fruit: NPDES Wastewater Discharge General Permit for Fresh Fruit Packing
Municipal: NPDES Municipal Wastewater Discharge Permit
Industrial SW: Industrial Stormwater Permit
Phase II SW: Municipal NPDES Stormwater Permit

Nonpoint sources

Nonpoint (diffuse) sources of FC bacteria are not controlled by discharge permits. Potential nonpoint sources in the study area include the following:

- Livestock with direct access to streams and other poor management of livestock manure.
- Poor management of pet waste.
- Poorly constructed or maintained onsite septic systems.
- Wildlife and background sources

FC bacteria from nonpoint sources are transported to the creeks by direct and indirect means. Manure that is spread over fields during certain times of the year can enter streams via direct discharge to the water, surface runoff, or fluctuating water levels. Often livestock have direct access to water. Manure can be deposited in the riparian area of the access points where fluctuating water levels, surface runoff, or constant trampling can bring the manure into the water. Pet waste concentrated in public parks or private residences can be a source of contamination, particularly in urban areas. Some residences may have wastewater piped directly to waterways or may have malfunctioning onsite septic systems where effluent seeps to nearby waterways. Swales, sub-surface drains, and flooding through pastures and near homes can carry FC bacteria from sources to waterways.

All three creeks have areas where wildlife can contribute background loads of FC bacteria. Elk, deer, beaver, muskrat, and other wildlife in headwater and rural valley areas are potential sources of FC bacteria. Bridge structures can attract large numbers of nesting birds whose droppings fall in the water. Open fields are attractive feeding area for some birds whose presence can increase FC counts in runoff.

Usually these sources are dispersed and do not elevate FC counts over state criteria. Sometimes animals are locally concentrated and can cause elevated counts. The winter elk feeding at Cowiche Wildlife Area is one area that was monitored on the SF Cowiche Creek for concentrated animal population effects. Ducks and geese at Randall Park along Wide Hollow Creek were noted as a potential FC source by Kendra (1988). FC loading from the park area was monitored. Seasonal bird-nesting under bridges was evaluated in field notes, and FC sampling results in the creeks were compared to their presence and absence.

Re-suspension and re-growth sources

There is evidence that FC bacteria can settle to the sediments where they can survive to later re-suspend into the water column after sediment disturbance (e.g., increased streamflow). There is also evidence that bacteria can survive the disinfection processes of POTWs to reactivate or re-grow in downstream receiving waters, particularly when there is a high dissolved organic carbon content in the wastewater. Rifai and Jensen (2002) provide a literature summary of these phenomena. Studies show that bacteria survival rates in sediment increase with declining sediment particle size. Re-growth of bacteria has been seen downstream of POTW discharges where the chlorine has dissipated from chlorinated discharges or when the discharge was de-chlorinated prior to discharge.

Goals and Objectives

Project goals

The goal of this TMDL is to achieve compliance with Washington State fecal coliform (FC) criteria, which will return Cowiche Creek, Wide Hollow Creek, Moxee Drain, and their tributaries to a condition that provides low illness risk to people and animals using the streams.

Study objectives

A Quality Assurance Project Plan (Joy, 2005) was approved in January 2005 to gather the majority of the data in 2004-06 for this Water Quality Improvement Plan. A Supplemental Quality Assurance Project Plan (Ross, 2012) was developed in 2010 to gather additional data in 2010 for this Water Quality Improvement Plan.

The objectives of the 2004-06 study were to:

- Identify FC loads by reach and from specific sources along Cowiche and Wide Hollow Creeks and Moxee Drain under various seasonal or hydrological conditions.
- Determine the cumulative FC loads and calculate loading capacities along key points in Cowiche and Wide Hollow Creeks and Moxee Drain.
- Estimate the FC count and load reductions necessary to meet the loading capacities.
- Determine *E. coli* concentrations and % *Klebsiella*, Enterobacter, and *Serratia* (KES) bacteria in some FC samples for better source identification and treatment.

The objectives of the 2010 study were to:

- Gather additional data to supplement the 2004-06 study.
- Determine if efforts to improve stormwater conveyances, after the 2004-06 sampling, in the Yakima urban areas have resulted in reducing bacteria loads to Wide Hollow Creek. Unfortunately no storm events were captured during the 2010 study, so this objective was not met.

Analytical Approach

Study area

FC bacteria and streamflow data were collected from 76 sites in the study area. Figures 3 - 6 shows all sampling locations. Tables 3 - 5 list the corresponding location identification, description, and latitude/longitude of the sampling sites.

Fixed-network, irrigation survey, and storm survey sites were sampled during the study (Joy, 2005). In some cases, the fixed-network and storm survey sites were co-located.

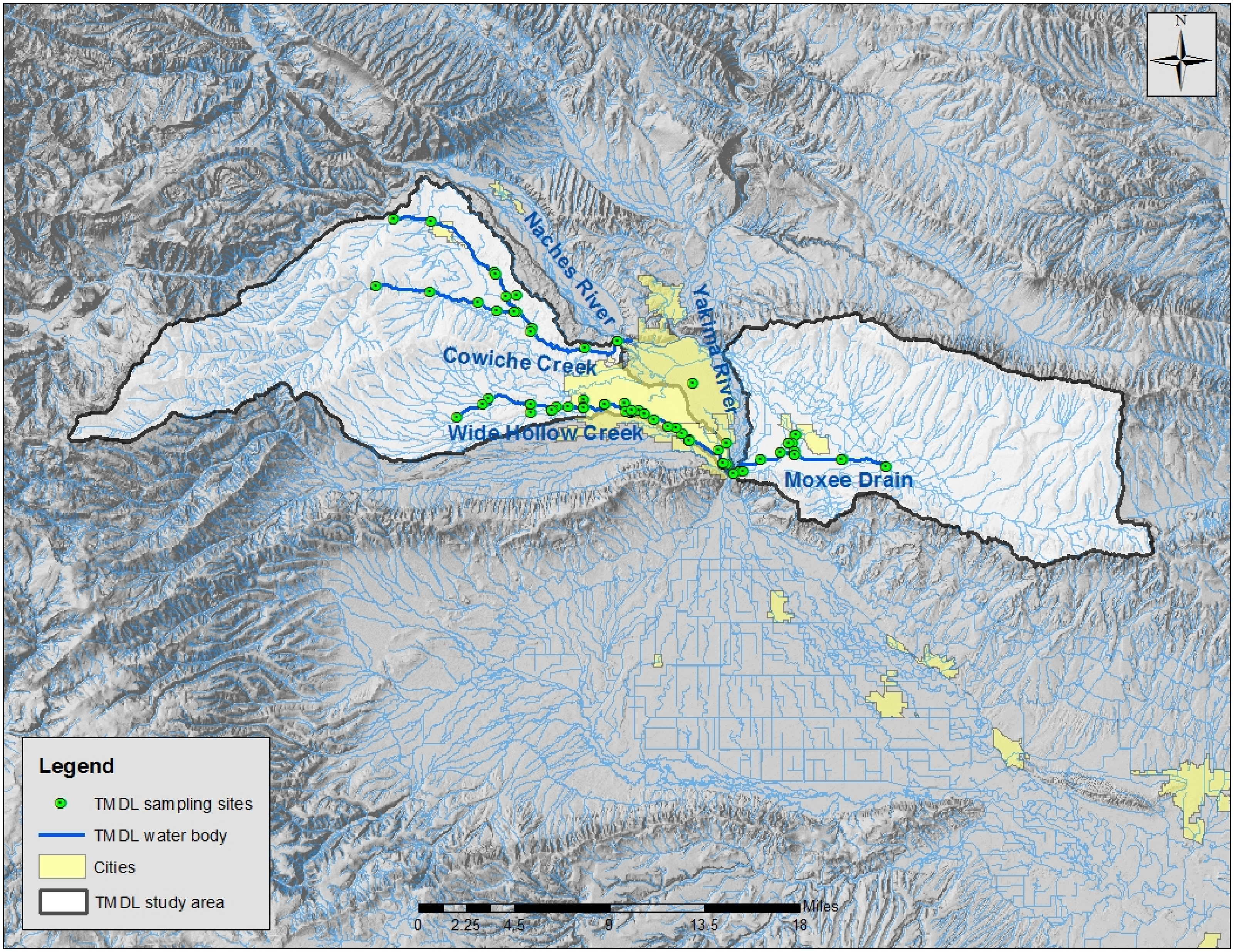


Figure 3. Map of the Mid-Yakima Basin Bacteria TMDL study area with sampling sites.

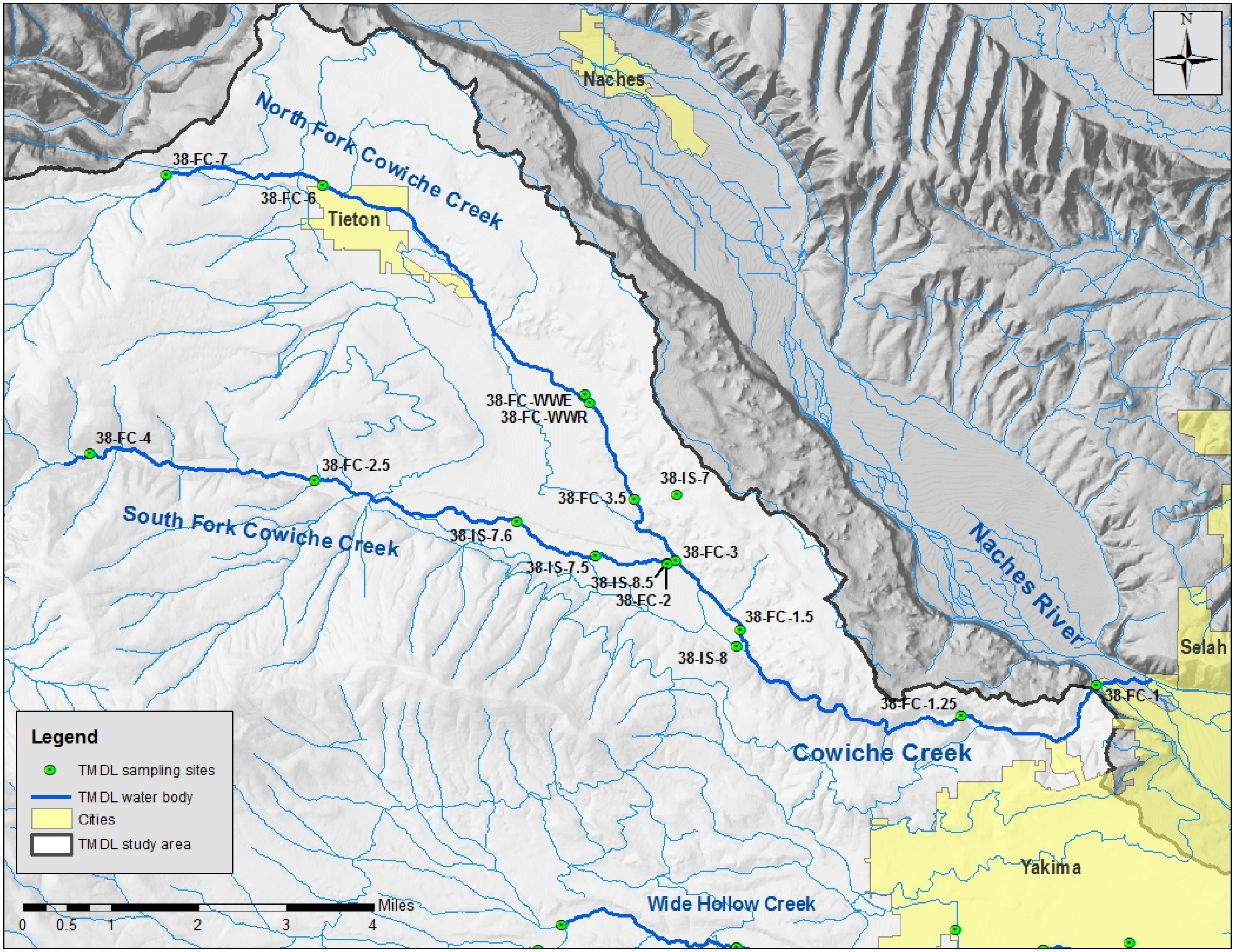


Figure 4. Map of the Cowiche Creek area with sampling sites.

Table 3. List of the Cowiche Creek area TMDL sampling sites, 2004-06 and 2010.

Sampling Site ID	Station Description	Latitude	Longitude
38-FC-1*	Cowiche Creek at Powerhouse Rd	46.6272	-120.5812
38-FC-1.25**	Cowiche Creek at the end of Cowiche Creek Rd downstream of bridge	46.6221	-120.6137
38-FC-1.5	Cowiche Creek at Zimmerman Rd Bridge	46.6361	-120.6667
38-FC-2	SF Cowiche Creek at Pioneer Rd/confluence	46.6471	-120.6842
38-FC-2.5	SF Cowiche Creek at WDFW bridge	46.6606	-120.7689
38-FC-3	NF Cowiche Creek at Mahoney Rd	46.6475	-120.6822
38-FC-3.5	NF Cowiche Creek at Thompson Rd	46.6577	-120.6921
38-FC-4	SF Cowiche Creek at Cowiche Mill Rd	46.6649	-120.8229
38-FC-6	NF Cowiche Creek at Rozenkranz Rd bridge	46.7093	-120.7672
38-FC-7	NF Cowiche Creek at French Rd above reservoir	46.7110	-120.8047
38-FC-WWE	Cowiche POTW effluent from UV chamber	46.6749	-120.7042
38-FC-WWR	Cowiche POTW effluent after cooling channel	46.6735	-120.7028
38-IS-7	Loop return to NF Cowiche Creek off Thompson Rd	46.6584	-120.6821
38-IS-7.5	SF Cowiche Creek at Summitview Rd	46.6484	-120.7015
38-IS-7.6	SF Cowiche Creek at Pioneer Way	46.6540	-120.7203
38-IS-8	Side branch return to Cowiche Creek at Weikel Rd	46.6334	-120.6675
38-IS-8.5	Irrigation return to SF Cowiche Creek at FC-2	46.6471	-120.6843

FC: Fixed-network sampling sites
IS: Irrigation and DID synoptic survey sites
* Site sampled during both the 2004-06 and 2010 surveys
** Site sampled only during the 2010 surveys

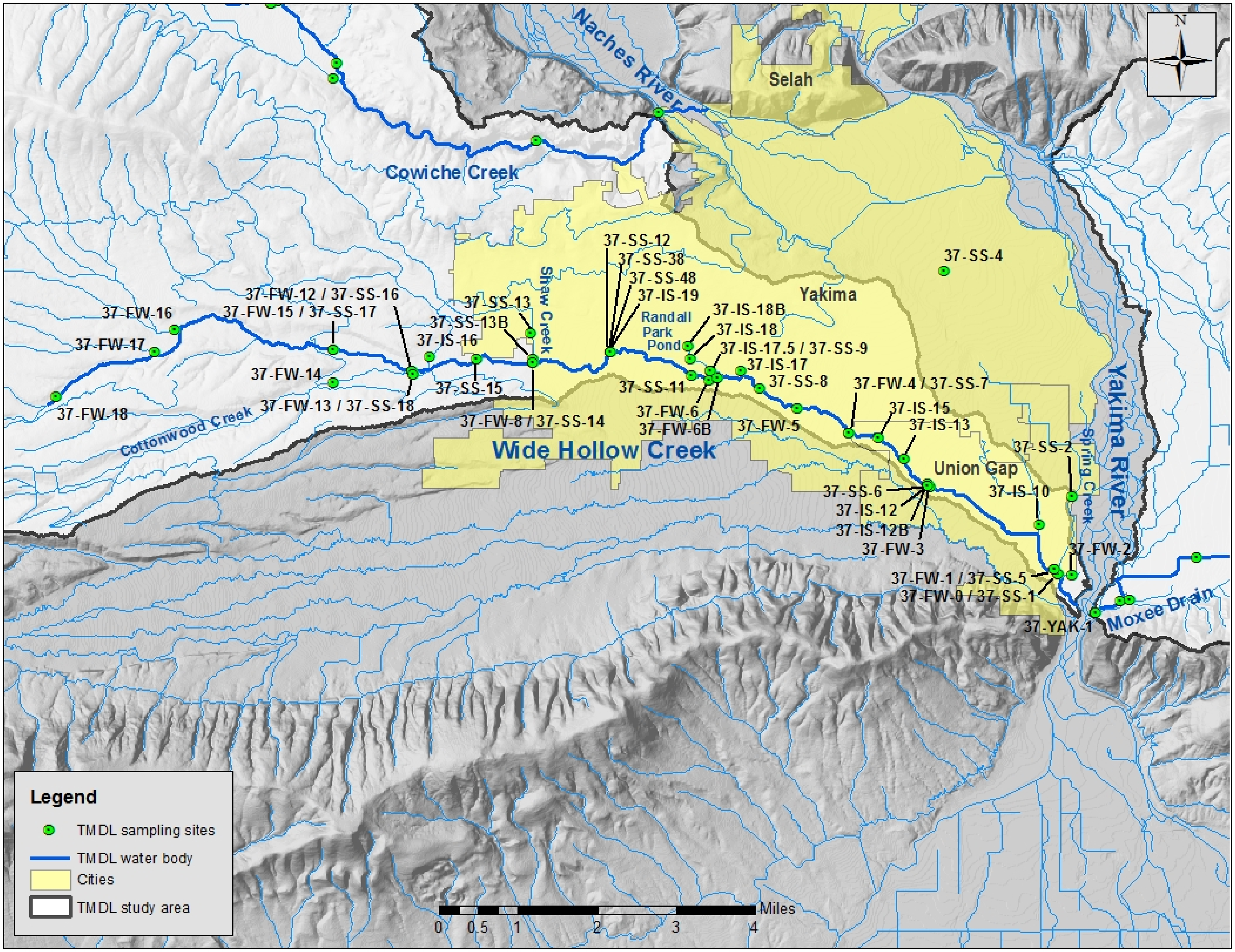


Figure 5. Map of the Wide Hollow Creek area with sampling sites.

Table 4. List of the Wide Hollow Creek area sampling sites, 2004-06 and 2010.

Sampling Site ID	Station Description	Latitude	Longitude
37-FW-0 / 37-SS-1*	Wide Hollow Creek at Union Gap Public Works	46.5429	-120.4752
37-FW-1 / 37-SS-5	Wide Hollow Creek at Main St. in Union Gap	46.5436	-120.4759
37-FW-2	Spring Creek at Union Gap Public Works	46.5427	-120.4715
37-FW-3**	Wide Hollow Creek downstream of 3rd Ave bridge	46.5587	-120.5090
37-FW-4 / 37-SS-7*	Wide Hollow Creek at 16th Ave	46.5685	-120.5305
37-FW-5	Wide Hollow Creek at gas station near airport	46.5731	-120.5442
37-FW-6	Wide Hollow Creek at 44th Ave/Randall Park	46.5782	-120.5676
37-FW-6B**	Wide Hollow Creek behind Bergren Screen Printing off 40th Ave	46.5786	-120.5656
37-FW-8 / 37-SS-14*	Wide Hollow Creek at park off 80th Ave	46.5813	-120.6146
37-FW-12 / 37-SS-16	Wide Hollow Creek at Dazet Rd	46.5798	-120.6464
37-FW-13 / 37-SS-18	Cottonwood Creek at Dazet Rd	46.5792	-120.6464
37-FW-14	Cottonwood Creek at Moore Rd	46.5778	-120.6675
37-FW-15 / 37-SS-17	Wide Hollow Creek at Wide Hollow Rd	46.5838	-120.6674
37-FW-16	Tributary to Wide Hollow Creek at Stone Road near school	46.5873	-120.7095
37-FW-17	Tributary to Wide Hollow Creek at Stone Rd	46.5832	-120.7149
37-FW-18	Wide Hollow Creek at Stone Rd near Burnham Rd	46.5749	-120.7411
37-IS-10*	Drain at 4th St and Pine St in Union Gap	46.5519	-120.4802
37-IS-12	DID #24 outfall L1 at 3rd Ave	46.5588	-120.5096
37-IS-12B**	Manhole for DID # 24 L1 in turn lane near 3rd Ave bridge, north of Ahtanum Rd	46.5592	-120.5095
37-IS-13*	DID #24 outfall L2; near Pioneer Ln and Cornell Ave	46.5639	-120.5159
37-IS-15*	DID #4 outfall at Gardner's Nursery	46.5677	-120.5228
37-IS-16*	Congdon Canal east of 101st Ave	46.5824	-120.6417
37-IS-17*	DID #40 outfall at 38th Ave and Logan Ave	46.5799	-120.5592
37-IS-17.5 / 37-SS-9*	Randall Park Pond outlet on 44th Ave	46.5800	-120.5673
37-IS-18	DID #48 near Viola Ave & 48th Ave	46.5821	-120.5726
37-IS-18B**	Open section of DID #48 behind 48th Ave	46.5846	-120.5733
37-IS-19	Large blue culvert under 64th Ave bridge	46.5833	-120.5939
37-SS-2	City storm outfall at east end of Ahtanum Rd	46.5570	-120.4714
37-SS-4	Storm outlet for Del Monte Foods 125	46.5982	-120.5054
37-SS-6	City stormwater outfall at 3rd Ave	46.5589	-120.5097
37-SS-8	City storm outfall at end of 34th Ave	46.5769	-120.5542
37-SS-11	Wide Hollow Creek at 48th Ave/Randall Park	46.5791	-120.5723
37-SS-12*	Wide Hollow Creek at 64th Ave	46.5834	-120.5940
37-SS-13	Shaw Creek west of 80th Ave and north of Nob Hill	46.5868	-120.6150
37-SS-13B**	Shaw Creek east of the corner of Wide Hollow Rd and 80th Ave	46.5820	-120.6145
37-SS-15	Wide Hollow Creek at 91st Ave and Wide Hollow Rd	46.5822	-120.6295
37-SS-38*	DID #38 outfall at 64th Ave	46.5833	-120.5939
37-SS-48*	DID #48 outfall at 64th Ave	46.5833	-120.5939

FW: Fixed-network sampling sites
IS: Irrigation and DID synoptic survey sites
SS: Storm synoptic survey sites
* Site sampled during both the 2004-06 and 2010 surveys
** Site sampled only during the 2010 surveys

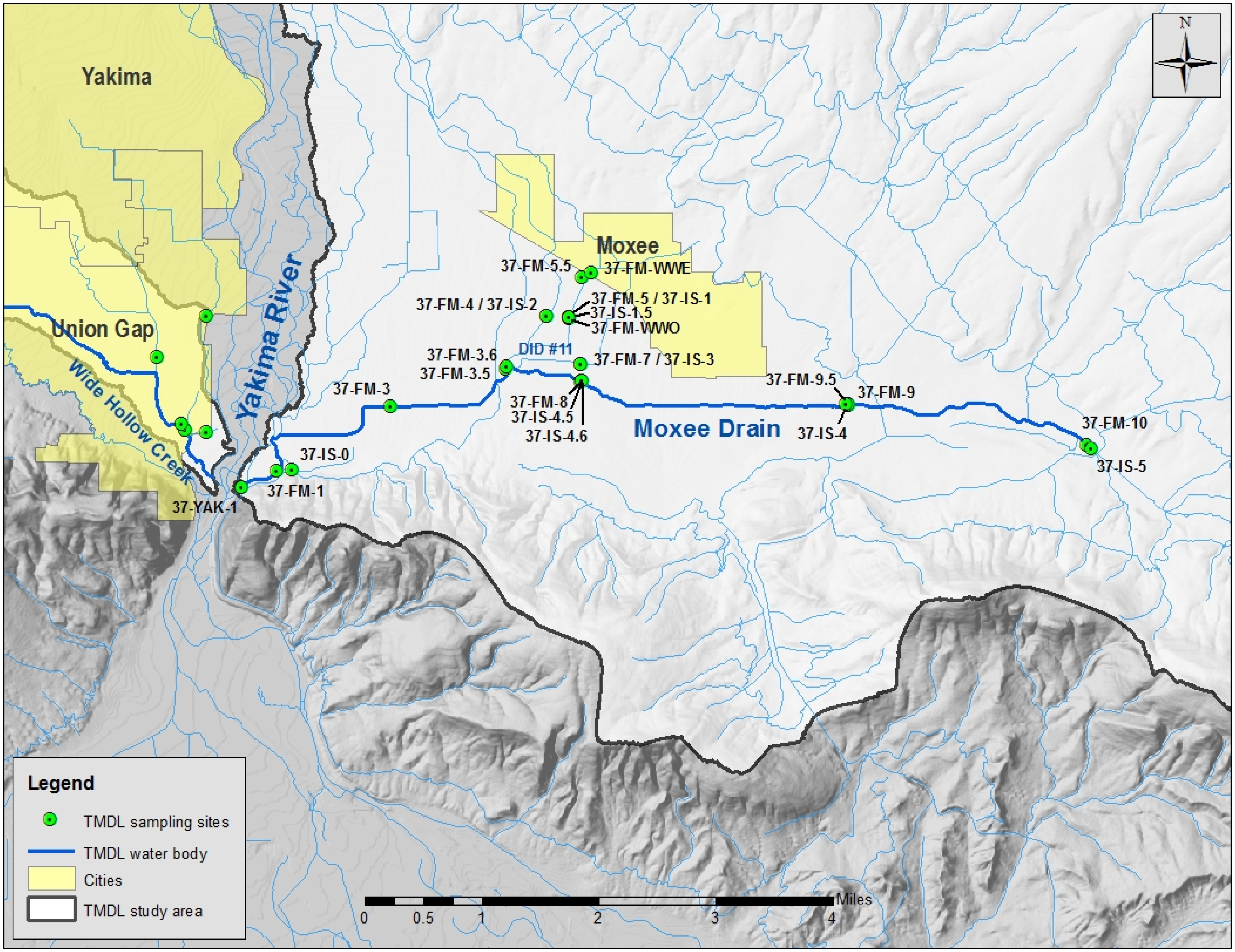


Figure 6. Map of the Moxee Drain area with sampling sites.

Table 5. List of the Moxee Drain area TMDL sampling sites, 2004-06 and 2010.

Note the single Yakima River site is also included.

Sampling Site ID	Station Description	Latitude	Longitude
Moxee Drain			
37-FM-1*	Moxee Drain near mouth off Thorp Rd	46.5378	-120.4587
37-FM-3*	Moxee Drain at Birchfield Rd	46.5458	-120.4383
37-FM-3.5	Moxee Drain just below DID #11	46.5505	-120.4176
37-FM-3.6	DID #11 at mouth	46.5507	-120.4175
37-FM-4 / 37-IS-2	Hubbard canal at Bell Rd	46.5570	-120.4104
37-FM-5 / 37-IS-1	DID #11 at Bell Rd	46.5568	-120.4064
37-FM-5.5	DID #11 at Beaudry Rd	46.5617	-120.4040
37-FM-7 / 37-IS-3	Irrigation ditch to Moxee Drain at Beaudry Rd	46.5510	-120.4042
37-FM-8	Moxee Drain at Beaudry near Beauchene Rd	46.5489	-120.4041
37-FM-9	Moxee Drain at Walters Rd	46.5459	-120.3561
37-FM-9.5	Outfall to Moxee Drain at Walters Rd	46.5460	-120.3562
37-FM-10*	Moxee Drain at Beane Rd	46.5408	-120.3134
37-FM-WWE	Moxee POTW effluent at UV chamber	46.5623	-120.4024
37-FM-WWO	Moxee POTW outfall to DID #11	46.5567	-120.4064
37-IS-0	Irrigation return to Moxee Drain near FM-1	46.5380	-120.4561
37-IS-1.5	Irrigation outfall to DID #11 at FM-5	46.5568	-120.4064
37-IS-4	Irrigation outfall to Moxee Drain at Walters	46.5460	-120.3567
37-IS-4.5	Irrigation outfall to Moxee Drain at FM-8	46.5488	-120.4042
37-IS-4.6	North irrigation outfall to Moxee Drain at FM-8	46.5489	-120.4041
37-IS-5	Outfall from Roza Canal to Moxee Drain	46.5404	-120.3127
Yakima River			
37-YAK-1	Yakima River at Thorp Rd boat launch	46.5358	-120.4650

FM: Fixed-network sampling sites
IS: Irrigation and DID synoptic survey sites
* Site sampled during both the 2004-06 and 2010 surveys

Ecology study methods

Data collection and quality

Field data collection methods were described in the *Quality Assurance Project Plan: Yakima Area Creeks Fecal Coliform Total Maximum Daily Load Study* (Joy, 2005) and the *Addendum to Quality Assurance Project Plan: 2010 Yakima Area Creeks Fecal Coliform Total Maximum Daily Load Study* (Ross, 2012). Some water collection and analyses – including dissolved oxygen, pH, temperature, and conductivity – were performed but will be excluded from this report.

During the field surveys, streamflow was measured at selected stations, and/or staff gage readings were recorded. Estimation of instantaneous flow measurements followed the Environmental Assessment Program standard operating procedure (Ecology, 2007b). Flow volumes were calculated from continuous stage height records, and rating curves were developed prior to, and during, the project. Stage heights were measured by pressure transducer and recorded by a data logger every 15 minutes. Streamflow data collected by the US Bureau of Reclamation (USBR) were also used.

Ecology's Manchester Environmental Laboratory (MEL) conducted all laboratory analyses. Laboratory data were generated according to laboratory quality assurance/quality control (QA/QC) procedures (MEL, 2005; MEL, 2008). MEL prepared and submitted QA memos to Ecology's Environmental Assessment Program for each sampling survey. Each memo summarized the QC procedures and results for sample transport and storage, sample holding times, and instrument calibration. The memo also included a QA summary of check standards, matrix spikes, method blanks (used to check for analytical bias), and lab-splits (used to check for analytical precision).

Measurement quality objectives (MQOs) were updated to be consistent with the current Environmental Assessment Program precision targets (Mathieu, 2006). Table 6 describes the analyses, methodologies, and measurement or data quality objectives used in the FC bacteria TMDL study.

Analytical laboratory precision was determined separately to account for its contribution to overall variability. Precision for chloride, total suspended solids (TSS), and turbidity was determined by calculating an average relative standard deviation (%RSD) of lab-split results. About 10% of the chloride, TSS, and turbidity samples were analyzed as laboratory split samples. Precision for FC bacteria was determined by conducting a frequency analysis for %RSD values of lab-split pairs below 20% RSD and 50% RSD. For FC samples, about 20% were analyzed as split samples.

The RSD was first calculated by dividing the standard deviation by the mean of the replicate measurements and multiplied by 100 for the %RSD. A higher %RSD is expected for values that are close to their reporting limits. For example, the %RSD for replicate samples with results of 1 and 2 is 47%, whereas the %RSD for replicate results of 100 and 101 is 0.7%, with each having a difference of 1.

Table 6. Study analysis methodologies with precision targets and reporting limits.

Analysis	Method	Lab and Total Precision MQO	Lab Duplicate MQO	Reporting Limit
Field Measurements				
Velocity[1]	Marsh McBirney Flow-Mate® Flowmeter	0.1 ft/s	n/a	0.01 ft/s
Water Temperature[1]	Hydrolab MiniSonde®	+/- 0.1° C	n/a	0.01° C
Specific Conductivity[2]	Hydrolab MiniSonde®	+/- 10%	n/a	0.1 umhos/cm
pH[1]	Hydrolab MiniSonde®	0.1 SU	n/a	1 to 14 SU
Dissolved Oxygen[1]	Hydrolab MiniSonde®	10% RSD	n/a	0.1 - 15 mg/L
	Winkler Titration	+/- 0.1 mg/L	n/a	0.01 mg/L
Laboratory Analyses				
Fecal Coliform – MF	SM 9222D	20% and 50% RSD[3]	40% RPD	1 cfu/100 mL
Escherichia coli	EPA 1103.1 (mTEC2)	20% and 50% RSD[3]	40% RPD	1 cfu/100 mL
% KES	Manchester SOP	20% and 50% RSD[3]	40% RPD	0%
Chloride	EPA 300.0	5% RSD[4]	20% RPD	0.1 mg/L
TSS	SM 2540D	15% RSD[4]	20% RPD	1 mg/L
Turbidity	SM 2130	15% RSD[4]	20% RPD	0.5 NTU

[1] as units of measurement, not percentages.
[2] as percentage of reading, not relative standard deviation (RSD).
[3] two-tiered: 50% of replicates ≤ 20% RSD; 90% of replicates ≤ 50% RSD.
[4] replicate results with a mean of less than or equal to 5 times the reporting limit will be evaluated separately.
MQO: Measurement quality objective.
SU: Standard pH units.
MF: Membrane filter method.
SM: Standard Methods for the Examination of Water and Wastewater, 20th Edition (APHA, 2005).
EPA: U.S. Environmental Protection Agency method code.
KES: *Klebsiella*, Enterobacter, and *Serratia*.

Higher %RSD is expected near the reporting limit, so two tiers were evaluated for chlorides, TSS, and turbidity: lab-split results less than five times the reporting limit were considered separately from lab-split results equal to, or more than five times, the reporting limit. For FC bacteria, *E. coli*, and % KES, the two tiers evaluated were 50% of replicates ≤ 20% RSD and 90% of replicates ≤ 50% RSD.

Both tiers were compared to the target precision objectives for FC bacteria, *E. coli*, and % KES. The upper tier was compared to the target precision objective for chloride, TSS, and turbidity.

Field replicate samples (side-by-side duplicates) were collected for at least 10% of the total number of general chemistry samples and at least 20% of the total number of microbiology samples in order to assess total precision (i.e., total variation) for field samples. As was done for the lab precision evaluation, two tiers were also evaluated for total precision: field-replicate results less than five times the reporting limit and field-replicate results equal to, or more than five times, the reporting limit for chloride, TSS, and turbidity. For FC bacteria, *E. coli*, and % KES, the two tiers evaluated were 50% of replicates ≤ 20% RSD and 90% of replicates ≤ 50% RSD. %RSD was calculated for each parameter using field replicate results greater then reporting limits.

Analytical framework

Although TMDL studies normally express allocations as pollutant loads (pollutant concentration multiplied by streamflow), this approach does not work well for bacteria TMDL studies. An allocation of FC pollutant loads in terms of "numbers of bacteria per day" is awkward, challenging to understand, and not useful.

Statistical Roll-Back Method

Instead of managing FC pollution in terms of total load, Ecology has used the Statistical Roll-Back Method (Ott, 1995) to manage the distribution of FC counts. The approach relates the analysis to the FC concentration standard better and has proven successful in past bacteria TMDL assessments (Joy, 2000; Sargeant, 2002; Tarbutton et al., 2010).

The Statistical Roll-Back Method was used to establish FC reduction targets at all sampling sites that had sufficient sampling size (>4 samplings). The roll-back method assumes that the distribution of FC concentrations follows a log-normal distribution. The cumulative probability plot of the observed data gives an estimate of the geometric mean and 90th percentile which can then be compared to the FC concentration standards. If the geometric mean and/or the 90th percentile do not meet the criteria, the whole distribution needs to be "rolled-back" to match the more restrictive of the two criteria. The amount a site's distribution of FC counts needs to be "rolled-back" is expressed as the FC target percent reduction required to comply with both parts of the FC water quality criteria.

The roll-back procedure used is as follows:

- A check was made to ensure the FC data collected in 2004-06 fit a log-normal distribution at each sampling location. WQHYDRO® (Aroner, 2003) was used to test the FC data for log-normal distribution fit.
- An Excel® spreadsheet was used to calculate the geometric mean of the data.
- The 90th percentile of the data was estimated by using the following statistical equation. (The 90th percentile value of samples was used in this TMDL evaluation as an estimate for the "no more than 10% samples exceeding …." criterion in the FC bacteria standard (WAC 173-201A.)).

$$90^{th} \text{ percentile} = 10^{(\mu_{log} + 1.28 * \sigma_{log})}$$

where: μ_{log} = mean of the log-transformed data.

σ_{log} = standard deviation of the log-transformed data.

- The target percent reduction required for the Yakima Area Creeks TMDL study was set as the highest of the following two resulting *Primary Contact* values:

$$\text{Target percent reduction} = \left[\frac{observed\ 90th\ percentile - 200\ cfu/100mL}{observed\ 90th\ percentile}\right]x100$$

$$\text{Target percent reduction} = \left[\frac{observed\ geometric\ mean - 100\ cfu/100mL}{observed\ geometric\ mean}\right]x100$$

The FC bacteria TMDL targets are developed to assist water quality managers in assessing the progress toward compliance with the FC water quality criteria. Compliance is measured as meeting water quality criteria. Any water body with FC bacteria TMDL targets is expected to meet both the applicable geometric mean and "not more than 10% of samples" criteria, and also to support beneficial uses of the water body.

Simple loading analysis

Simple load analyses were performed using a spreadsheet to evaluate the mass balance of FC bacteria, TSS, and chloride for each reach. Loads were not used to determine the amount of FC reduction needed at sites; only the measured concentration data were used to calculate the target percent reductions needed. A simple mass-balance was performed to show the general pattern of loading and possible unidentified sources within the watershed. The patterns will help in directing implementation to the highest loading sources first. Cleaning up high loading sources will benefit downstream stations where the upstream loads are also causing exceedances.

Loads were calculated by multiplying the FC concentration by the flow at each site. FC bacteria are measured in colony forming units (cfu) per 100 mL, and flow is measured in cubic feet per second (cfs). The resulting product was converted to the daily load of FC bacteria, measured in billion cfu per day.

For each sampling survey, measured upstream and tributary loads entering a reach were subtracted from the measured downstream load of that reach to calculate a nonpoint load within that reach. If the downstream load was less than the sum of the upstream load and tributary loads, then there was no apparent nonpoint load to that reach.

The loading analysis treated FC bacteria, TSS, and chloride conservatively. Loss from settling, gain from re-suspension, and FC bacteria loss from die-off were not measured or approximated. Therefore, the residual term of the mass balance (i.e., the unexplained gain or loss in a reach) includes these unmeasured losses and gains, plus any errors in measuring the known loads.

The lack of steady-state flow for some sample dates increased the error of the reach-load analysis. Generally, the flow was steady during both the non-irrigation season and irrigation season.

Individual reach loads were averaged over a non-irrigation season and irrigation season, and then compared to other reach loads to develop an overall loading pattern. Averaging the loads lessened the impact of any one individual survey load, which helped smooth out the inherent variability of the loads.

Again, the goal of the simple mass-balance was to show the general pattern of loading within the watershed to help in direct implementation efforts.

Ecology Study Results and Discussion

Ecology developed the *Data Summary Report: Yakima Area Creeks Fecal Coliform Total Maximum Daily Load Study* (Mathieu and Joy, 2008) to summarize the water quality and streamflow data collected from December 2004 through March 2006.

All laboratory and field data collected for the *Yakima Area Creeks Fecal Coliform TMDL Study*, 2004-06 and 2010, are loaded into Ecology's Environmental Information Management (EIM) database. These data are available online from the Ecology website at: www.ecy.wa.gov/eim/. Several query options are available. The study identification (study ID) designation is "YUTTMDL," and the study name is "Yakima Urban Tributaries Fecal Coliform TMDL."

Sample dates

2004-06 survey dates

Sampling began on December 6, 2004 and continued until March 7, 2006. Table 7 lists the 30 sampling surveys. The surveys were partitioned into either a non-irrigation season or irrigation season group based on the start and end of irrigation use in the study area (April to October).

Table 7. Sampling dates for the Mid-Yakima Basin Bacteria TMDL, 2004-06.

Non-Irrigation Season	Irrigation Season
December 6, 2004	April 4-5, 2005
December 13-15, 2004	April 18-20, 2005
January 10-12, 2005	May 2-3, 2005
February 7-9, 2005	May 9, 2005
March 7-9, 2005	May 10, 2005
November 6-7, 2005	May 23-24, 2005
November 28-30, 2005	June 13-14, 2005
December 5-7, 2005	June 27-28, 2005
December 19-21, 2005	July 11-12, 2005
January 10-11, 2006	July 25-27, 2005
February 28, 2006	August 8-9, 2005
March 5, 2006	August 22-24, 2005
March 6-7, 2006	September 12-13, 2005
	September 14, 2005
	September 26-27, 2005
	October 3-5, 2005
	October 17-18, 2005

2010 survey dates

Sampling began on June 14, 2010 and continued until December 1, 2010. Table 8 lists the 14 sampling surveys. The surveys were partitioned into either a non-irrigation season or irrigation season group based on the start and end of irrigation use in the study area (April to October).

Table 8. Sampling dates for the Mid-Yakima Basin Bacteria TMDL, 2010.

Non-Irrigation Season	Irrigation Season
November 2-3, 2010	June 14-15, 2010
November 15, 2010	June 29-30, 2010
December 1, 2010	July 13-14, 2010
	July 27, 2010
	August 11, 2010
	August 24, 2010
	September 14-15, 2010
	September 20-21, 2010
	September 27, 2010
	October 4-5, 2010
	October 18-20, 2010

Seasonal source assessment

Separate bacteria source assessment (or screening) was analyzed for either a low-flow or high-flow season. The determination of low-flow and high-flow seasons was based on the irrigation schedule and the associated streamflows. Figure 2 is an example of the seasonal hydrologic characteristics associated with agricultural irrigation and drainage operation in the study area. Historical data suggest that the months April through October, the high-flow irrigation season, are the critical period for elevated FC counts (Joy, 2005).

Typically, months that receive less precipitation yield lower runoff events; however, with the irrigation and drainage, runoff pollution during these months is still a potential source of bacteria. However, the large volume of dilution water during the irrigation season may also potentially mask some FC sources.

Irrigation season (April through October) sources include:

- Direct discharge from POTWs.
- Indirect discharge from leaking sanitary sewer and septic systems.
- Direct discharge from failing septic systems.
- Direct deposition of feces into surface waters by animals.
- Contaminated runoff from dry-weather outdoor water use, such as agriculture and landscape irrigation and vehicle washing.

- Direct discharge of contaminated non-stormwater discharges. During non-runoff periods, water from springs and other sources may be discharged to streams. It is possible for this water to be contaminated with bacteria at the source or within the conveyance system.

Non-irrigation season (November through March) sources include all of the sources listed above. But in addition, pollutant loading likely includes a high proportion of urban, rural, and agricultural runoff from precipitation, snowmelt, and stormwater flow.

Quality assurance results

Data collected for the Yakima Area Creeks FC Bacteria TMDL study were in compliance with Washington State law (RCW 90.48.585; Ecology, 2012b) and Ecology Water Quality Program Policy 1-11 (Ecology, 2006). The collection of the data followed standard data quality assurance (QA) procedures. The data were also evaluated to determine whether data QA/quality control (QC) objectives for the project were met. As a result, the data are credible and representative, and appropriate for use in TMDL development. Water quality data QA/QC objectives for precision are described in Table 6.

QA/QC for samples

Laboratory

All samples were received in good condition and were properly preserved, as necessary. The temperature of the shipping coolers was between proper ranges of 2°C to 6°C for nearly all sample shipments. Two sample coolers were shipped out of the proper temperature ranges. One sample cooler was too cold (0°C) upon arrival to MEL, and the other sample cooler was too warm (8°C) upon arrival to MEL. These samples were qualified as estimates using a “J” qualifier.

Although all samples were shipped the same day they were collected, holding times were sometimes violated because of delayed in-transport problems or because the samples were held too long at MEL before analysis. MEL qualified all samples that were analyzed beyond holding time as an estimate using a “J” qualifier. The qualified FC bacteria results were taken into consideration during the log-normal distribution plots, so that the estimated result did not inappropriately affect the FC bacteria sample set distribution.

For the most part, data quality for this project met all laboratory QA/QC criteria as determined by MEL. Individual exceptions that caused the results to be qualified as an estimate were qualified with a “J” qualifier in the data tables. All qualifications will be taken into consideration for the purpose of data analysis.

Precision

Analytical precision

The analytical precision results are listed in Table 9.

Table 9. Lab precision results for the Mid-Yakima Basin Bacteria TMDL study.

Results at or below the detection limit were excluded from consideration.

Parameter	Reporting Limit	Target Precision	% of replicates ≤ 20% RSD or Average %RSD for replicates < 5X reporting limit	% of replicates ≤ 50% RSD or Average %RSD for replicates ≥ 5X reporting limit
Fecal Coliform[1]	1 cfu/100 mL	> 50% and > 90%	60.9%	92.2%
Escherichia coli[1]	1 cfu/100 mL	> 50% and > 90%	65.2%	92.4%
% KES[1]	0%	> 50% and > 90%	59.0%	79.5%
Chloride[2]	0.1 mg/L	< 5% RSD	all samples ≥ 5X	0.8%
TSS[2]	1 mg/L	< 15% RSD	10.5%	4.3%
Turbidity[2]	0.5 mg/L	< 15% RSD	2.3%	2.2%

[1]Two-tiered: 50% of replicates ≤ 20% RSD; 90% of replicates ≤ 50% RSD

[2]Replicates divided into two categories; < 5 times and ≥ 5 times the reporting limit

The majority of analytical precision values met the target precision objectives. The only one not to meet its objectives was the upper tier for % KES. % KES and *E. coli* were collected for better source identification and treatment, and since % KES is being used solely as a guide for implementation, the analytical precision for % KES is acceptable for those purposes.

Total precision

The total precision results are listed in Table 10.

Table 10. Total precision for the Mid-Yakima Basin Bacteria TMDL study.

Results at or below the detection limit were excluded from consideration.

Parameter	Reporting Limit	Target Precision	% of replicates ≤ 20% RSD or Average %RSD for replicates < 5X reporting limit	% of replicates ≤ 50% RSD or Average %RSD for replicates ≥ 5X reporting limit
Fecal Coliform[1]	1 cfu/100 mL	> 50% and > 90%	61.5%	90.2%
Escherichia coli[1]	1 cfu/100 mL	> 50% and > 90%	60.4%	97.9%
% KES[1]	0%	> 50% and > 90%	71.4%	82.1%
Chloride[2]	0.1 mg/L	< 5% RSD	all samples ≥ 5X	3.0%
TSS[2]	1 mg/L	< 15% RSD	18.1%	9.7%
Turbidity[2]	0.5 mg/L	< 15% RSD	5.5%	6.4%

[1]Two-tiered: 50% of replicates ≤ 20% RSD; 90% of replicates ≤ 50% RSD

[2]Replicates divided into two categories; < 5 times and ≥ 5 times the reporting limit

As expected, %RSD for field replicates was higher than that for lab splits because the %RSD is a measurement of total variability, including both field and analytical variability.

The majority of total precision values met the target precision objectives. The only ones not to meet their objectives were the upper tier for % KES and the lower tier for TSS. Again, % KES and E. coli were collected for better source identification and treatment, and since % KES is being used solely as a guide for implementation, the analytical precision for % KES is acceptable. As previously stated, %RSD is expected to be higher for values close to their reporting limit, so the upper tier, not the lower tier, for chloride, TSS, and turbidity was compared to the target precision to determine if the data were appropriate for use.

Conclusion

Overall, the data collected by Ecology for this project met the data quality objectives. There was higher variability in the upper tier % KES and lower tier TSS data, but this is acceptable. Based on the QA and QC review, the Ecology data are of good quality, properly qualified, and acceptable for use in a TMDL analysis.

Study results and discussion

Seasonal and monitoring period variation

Joy (2005) reviewed the historical FC data from the long-term monitoring stations in the Mid-Yakima Basin Bacteria TMDL study area (Stations 37G120, and 38E120). That assessment revealed that considerable monthly variation in FC counts exists in this study area. Higher concentrations occurred from May to October.

A similar seasonal pattern is apparent during the 2004-06 monitoring period. Combining data from all sites in the study area provides a visual example for the region. Figure 7 shows the monthly geometric means and 90^{th} percentiles for all data collected in the Mid-Yakima Basin Bacteria TMDL study area during the 2004-06 study. Geometric mean and 90^{th} percentiles statistics both were out of compliance with criteria for the months of May through October. The 90^{th} percentiles of all months except February were out of compliance as well.

Combining the data collected in 2010 from all sites appears to yield a similar seasonal pattern. Figure 8 shows the monthly geometric means and 90^{th} percentiles for all data collected in the Mid-Yakima Basin Bacteria TMDL study are during the 2010 study. Geometric mean and 90^{th} percentiles statistics both were out of compliance with criteria for the months of June through October. The 90^{th} percentiles of all months were out of compliance. No samples were taken for the months of January through May during the 2010 study.

Improvements were made in the study area between the 2004-06 and 2010 data collections. Therefore, the two data sets were analyzed separately to determine if these improvements have led to water quality improvements. Roll-back statistics for common sites in the two data sets were compared. Unfortunately no storm events were captured during the 2010 study, so the stormwater improvements made in the Wide Hollow Creek drainage after the 2004-06 study were not assessed.

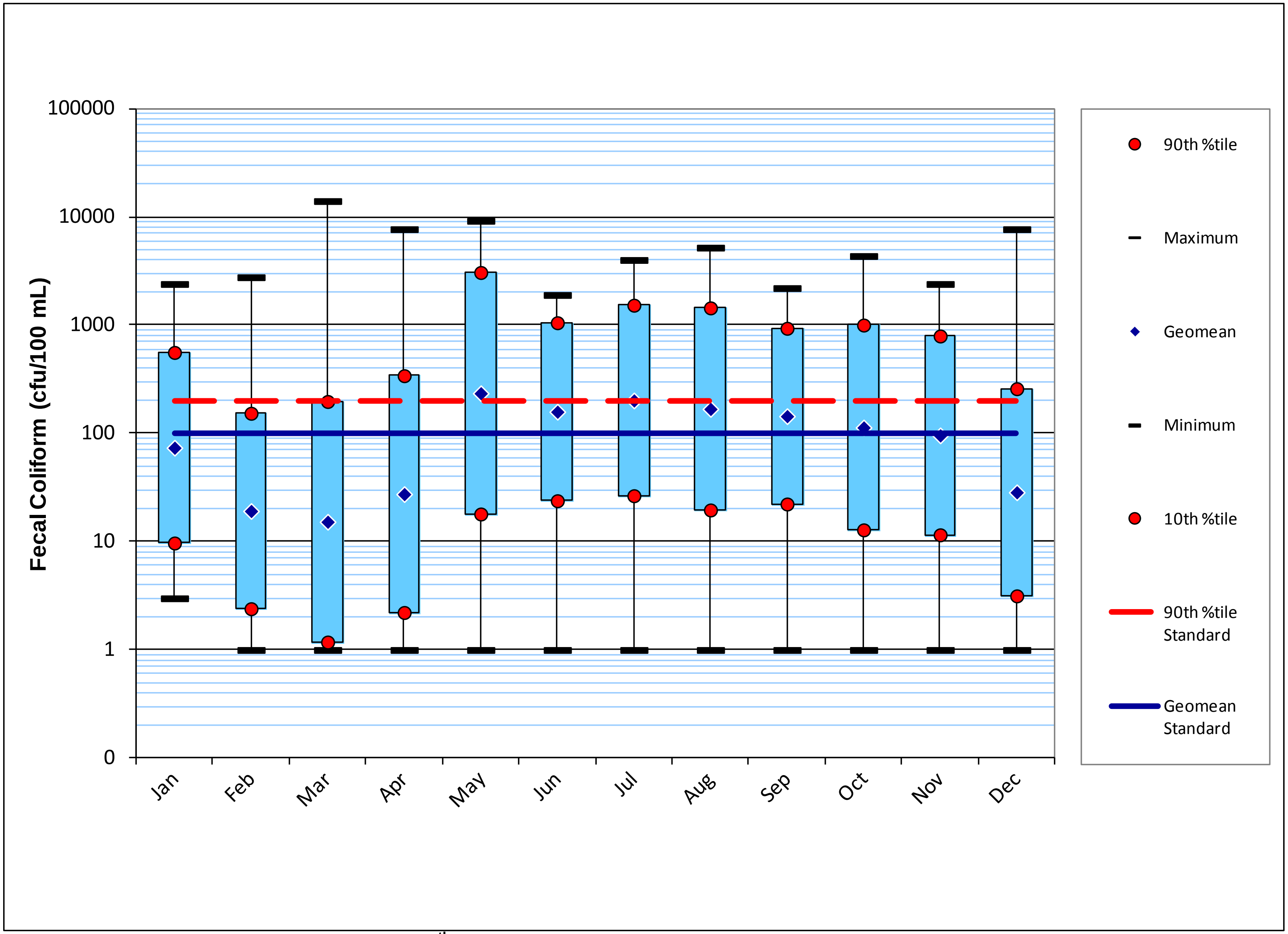


Figure 7. Monthly geometric means and 90th percentiles for FC data collected at all sites in the Mid-Yakima Basin Bacteria TMDL study area during 2004-06

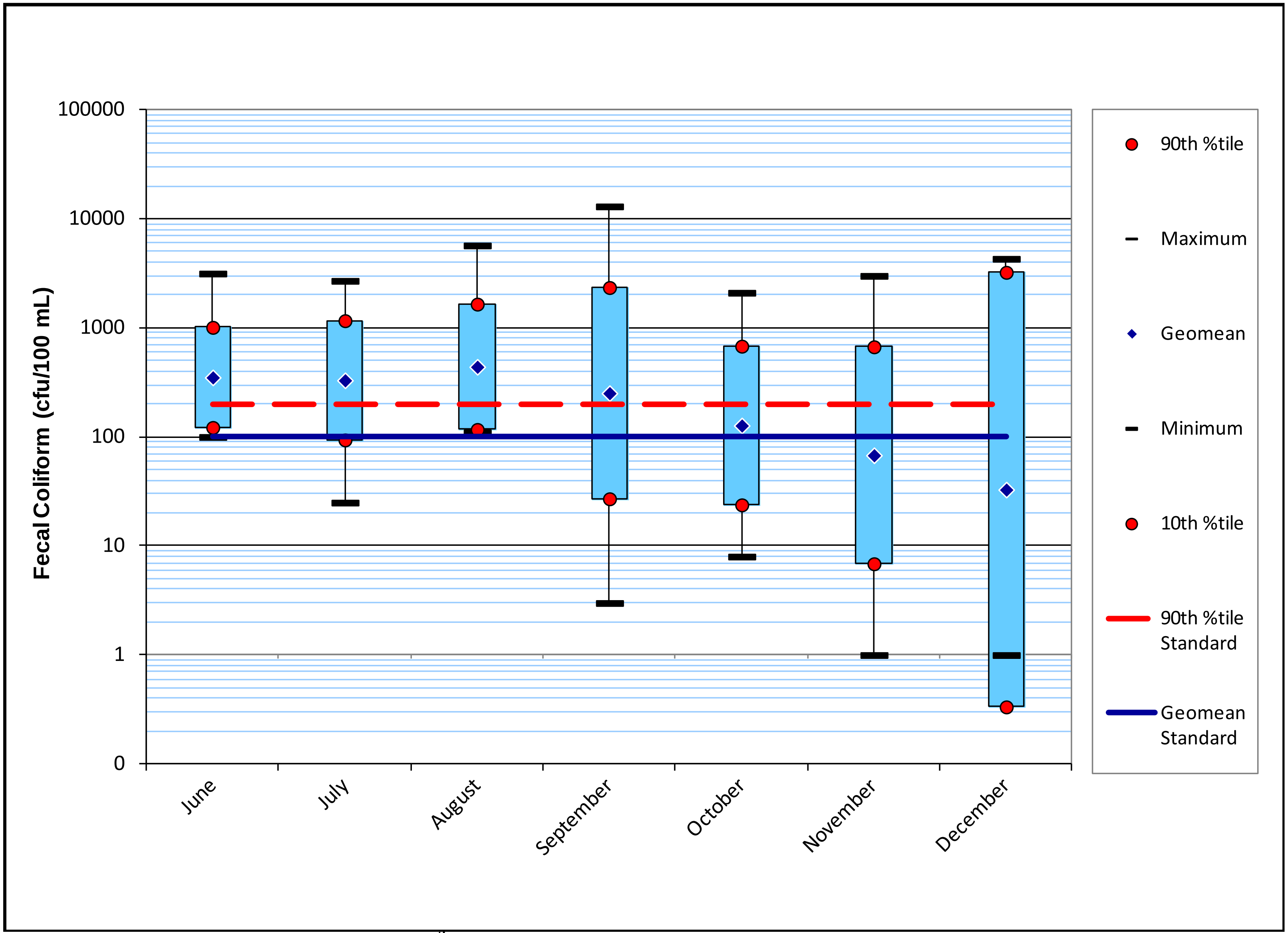


Figure 8. Monthly geometric means and 90th percentiles for FC data collected at all sites in the Mid-Yakima Basin Bacteria TMDL study area during 2010.

TMDL analyses

Ecology divided the study year into two seasons based on the hydrologic conditions associated with the agriculture irrigation and drainage operation (Tables 7 and 8).

Seasonal loading analysis of the Mid-Yakima Basin creeks had limitations:

- During both the non-irrigation and irrigation season, even though there were mostly steady-state flow conditions in the creeks, large time-of-travel between sites meant that the conservative transport of bacteria and TSS from site to site was unlikely. This means nonpoint contributions between sites could be under-estimated, because losses during the transport of upstream loads are not accounted for (i.e., die-off, settling).
- During the non-irrigation season, large rain events can dominate the seasonal trend. Generally, these events create non-steady-state conditions that affect the ability to conduct mass balance loading calculations.

The loading analysis is a tool used to assess loading contributions from different sources, which help to identify and prioritize areas in need of cleanup efforts. The loading contributions are expressed as load percentages of the total load.

While the loading percentages are helpful, it is important to remember that they do not equate with a violation in the standard's numeric criteria. Loading is the product of streamflow and concentration, so high loading may at times reflect mostly high streamflows. The numeric criteria exceedances are identified using concentrations only.

The monthly comparisons of precipitation between historical (1946-2003) and the two studies (2004-06 and 2010) are shown in Figure 9 (NOAA, 2012). The comparisons of cumulative precipitation between historical (1946-2003) and the two studies (2004-06 and 2010) are shown in Figure 10. December 2004 was 15% drier than the historical average for December. During 2005, 7 months were drier than the historical averages. However, the annual cumulative amount of precipitation during 2005 was slightly wetter (5%) than the historical average. January 2006 was wetter than the historical average, but February and March 2006 were drier than the historical averages. The cumulative amount of precipitation during these three months was slightly wetter (7%) than the historical averages. During 2010, 4 out of the 7 months sampled were wetter than the historical averages. The total amount of precipitation during these 7 months was 36% wetter than the historical averages.

Presented below are the 2004-06 and 2010 seasonal FC bacteria, TSS, and chloride results for Cowiche Creek, Wide Hollow Creek, and Moxee Drain.

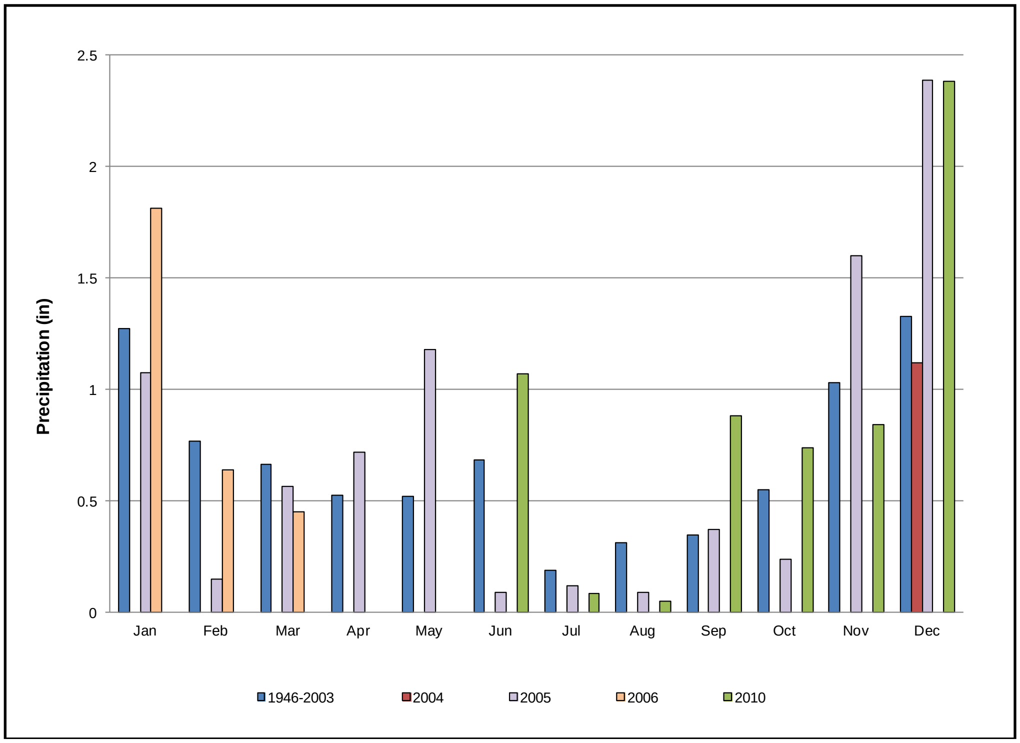


Figure 9. Historical and study precipitation comparison for Mid-Yakima Basin Bacteria TMDL.

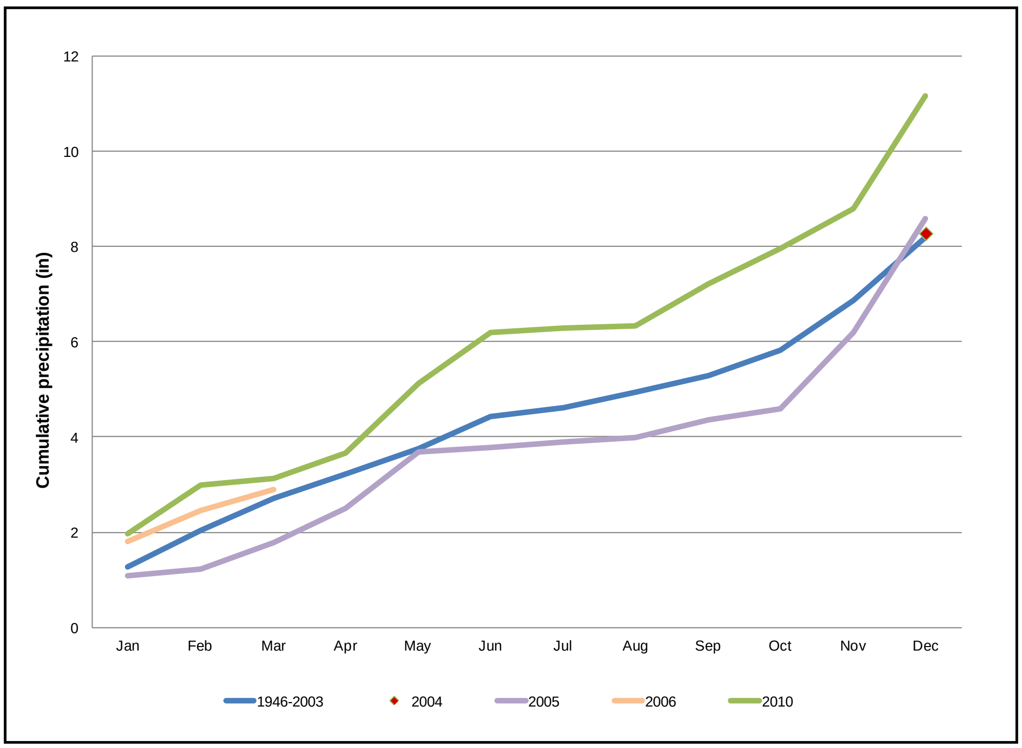


Figure 10. Historical and study cumulative precipitation comparison for Mid-Yakima Basin Bacteria TMDL.

Cowiche Creek

Cowiche Creek and its tributaries were monitored from near the headwaters on the NF and SF Cowiche Creeks (sites 38-FC-7 and 38-FC-4, respectively) to just upstream of the confluence with the Naches River (site 38-FC-1). During the 2004-06 surveys, Ecology sampled 7 sites along NF Cowiche Creek, 6 sites along SF Cowiche Creek, and 3 sites along Cowiche Creek. During the 2010 surveys, Ecology sampled 2 sites along Cowiche Creek.

NF Cowiche Creek

NF Cowiche Creek and its tributaries were monitored from near the headwaters above the reservoir (site 38-FC-7) to its confluence with SF Cowiche Creek (site 38-FC-3). During the 2004-06 surveys, Ecology sampled 4 mainstem NF Cowiche Creek sites, 2 Cowiche POTW sites, and 1 irrigation return site. NF Cowiche Creek was not monitored during the 2010 surveys.

Table 11, Figure 11, and Figure 12 present the non-irrigation season and irrigation season summary statistics of FC counts. Table 11 also presents the target reductions necessary to meet the water quality standards in NF Cowiche Creek.

Table 11. 2004-06 non-irrigation and irrigation season summary statistics of FC counts and target percent reductions for stations in the NF Cowiche Creek.

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile*	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
Non-Irrigation Season								
38-FC-7	2	1	0	6	185	41	0%	0%
38-FC-6	3	3	2	17	166	108	0%	0%
38-FC-WWR[1]	9	14	18	132	964	1700	44%	90%
38-IS-7	0	-	-	-	-	-	-	-
38-FC-3.5	5	4	5	34	247	170	0%	19%
38-FC-3	4	2	2	7	30	22	0%	0%
Irrigation Season								
38-FC-7	0	-	-	-	-	-	-	-
38-FC-6	3	63	31	159	826	690	33%	76%
38-FC-WWR[1]	15	6	16	167	1721	4350	60%	94%
38-IS-7	1	830	-	830	-	830	100%	88%
38-FC-3.5	6	38	46	93	189	200	0%	0%
38-FC-3	8	2	4	48	553	330	13%	64%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.
**Cells shaded in this column are values based on less than 5 samples collected at that station.
[1] Permit limits are a monthly geomean of 50 cfu/100 mL and a weekly maximum of 100 cfu/100 mL.
- Not enough data for the calculations.

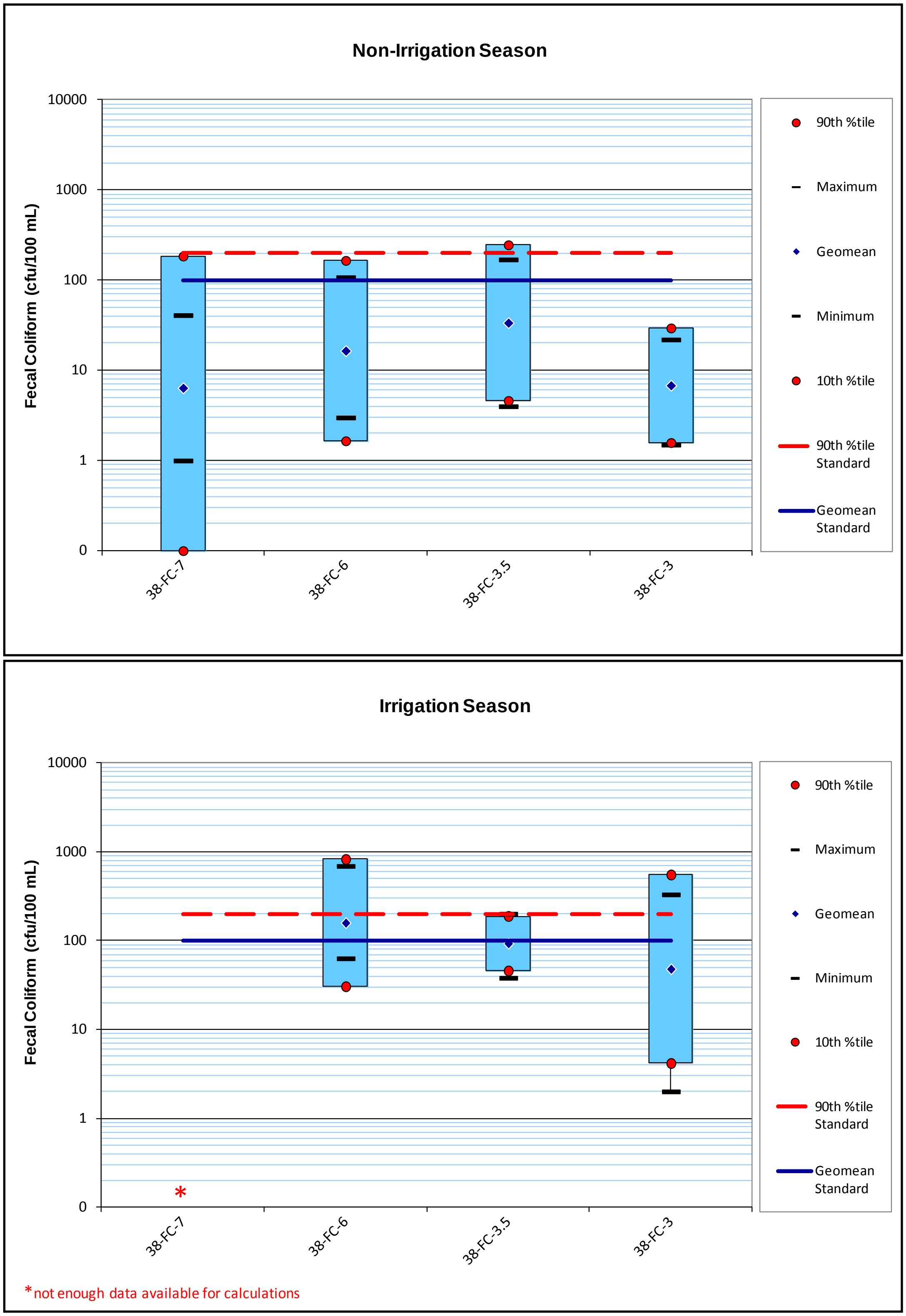
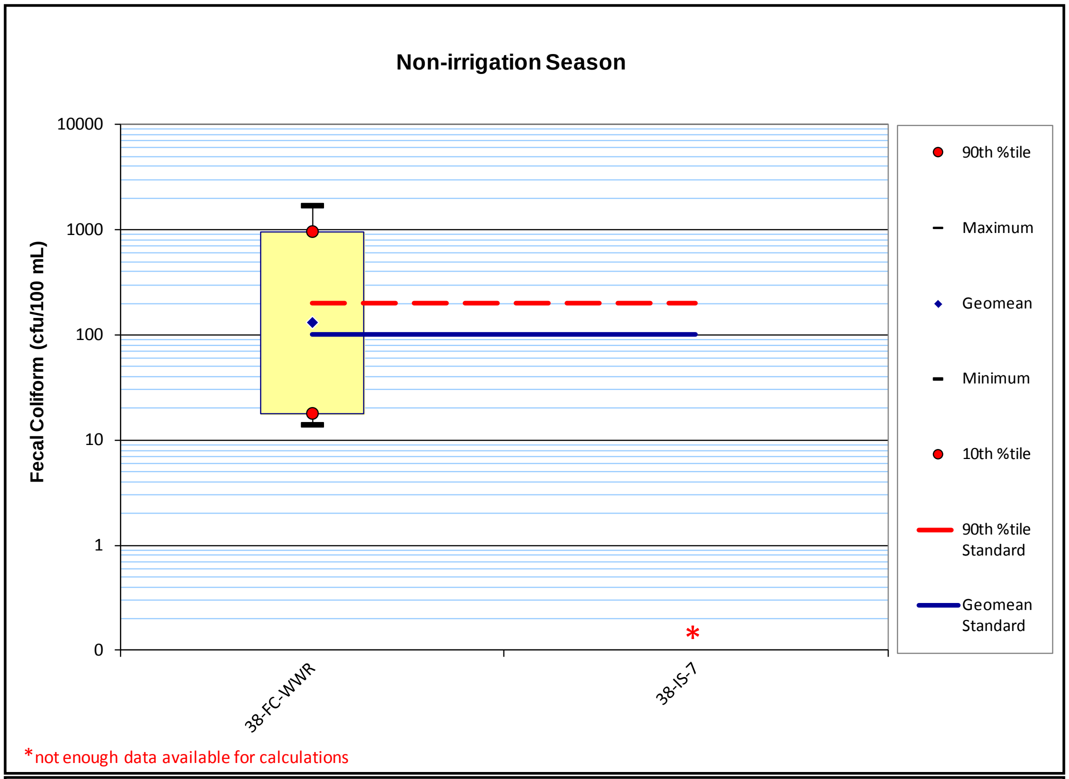


Figure 11. 2004-06 non-irrigation and irrigation season summary statistics of FC counts for mainstem sites of NF Cowiche Creek.



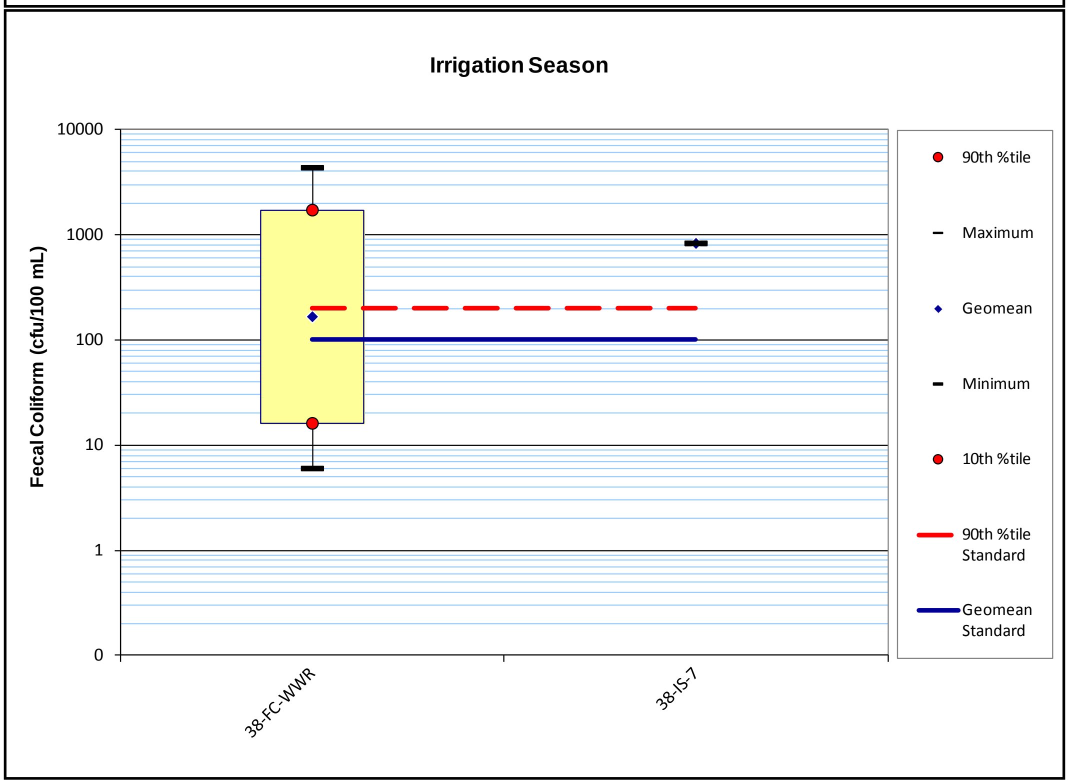


Figure 12. 2004-06 non-irrigation and irrigation season summary statistics of FC counts for tributary sites of NF Cowiche Creek.

Note the ambient water quality criteria are presented, but the permit limits at the POTW (38-FC-WWR) are a monthly geomean of 50cfu/100mL and a weekly maximum of 100cfu/100mL.

The most upstream site (38-FC-7) at French Road above the reservoir met the criteria for Primary Contact Recreation during the non-irrigation season when water was present. The creek was dry during the irrigation season at this site.

FC concentrations below the reservoir (site 38-FC-6) met the criteria for during the non-irrigation season when water was present. However, on the three occasions when water was present during the irrigation season this site did not meet either part, geomean and 90th percentile, of the criteria. FC counts were 63 to 690 cfu/100 mL.

The Cowiche POTW effluent was sampled after the UV disinfection chamber (site 38-FC-WWE) and again after the cooling channel just prior to the discharge to NF Cowiche Creek (site 38-FC-WWR). A comparison between observed concentrations and the permit limits at the POTW is included in another section later in this report.

The irrigation return off Thompson Road had a very high concentration result (830 cfu/100 mL). This concentration does not meet the criteria, but more samples are needed to better calculate the necessary parts of the criteria at this site.

The NF Cowiche Creek was sampled at Thompson Road and Mahoney Road before its confluence with the SF Cowiche Creek (sites 38-FC-3.5 and 38-FC-3, respectively). At Thompson Road the FC concentrations yielded a 90th percentile value greater than the criteria during the non-irrigation season. At this site during the irrigation season, the concentrations yielded a 90th percentile that met the criteria. At Mahoney Road, the FC concentrations met both parts of the criteria in the non-irrigation season, but the concentrations did not meet the 90th percentile criteria in the irrigation season. The site at Mahoney Road (38-FC-3) was moved upstream to Thompson Road (38-FC-3.5) in the middle of the project due to a poor streamflow cross-section. 38-FC-3 was sampled December 2004 to July 2005, and 38-FC-3.5 was sampled August 2005 to March 2006. Therefore, the differences between the statistics at these two sites may be due to the difference in the time of year samples were collected.

Average seasonal FC loads were calculated for three reaches of the NF Cowiche Creek using sampling surveys where concentration and streamflow data were collected at the three fixed-network mainstem sites. Data were used from two sampling surveys in the non-irrigation season and three sampling surveys in the irrigation season, and the loads presented below are estimates due to the lack of data available for average loading calculations. Streamflows during the non-irrigation season were much greater than during the irrigation season. Figure 13 presents the average non-irrigation season and irrigation season FC loads for each reach and tributary. Table 12 summarizes the average loads as their percentages of the total load to NF Cowiche Creek if FC die-off or settling is not considered.

The entire irrigation season load to NF Cowiche Creek was from the Cowiche POTW (60%) and above RM 6.7 (40%). Since 38-FC-7 was dry during the irrigation season, the average load calculated at 38-FC-6 represented the sum of the intermittent nonpoint loads above RM 6.7.

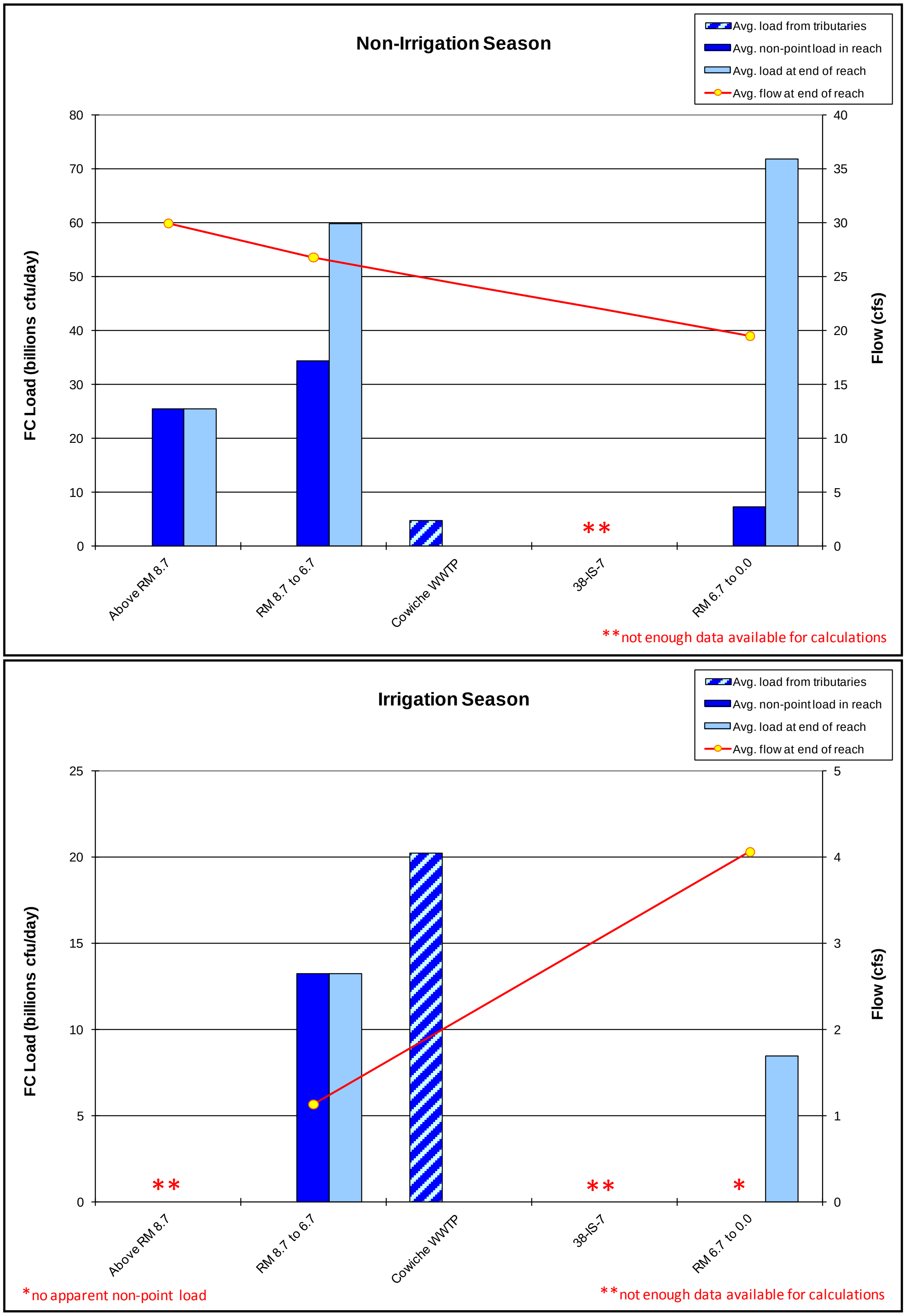


Figure 13. 2004-06 non-irrigation and irrigation season average FC loads for NF Cowiche Creek.

Note the differences in vertical axes scale between the charts.

Table 12. 2004-06 non-irrigation and irrigation season FC loading percentages to NF Cowiche Creek.

Reach (NF Cowiche RM) or Tributary	Site	Non-Irrigation Season	Irrigation Season
Above RM 8.7	38-FC-7	35.5%	-
RM 8.7 to 6.7	38-FC-6	47.9%	39.6%[1]
Cowiche POTW	38-FC-WWR	6.5%	60.4%
38-IS-7	38-IS-7	-	-
RM 6.7 to 0.0	38-FC-3.5 / 38-FC-3	10.1%[2]	0.0%[2]

[1] This percentage is the sum of all unaccounted for nonpoint loads above RM 6.7.
[2] This percentage is the sum of all unaccounted for nonpoint loads between RM 6.7 and RM 1.1.
- No data available for calculations

The irrigation return off Thompson Road was running only once during the irrigation season, but this sample was not taken during a sample survey where the mainstem sites were also sampled. Therefore, it was omitted from the loading analysis. More samples need to be taken at this site to characterize its frequency and percentage of loading to NF Cowiche Creek.

Most of the non-irrigation season FC load to NF Cowiche Creek was from unidentified sources in the reach between RM 8.7 and RM 6.7 (48%), above RM 8.7 (36%), and in the reach between RM 6.7 and RM 1.1 (10%). For the most part, these loads were within the capacity of the creek to meet water quality criteria.

The site at Mahoney Road (38-FC-3) was moved upstream to Thompson Road (38-FC-3.5) in the middle of the project, due to a poor streamflow cross-section. The data collected at 38-FC-3 were not taken during sample surveys where the other mainstem sites were also sampled, so 38-FC-3 data were omitted from the loading analysis. The seasonal average loads for the combined site 38-FC-3.5 / 38-FC-3 were calculated using data collected from 38-FC-3.5. Since 38-FC-3.5 is approximately 1.1 miles upstream of the confluence with SF Cowiche Creek, there is potential for additional loading being added downstream of this site prior to the confluence.

The non-irrigation season TSS loads were an order of magnitude higher than irrigation TSS loads in part from increased streamflows.

Table 13 presents the non-irrigation season and irrigation season TSS load contribution percentages. Nearly all of the non-irrigation season loading was from the reach between RM 6.7 to RM 1.1 (61%) and above RM 8.7 (39%).

Non-irrigation FC loading percentages were also high in the reach between RM 6.7 and RM 1.1 and above RM 8.7. Although only one rain event was sampled, the data suggests that conditions that elevate TSS, such as high flows or runoff processes (causing soil erosion), could also elevate FC concentrations in these reaches.

Since the creek was usually dry above 38-FC-6, the majority of irrigation season TSS loading to NF Cowiche Creek was from the reach between RM 6.7 and RM 1.1 (91%).

There is no apparent correlation between irrigation season TSS loading percentages and FC loading percentages in NF Cowiche Creek.

Table 13. 2004-06 non-irrigation season and irrigation season TSS and chloride loading percentages for NF Cowiche Creek.

Reach (NF Cowiche RM) or Tributary	Site	TSS		Chloride	
		Non-Irrigation Season	Irrigation Season	Non-Irrigation Season	Irrigation Season
Above RM 8.7	38-FC-7	39.1%	-	51.1%	-
RM 8.7 to 6.7	38-FC-6	0.0%	4.7%[1]	0.0%	4.3%[1]
Cowiche POTW	38-FC-WWR	0.1%	4.8%	8.4%	37.6%
38-IS-7	38-IS-7	-	-	-	-
RM 6.7 to 0.0	38-FC-3.5 / 38-FC-3	60.8%[2]	90.5%[2]	40.5%[2]	58.1%[2]

[1] This percentage is the sum of all unaccounted for nonpoint loads above RM 6.7.
[2] This percentage is the sum of all unaccounted for nonpoint loads between RM 6.7 and RM 1.1.
- Not enough data available for calculations

Non-irrigation season chloride loads were larger than irrigation season chloride loads.

Table 13 also presents the non-irrigation season and irrigation season chloride load contribution percentages. The majority of non-irrigation season loading was from above RM 8.7 (51%) and the reach between RM 6.7 and RM 1.1 (41%).

Non-irrigation FC loading percentages were also high above RM 8.7 and in the reach between RM 6.7 and RM 1.1. This suggests that conditions and nonpoint sources that elevate chloride, such as new water or waste sources (failing septic tanks), could be elevating FC concentrations. These unidentified sources should be considered for FC contamination in these reaches.

The majority of irrigation season chloride loading to NF Cowiche Creek was from the reach between RM 6.7 and RM 1.1 (58%) and the Cowiche POTW (38%).

There is no apparent correlation between irrigation season chloride loading percentages and FC loading percentages, except for at the Cowiche POTW.

Cowiche POTW

Cowiche POTW effluent was monitored at the UV chamber outlet (site 38-FC-WWE) and again after the cooling channel (site 38-FC-WWR) prior to its discharge to NF Cowiche Creek. These two sites were monitored only during the 2004-06 survey, not during the 2010 surveys. The FC counts are to meet permit limits at the latter site prior to discharge into the creek. The discharge does not have a mixing zone. The FC bacteria permit limits for the POTW effluent are a monthly geomean of 50 cfu/100 mL and a weekly maximum of 100 cfu/100 mL.

Table 14 and Figure 14 present the monthly summary statistics of FC counts based on the samples collected by Ecology.

Table 14. 2004-06 monthly summary statistics of FC counts based on Ecology samples for stations at Cowiche POTW.

Station ID	Month	Total # of Samples	Monthly Geomean > 50 cfu/100 mL*	Weekly Maximum > 100 cfu/100 mL*
38-FC-WWE	Dec-04	1	68	68
	Jan-05	1	2400	2400
	Feb-05	1	11	11
	Mar-05	1	43	43
	Apr-05	2	70	120
	May-05	2	14	19
	Jun-05	2	20	100
	Jul-05	2	147	500
	Aug-05	2	146	160
	Sep-05	2	70	700
	Oct-05	2	136	240
	Nov-05	1	220	220
	Dec-05	2	7	51
	Jan-06	1	960	960
	Feb-06	0	-	-
	Mar-06	1	230	230
38-FC-WWR	Dec-04	1	53	53
	Jan-05	1	1700	1700
	Feb-05	1	42	42
	Mar-05	1	14	14
	Apr-05	2	123	285
	May-05	2	10	17
	Jun-05	2	29	45
	Jul-05	2	179	290
	Aug-05	2	332	1200
	Sep-05	3	712	990
	Oct-05	2	1123	4350
	Nov-05	1	340	340
	Dec-05	2	59	80
	Jan-06	1	690	690
	Feb-06	0	-	-
	Mar-06	1	270	270

*Cells shaded in these columns are values that do not meet (exceed) permit numeric criteria.
- No samples available for calculations.

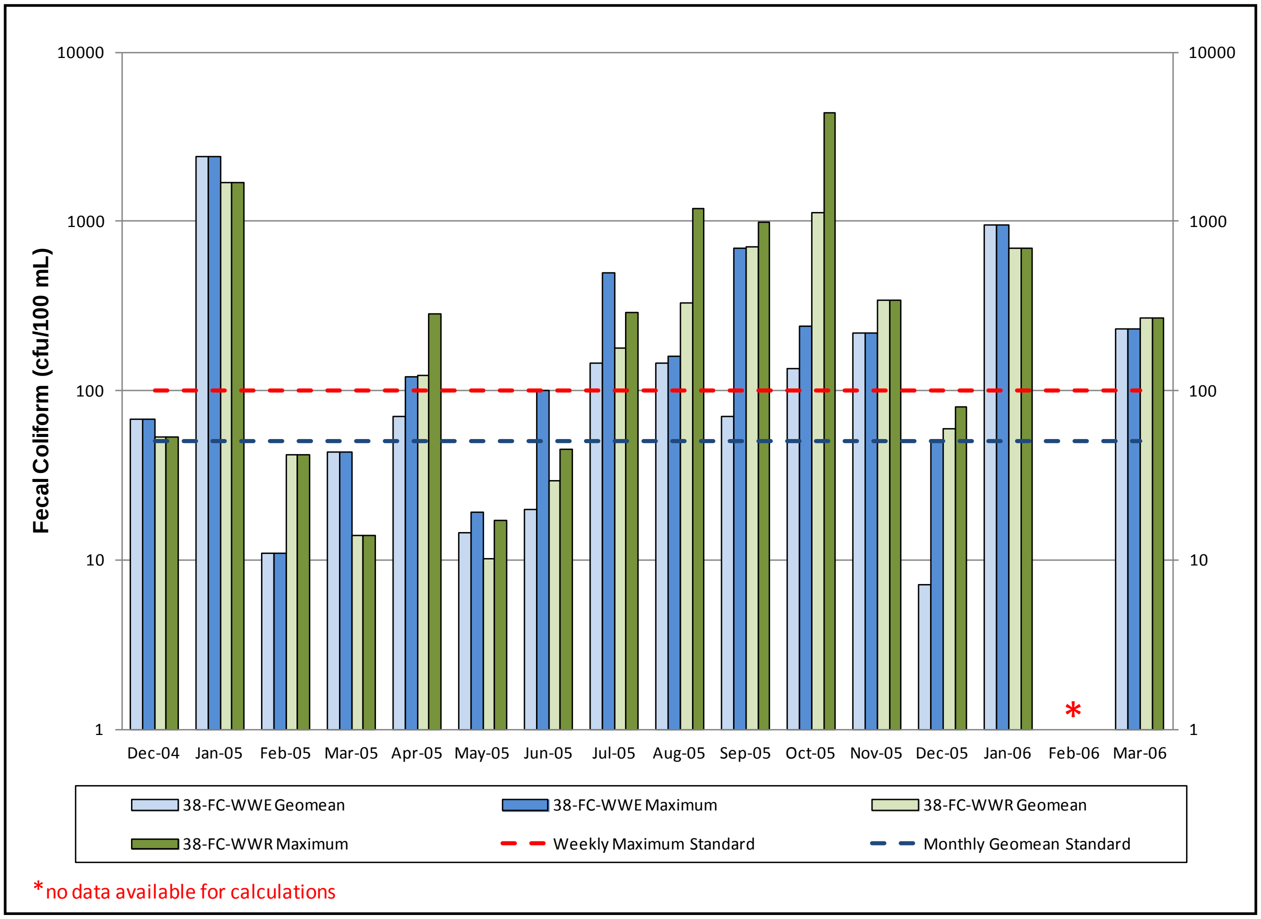


Figure 14. 2004-06 monthly summary statistics of FC counts based on Ecology samples for stations at Cowiche POTW.

The UV chamber was not consistently disinfecting effluent. The POTW had FC concentrations that exceeded permit limits during a majority of the months sampled. The concentrations appear to be slightly elevated at the downstream site (38-FC-WWR) between August 2005 and December 2005.

Average seasonal FC loads were calculated using sampling surveys where concentration and streamflow data were available at both sites. Therefore, data were used from 8 sampling surveys in the non-irrigation season and 14 sampling surveys in the irrigation season. Figure 15 presents the average non-irrigation season and irrigation season FC loads at the POTW. Table 15 summarizes the average loads as their percentages of the total load at the POTW.

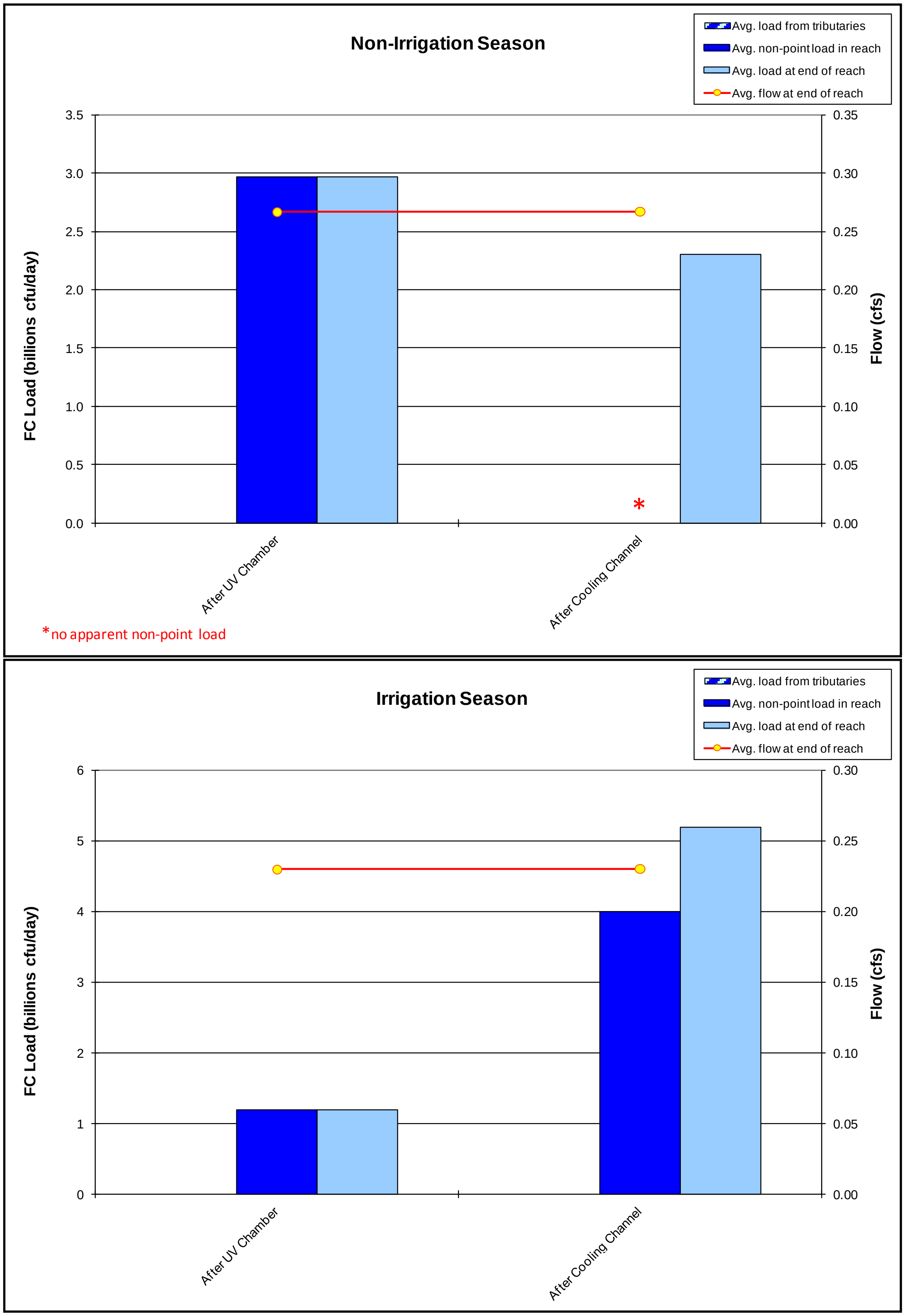


Figure 15. 2004-06 non-irrigation season and irrigation season average FC loads of the Cowiche POTW.

Note the differences in vertical axes scale between the charts.

Table 15. 2004-06 non-irrigation season and irrigation season FC loading percentages of the Cowiche POTW.

Reach (POTW)	Site (End of Reach)	Non-Irrigation Season	Irrigation Season
After UV Chamber	38-FC-WWE	100.0%	23.0%
After Cooling Channel	38-FC-WWR	0.0%	77.0%

The non-irrigation season and irrigation season FC loads at the Cowiche POTW were of similar magnitude. It appears that the entire non-irrigation season load at the POTW was from immediately after the UV chamber (100%). Therefore, the cooling channel appears to not be contributing additional FC loads to NF Cowiche Creek during the non-irrigation season.

Most of the irrigation season load at the POTW was from within the cooling channel (77%). Therefore, the cooling channel appears to be contributing additional FC loads to NF Cowiche Creek during the irrigation season. Beavers and their dams were present in the cooling channel during the sampling period, and their presence should be considered for the increase in FC loads within the cooling channel.

There is no apparent relationship between irrigation season TSS loads and FC loads at the Cowiche POTW.

Table 16. 2004-06 non-irrigation season and irrigation season TSS and chloride loading percentages of the Cowiche POTW.

Reach (POTW)	Site (End of Reach)	TSS		Chloride	
		Non-Irrigation Season	Irrigation Season	Non-Irrigation Season	Irrigation Season
After UV Chamber	38-FC-WWE	100.0%	100.0%	100.0%	100.0%
After Cooling Channel	38-FC-WWR	0.0%	0.0%	0.0%	0.0%

There is no apparent relationship between irrigation season chloride loads and FC loads at the Cowiche POTW. This suggests that conditions or sources that elevate chloride do not appear to be elevating FC concentrations in the cooling channel during the irrigation season.

SF Cowiche Creek

SF Cowiche Creek and its tributaries were monitored from near the headwaters at Cowiche Mill Road (site 38-FC-4) to its confluence with NF Cowiche Creek (site 38-FC-2). During the 2004-06 surveys, Ecology sampled 5 mainstem SF Cowiche Creek sites and 1 irrigation return site. SF Cowiche Creek was not monitored during the 2010 surveys. Streamflows dropped rapidly over the irrigation season to less than 1 cfs along the course of the creek from FC-4 to FC-2 in July through September. Streamflow gradually increased from mid-October through May.

Table 17, Figure 16, and Figure 17 present the non-irrigation season and irrigation season summary statistics of FC counts. Table 17 also presents the target reductions necessary to meet the water quality standards in SF Cowiche Creek.

Table 17. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts and target percent reductions for sites on SF Cowiche Creek.

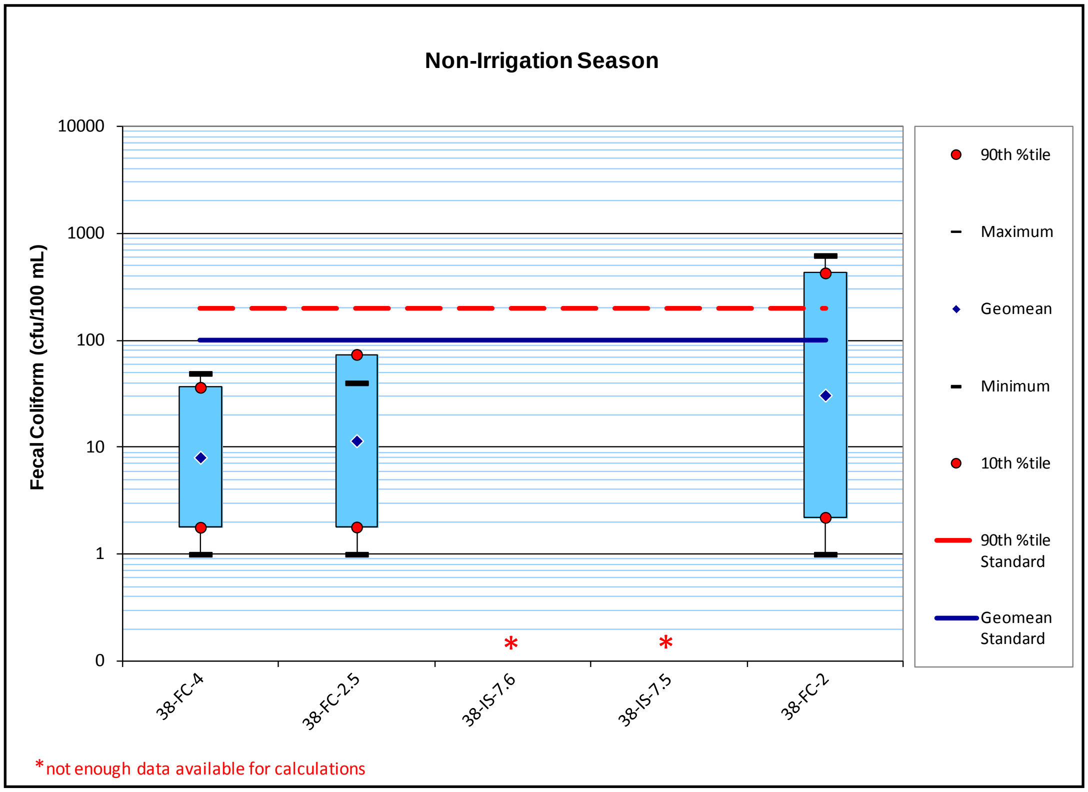
Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile*	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
Non-Irrigation Season								
38-FC-4	9	1	2	8	36	49	0%	0%
38-FC-2.5	5	1	2	12	74	40	0%	0%
38-IS-7.6	0	-	-	-	-	-	-	-
38-IS-7.5	0	-	-	-	-	-	-	-
38-IS-8.5	0	-	-	-	-	-	-	-
38-FC-2	9	1	2	31	426	620	22%	53%
Irrigation Season								
38-FC-4	13	1	3	19	103	150	0%	0%
38-FC-2.5	8	48	35	140	567	1500	25%	65%
38-IS-7.6	3	8	6	87	1313	440	33%	85%
38-IS-7.5	2	285	209	417	831	610	100%	76%
38-IS-8.5	3	37	19	164	1399	1000	33%	86%
38-FC-2	15	4	25	184	1378	2200	53%	85%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.
**Cells shaded in this column are values based on less than 5 samples collected at that station.
- Not enough data for the calculations.

FC concentrations at the most upstream site (38-FC-4) met both parts of the criteria for Primary Contact Recreation during both the non-irrigation season and irrigation season. Further downstream at 38-FC-2.5, FC concentrations became elevated. This site met both parts of the criteria in the non-irrigation season, but did not meet either part of the criteria in the irrigation season.

The three irrigation synoptic survey sites (38-IS-7.6, 38-IS-7.5, and 38-IS-8.5) were sampled only during the irrigation season and when flows were below 1 cfs. SF Cowiche Creek at Pioneer Way (38-IS-7.6) met the first part, geomean, of the criteria but did not meet the second part, 90th percentile. SF Cowiche Creek at Summitview Road (38-IS-7.5) and the irrigation return at Pioneer Road (38-IS-8.5) did not meet either part of the criteria.

SF Cowiche Creek at its confluence with NF Cowiche Creek (38-FC-2) was the only site with FC concentrations that did not meet both parts of the criteria during the non-irrigation season. This site met the first part of the criteria but did not meet the second part, 90th percentile. During the irrigation season, 38-FC-2 did not meet either part of the criteria.



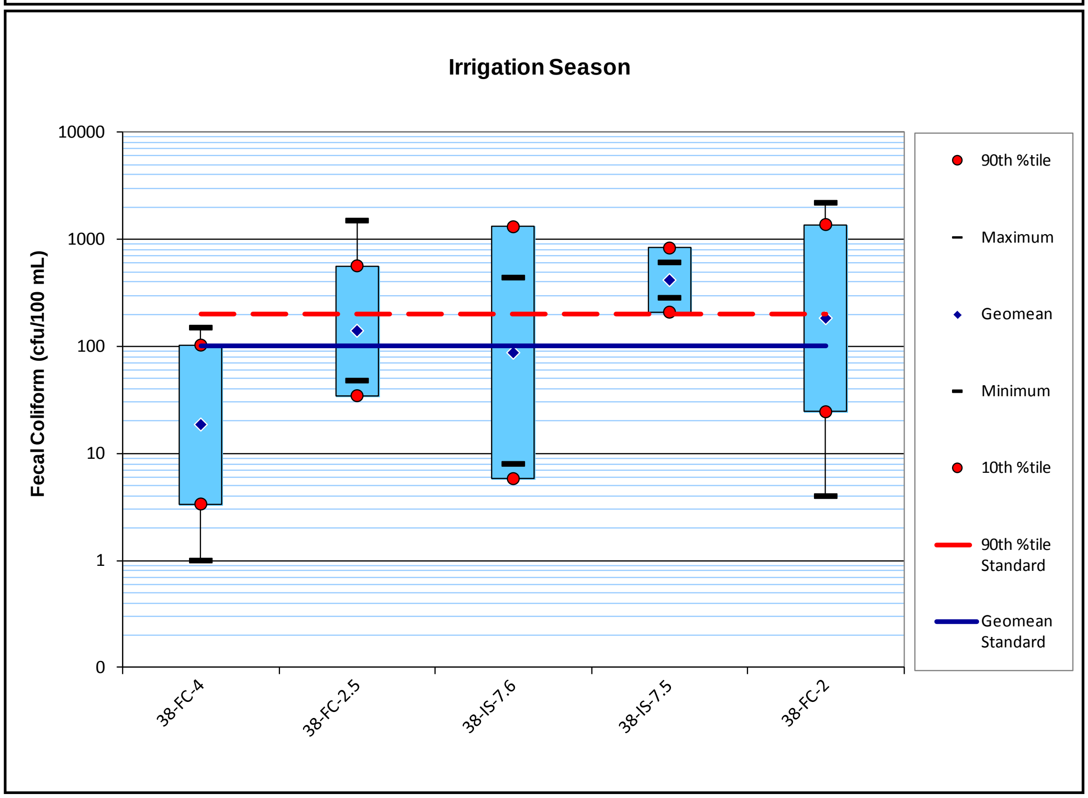


Figure 16. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts for mainstem sites of SF Cowiche Creek.

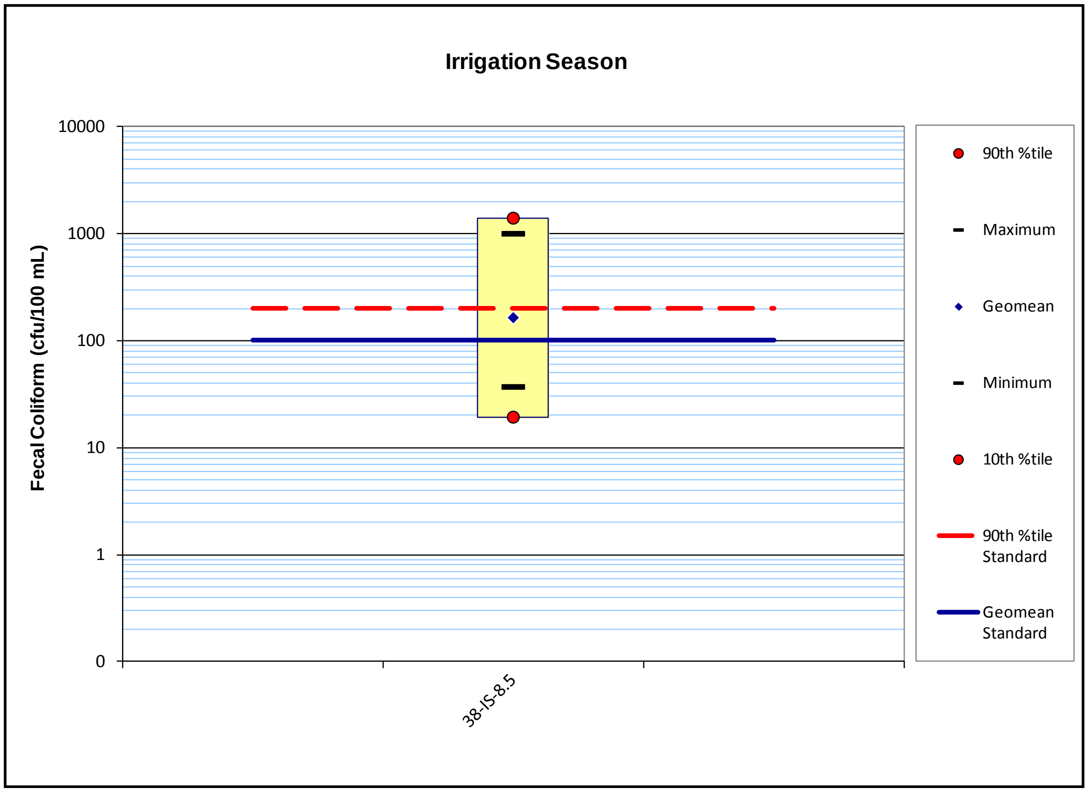
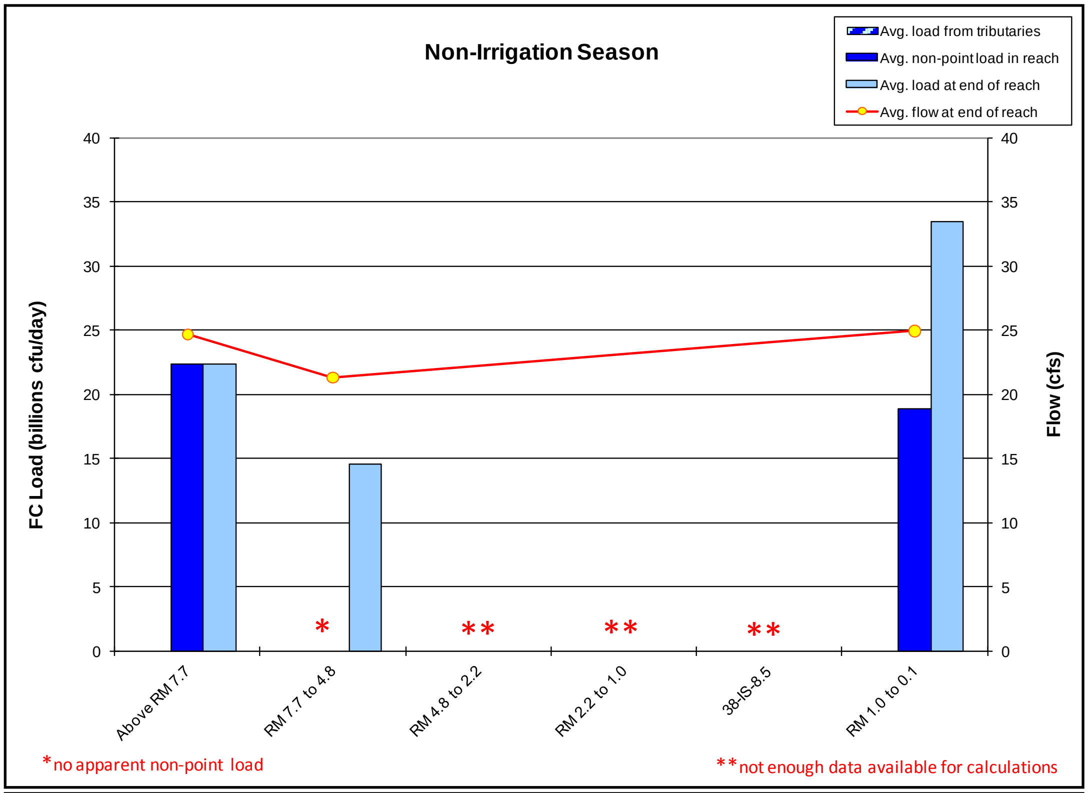


Figure 17. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts for tributary sites of SF Cowiche Creek.

Average seasonal FC loads were calculated using sampling surveys where concentration and streamflow data were available at all fixed-network mainstem sites. Therefore, data were used from 5 sampling surveys in the non-irrigation season and 8 sampling surveys (however, IS 7.5, 7.6 & 8.5 only were sampled 3 times) in the irrigation season. Figure 18 presents the average non-irrigation season and irrigation season FC loads for each reach and tributary. Table 18 summarizes the average loads as their percentages of the total load to SF Cowiche Creek if FC die-off or settling are not considered.



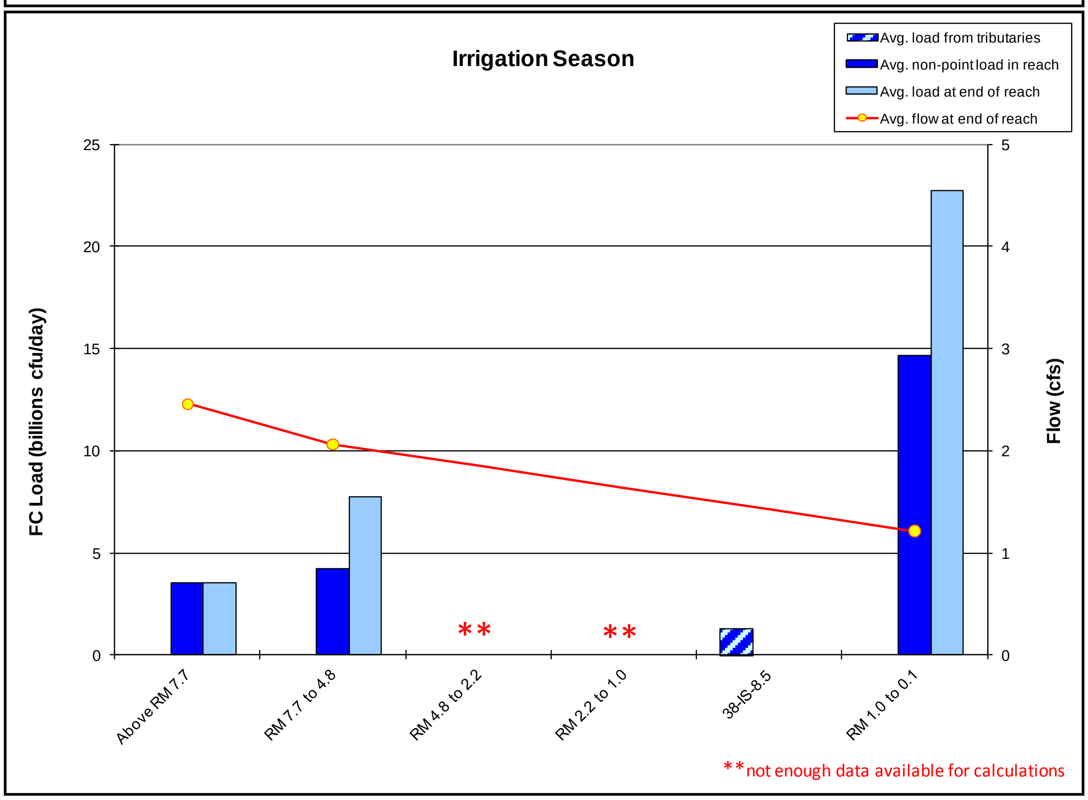


Figure 18. 2004-06 non-irrigation season and irrigation season average FC loads for SF Cowiche Creek.

Note the difference in vertical axes scale between the charts.

Table 18. 2004-06 non-irrigation season and irrigation season FC loading percentages to SF Cowiche Creek.

Reach (SF Cowiche RM) or Tributary	Site	Non-Irrigation Season	Irrigation Season
Above RM 7.7	38-FC-4	54.2%	14.9%
RM 7.7 to 4.8	38-FC-2.5	0.0%	17.8%
RM 4.8 to 2.2	38-IS-7.6	-	-
RM 2.2 to 1.0	38-IS-7.5	-	-
38-IS-8.5	38-IS-8.5	-	5.5%
RM 1.0 to 0.1	38-FC-2	45.8%[1]	61.9%[1]

[1] This percentage is the sum of all unaccounted for nonpoint loads between RM 4.8 and RM 0.1.

\- Not enough data available for calculations

All of the non-irrigation season FC load to SF Cowiche Creek was from above RM 7.7 (54%) and the reach between RM 4.8 and RM 0.1 (46%). FC load capacity was met at RM 7.7. 38-IS-7.6 and 38-IS-7.5 were omitted due to lack of data at these sites, so the average load calculated at 38-FC-2 represented the sum of the loads between RM 4.8 and RM 0.1. To increase resolution on SF Cowiche Creek between RM 4.8 and RM 1.0, more data need to be collected at these sites.

Most of the irrigation season load to SF Cowiche Creek was from the reach between RM 4.8 and RM 0.1 (62%), the reach between RM 7.7 and RM 4.8 (18%), and above RM 7.7 (15%). FC load capacity was met at RM 7.7. 38-IS-7.6 and 38-IS-7.5 were omitted due to lack of data at these sites, so the average load calculated at 38-FC-2 represented the sum of the loads between RM 4.8 and RM 0.1. To increase resolution on SF Cowiche Creek between RM 4.8 and RM 1.0 more data need to be collected at these sites.

The non-irrigation season TSS load to SF Cowiche Creek was divided nearly evenly between the 3 fixed-network sites; above RM 7.7 (39%), the reach between RM 4.8 and RM 0.1 (33%), and the reach between RM 7.7 and RM 4.8 (28%).

Non-irrigation season FC loading percentages to SF Cowiche Creek were also elevated above RM 7.7 and for the reach between RM 4.8 and RM 0.1. This suggests that conditions that elevate TSS, such as high flows or runoff processes (causing soil erosion), could also be elevating FC concentrations in these reaches.

Conversely, the reach between RM 7.7 and RM 4.8 did not have a high non-irrigation season FC loading percentage, so conditions that elevate TSS do not appear to be elevating FC concentrations in this reach.

Nearly all of the irrigation season TSS loading percentage to SF Cowiche Creek was from above RM 7.7 (99%). Irrigation season FC loading percentage was also high above RM 7.7, so conditions that elevate TSS could be elevating FC concentrations above RM 7.7.

There is no apparent relationship between TSS loads and FC loads in the reach between RM 7.7 and RM 4.8 or in the reach between RM 4.8 and 0.1. Conditions that elevate TSS do not appear to be elevating FC concentrations during the irrigation season in these reaches.

Table 19. 2004-06 non-irrigation season and irrigation season TSS and chloride loading percentages for SF Cowiche Creek.

Reach (SF Cowiche RM) or Tributary	Site	TSS		Chloride	
		Non-Irrigation Season	Irrigation Season	Non-Irrigation Season	Irrigation Season
Above RM 7.7	38-FC-4	39.2%	99.0%	67.9%	52.7%
RM 7.7 to 4.8	38-FC-2.5	27.8%	0.0%	0.0%	0.0%
RM 4.8 to 2.2	38-IS-7.6	-	-	-	-
RM 2.2 to 1.0	38-IS-7.5	-	-	-	-
38-IS-8.5	38-IS-8.5	-	1.0%	-	8.8%
RM 1.0 to 0.1	38-FC-2	33.1%[1]	0.0%[1]	32.1%[1]	38.5%[1]

[1] This percentage is the sum of all unaccounted for nonpoint loads between RM 4.8 and RM 0.1.
- Not enough data available for calculations

All of the non-irrigation season chloride loads to SF Cowiche Creek were from above RM 7.7 (68%) and the reach between RM 4.8 and RM 0.1 (32%).

Non-irrigation season FC loading percentage to SF Cowiche Creek was also elevated above RM 7.7 and for the reach between RM 4.8 and RM 0.1. Conditions that elevate chloride, such as failing septic tanks, could also be elevating FC concentrations in these reaches.

Most of the irrigation season chloride loads to SF Cowiche Creek were from above RM 7.7 (53%) and the reach between RM 4.8 and RM 0.1 (39%).

Irrigation season FC loading percentage to SF Cowiche Creek was also elevated above RM 7.7 and for the reach between RM 4.8 and RM 0.1. This suggests that conditions that elevate chloride, such as failing septic tanks, could also be elevating FC concentrations during the irrigation season in these reaches.

Cowiche Creek

Cowiche Creek and its tributaries were monitored from the mouths of the north and south forks (sites 38-FC-3.5 / 38-FC-3 and 38-FC-2, respectively) to near its confluence with the Naches River (38-FC-1). During the 2004-06 surveys, Ecology sampled 2 mainstem Cowiche Creek sites and 3 tributary sites (NF Cowiche Creek, SF Cowiche Creek, and a irrigation return at Weikel Road). During the 2010 surveys, Ecology sampled 2 mainstem Cowiche Creek sites.

Table 20, Figure 19, and Figure 20 present the 2004-06 non-irrigation season and irrigation season summary statistics of FC counts. Table 20 also presents the target reductions necessary to meet the water quality standards in Cowiche Creek.

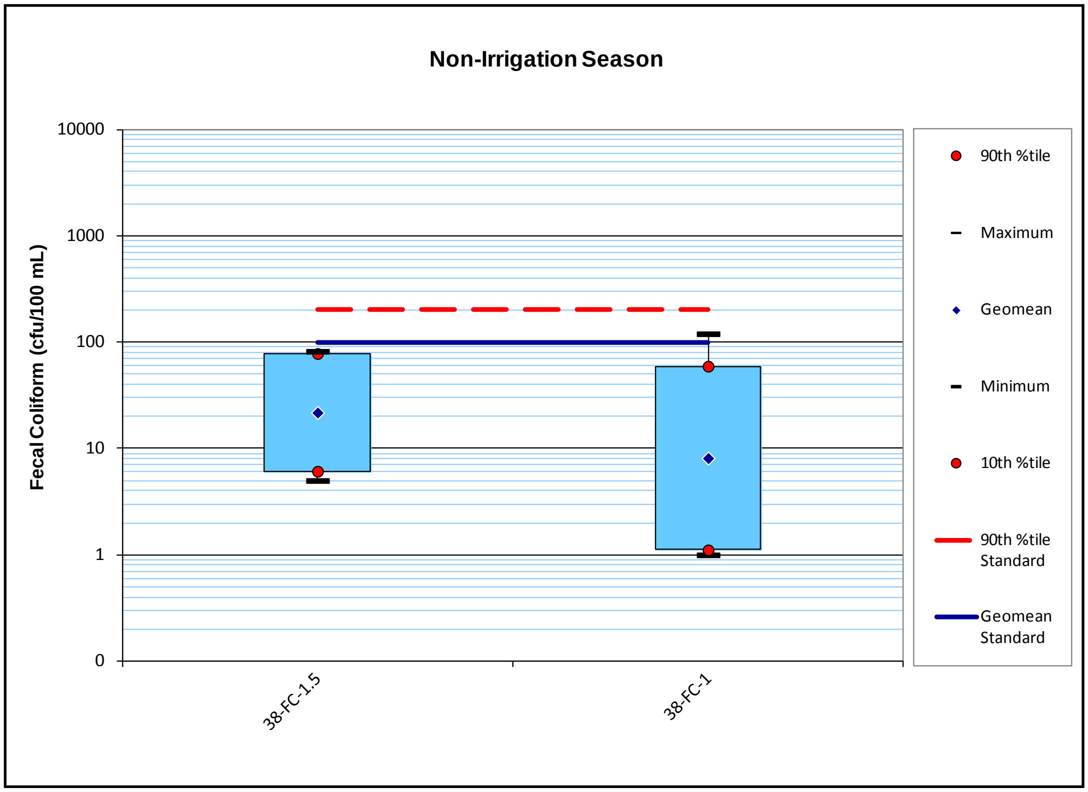
Table 20. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts and target percent reductions for Cowiche Creek.

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile*	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
Non-Irrigation Season								
38-FC-2	9	1	2	31	426	620	22%	53%
38-FC-3	4	2	2	7	30	22	0%	0%
38-FC-1.5	9	5	6	22	78	82	0%	0%
38-IS-8	0	-	-	-	-	-	-	-
38-FC-1	10	1	1	8	59	120	0%	0%
Irrigation Season								
38-FC-2	15	4	25	184	1378	2200	53%	85%
38-FC-3	8	2	4	48	553	330	13%	64%
38-FC-1.5	14	30	52	179	616	1000	57%	68%
38-IS-8	4	72	77	246	790	630	75%	75%
38-FC-1	15	2	8	60	441	400	20%	55%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.

**Cells shaded in this column are values based on less than 5 samples collected at that station.

- Not enough data for the calculations.



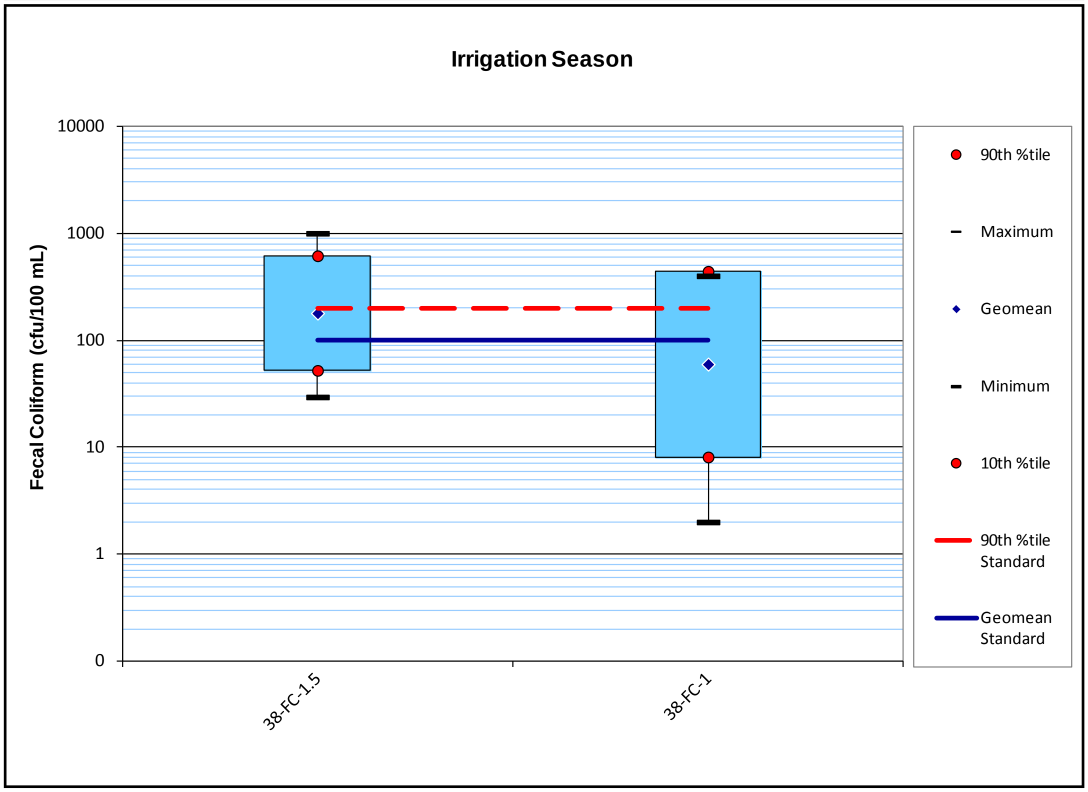


Figure 19. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts for mainstem sites of Cowiche Creek.

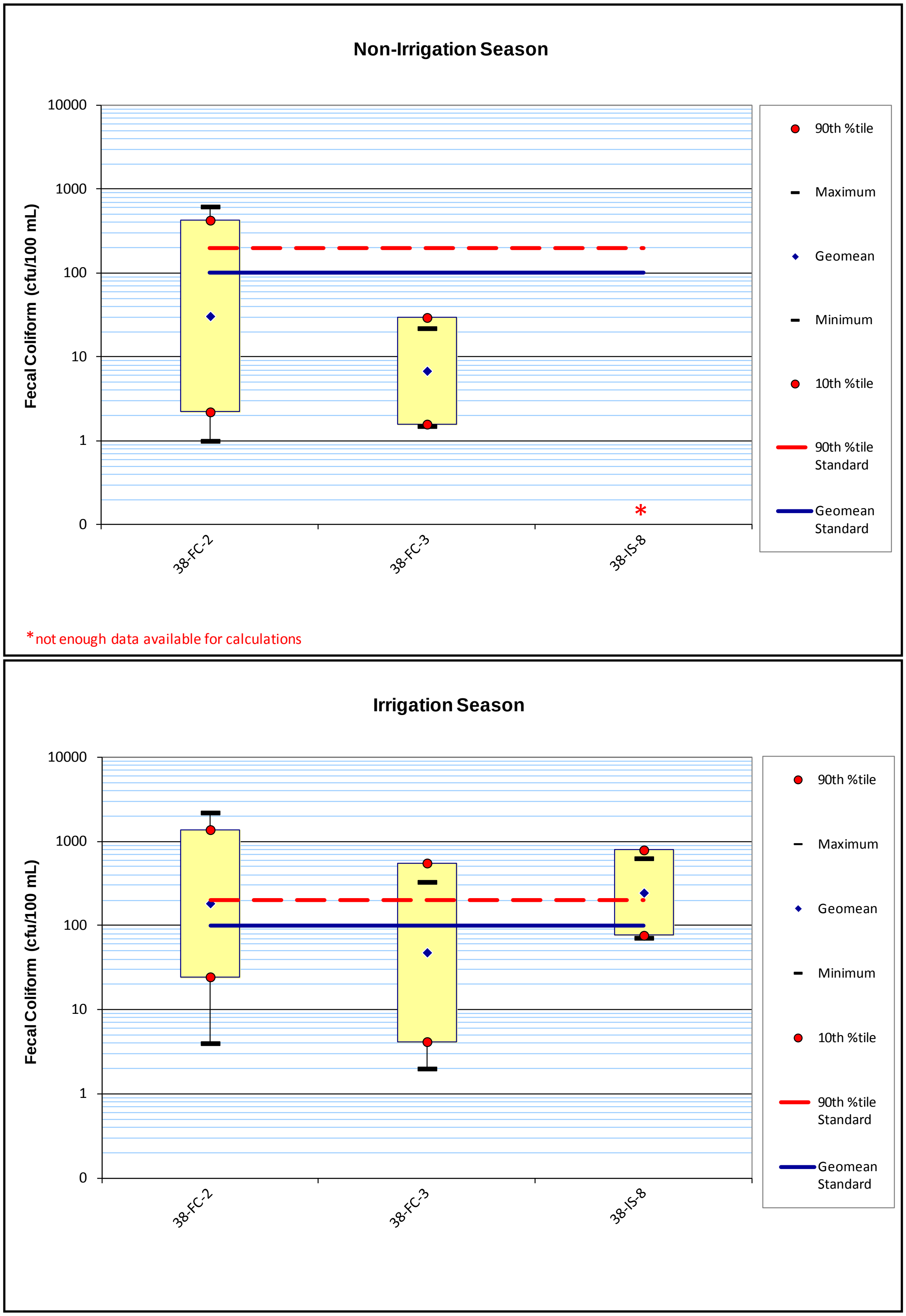


Figure 20. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts for tributary sites of Cowiche Creek.

The discussions of FC concentrations for NF and SF Cowiche Creeks were presented in previous sections of this report.

FC concentrations for Cowiche Creek at Zimmerman Road (38-FC-1.5) met the criteria during the non-irrigation season, but did not meet either part of the criteria during the irrigation season.

The irrigation return at Weikel Road (38-IS-8) was an irrigation synoptic survey site; therefore, it was only sampled in the irrigation season. This site did not meet either part of the criteria during the irrigation season.

Cowiche Creek near the mouth at Powerhouse Road (38-FC-1) had FC concentrations that met the criteria during the non-irrigation season, but the FC concentrations near the mouth in the irrigation season did not meet the 90^{th} percentile part of the criteria.

Average seasonal FC loads were calculated using sampling surveys where concentration and streamflow data were available at all fixed-network mainstem sites. Data were used from 9 sampling surveys in the non-irrigation season and 14 sampling surveys in the irrigation season. Figure 21 presents the average non-irrigation season and irrigation season FC loads for each reach and tributary. Table 21 summarizes the average loads as their percentages of the total load to Cowiche Creek if FC die-off and settling are not considered.

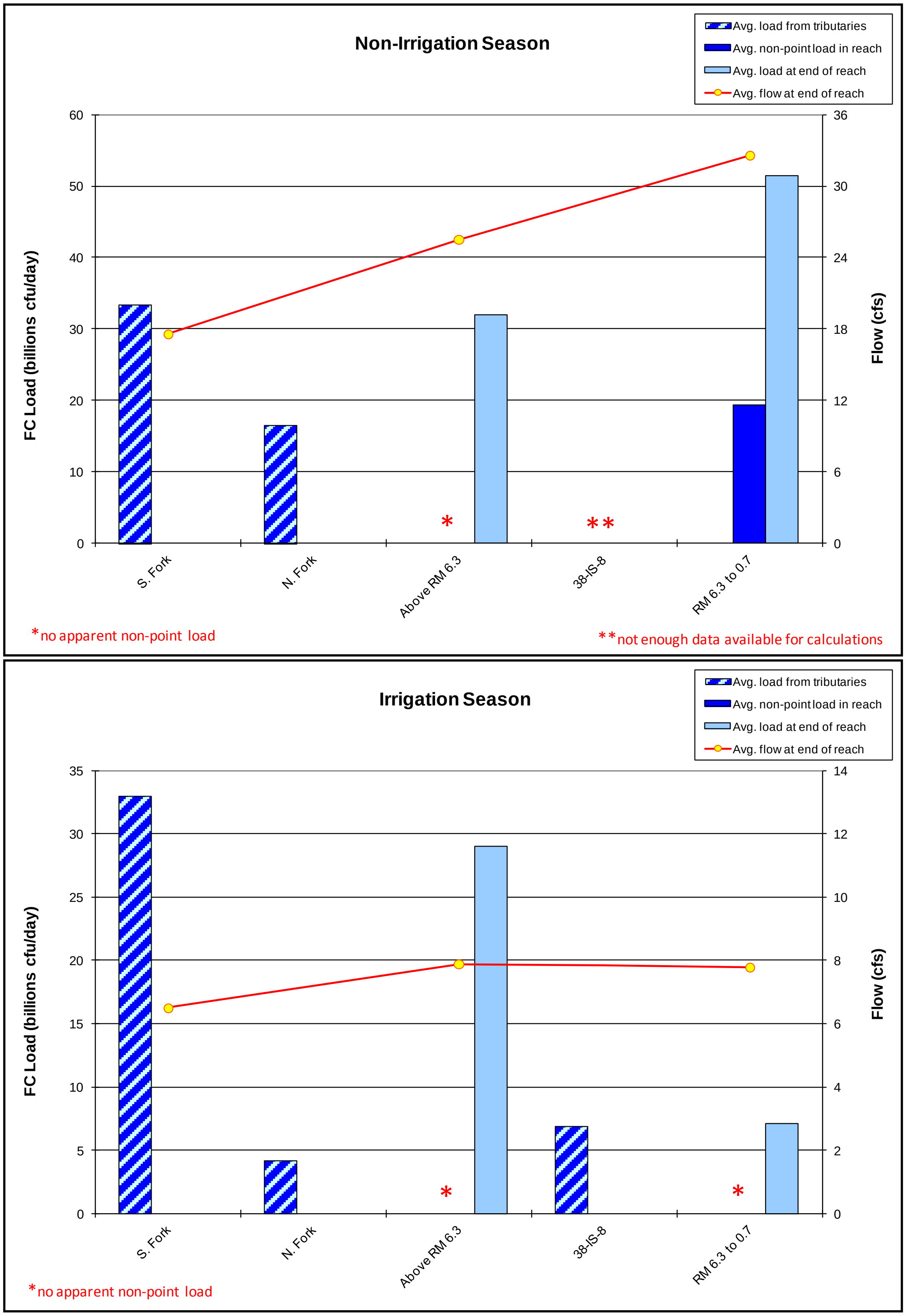


Figure 21. 2004-06 non-irrigation season and irrigation season average FC loads in Cowiche Creek.

Note the differences in vertical axes scale between the charts.

Table 21. 2004-06 non-irrigation season and irrigation season FC loading percentages to Cowiche Creek.

Reach (Cowiche RM) or Tributary	Site	Non-Irrigation Season	Irrigation Season
S. Fork	38-FC-2	48.2%	75.0%
N. Fork	38-FC-3 / 38-FC-3.5	23.9%	9.4%
Above RM 6.3	38-FC-1.5	0.0%	0.0%
38-IS-8	38-IS-8	-	15.6%
RM 6.3 to 0.7	38-FC-1	28.0%	0.0%

- Not enough data available for calculations

Nearly half of the non-irrigation FC loads to Cowiche Creek were from SF Cowiche Creek (48%). The other half of the non-irrigation loads was from the reach between RM 6.3 and RM 0.7 (28%) and NF Cowiche Creek (24%).

Two-thirds of the irrigation FC loads to Cowiche Creek were from SF Cowiche Creek (75%). The other third of irrigation loads was from the irrigation return at Weikel Road (16%) and NF Cowiche Creek (9%).

Cowiche Creek downstream of the confluence of the two forks to RM 6.3 did not have any additional nonpoint load in either season.

The non-irrigation season TSS loads to Cowiche Creek were from all reaches; the reach between RM 6.3 and RM 0.7 (39%), SF Cowiche Creek (29%), NF Cowiche Creek (17%), and Cowiche Creek above RM 6.3 to the forks (14%).

The three reaches with the largest non-irrigation TSS loading percentage; SF Cowiche Creek, the reach between RM 6.3 and RM 0.7, and NF Cowiche Creek, also had the largest non-irrigation FC loading percentage to Cowiche Creek. This suggests that conditions that elevate TSS, such as high flows or runoff processes (causing soil erosion), could also be elevating FC concentrations in these reaches during the non-irrigation season.

Nearly half of the irrigation season TSS loads to Cowiche Creek were from SF Cowiche Creek (48%). The other half of TSS loads was divided among the other reaches: the irrigation return (16%), the reach between RM 6.3 and RM 0.7 (14%), Cowiche Creek above RM 6.3 to the forks (12%), and NF Cowiche Creek (10%).

Irrigation season FC loading percentages were also high for SF Cowiche Creek, the irrigation return, and NF Cowiche Creek. Therefore, conditions that elevate TSS could also be elevating FC concentrations in these reaches during the irrigation season.

There is no apparent relationship between irrigation season TSS loads and FC loads in Cowiche Creek above RM 6.3 to the forks and the reach between RM 6.3 and RM 0.7. This suggests that conditions that elevate TSS, such as high flows or runoff processes (causing soil erosion), do not appear to be elevating FC concentrations during the irrigation season in these reaches.

Table 22. 2004-06 non-irrigation season and irrigation season TSS and chloride loading percentages to Cowiche Creek.

Reach (Cowiche RM) or Tributary	Site	TSS		Chloride	
		Non-Irrigation Season	Irrigation Season	Non-Irrigation Season	Irrigation Season
S. Fork	38-FC-2	29.4%	47.5%	28.3%	28.4%
N. Fork	38-FC-3 / 38-FC-3.5	17.4%	10.4%	32.6%	42.7%
Above RM 6.3	38-FC-1.5	14.3%	12.1%	7.8%	2.9%
38-IS-8	38-IS-8	-	16.4%	-	12.7%
RM 6.3 to 0.7	38-FC-1	38.9%	13.5%	31.3%	13.3%

- Not enough data available for calculations

The majority of non-irrigation season chloride loads were from NF Cowiche Creek (33%), the reach between RM 6.3 and RM 0.7 (31%), and SF Cowiche Creek (28%).

Non-irrigation season FC loading percentages were also high for NF Cowiche Creek, the reach between RM 6.3 and RM 0.7, and SF Cowiche Creek. This suggests that conditions and nonpoint sources that elevate chloride could also be elevating FC concentrations. These sources should be considered for FC contamination in these reaches during the non-irrigation season.

More than two-thirds of the irrigation season chloride loads were from NF Cowiche Creek (43%) and SF Cowiche Creek (28%). The other third of irrigation season chloride loads was from the reach between RM 6.3 and RM 0.7 (13%) and the irrigation return at Weikel Road (13%).

Irrigation season FC loading percentages were also high for SF Cowiche Creek and the irrigation return at Weikel Road. Conditions and sources that elevate chloride concentrations may also be elevating FC concentrations in these reaches in the irrigation season.

The relationship between chloride loads and FC loads is ambiguous for the other sites: NF Cowiche Creek, Cowiche Creek above RM 6.3, and Cowiche Creek between RM 6.3 and RM 0.7.

2010 FC Bacteria analysis

Table 23 and Figure 22 present the 2010 non-irrigation season and irrigation season summary statistics of FC counts. Table 23 also presents the target reductions necessary to meet the water quality standards in Cowiche Creek. The 2010 study was conducted June through December, and included one of the existing sites from the 2004-06 study (38-FC-1). The other site sampled during 2010 (38-FC-1.25) was a new site. It was added to increase the resolution of sampling near the mouth of Cowiche Creek.

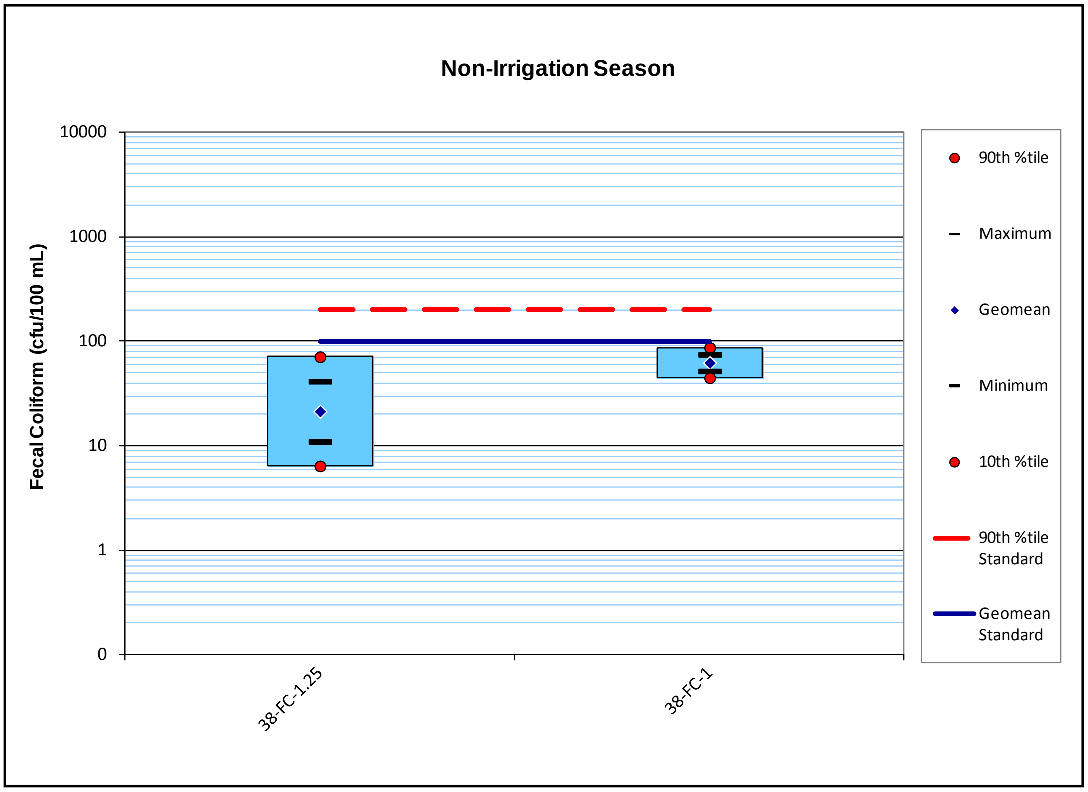
Cowiche Creek at the end of Cowiche Creek Road (38-FC-1.25) was the most upstream sampling site during the 2010 surveys. This site met criteria during the non-irrigation season, but did not meet either part of the criteria in the irrigation season.

Cowiche Creek near the mouth at Powerhouse Road (38-FC-1) also met the criteria during the non-irrigation and did not meet either part of the criteria in the irrigation season. This pattern in the statistics was similar to those from the 2004-06 study. However, the geomean in the irrigation season for the 2004-06 study met the criteria.

Table 23. 2010 non-irrigation season and irrigation season summary statistics of FC counts and target percent reductions for sites in Cowiche Creek.

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile*	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
Non-Irrigation Season								
38-FC-1.25	2	11	6	21	71	42	0%	0%
38-FC-1	2	52	45	62	87	75	0%	0%
Irrigation Season								
38-FC-1.25	10	46	49	161	533	1100	30%	63%
38-FC-1	10	25	40	153	581	960	30%	66%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.
**Cells shaded in this column are values based on less than 5 samples collected at that station.



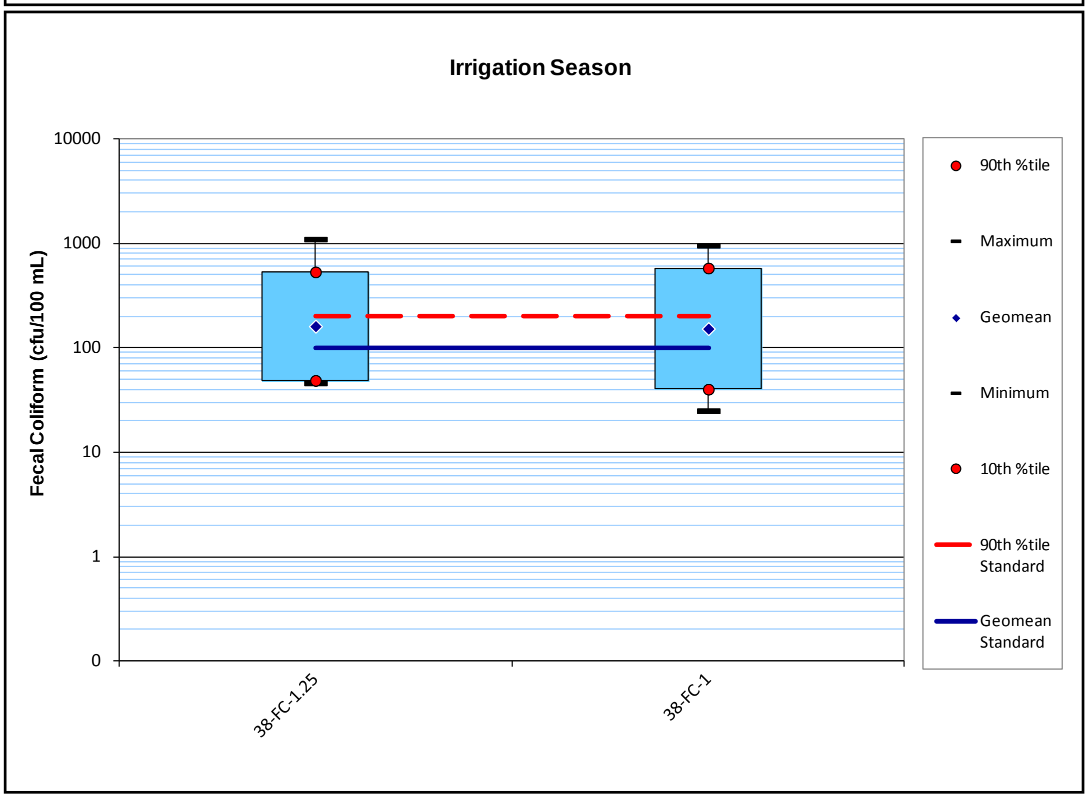


Figure 22. 2010 non-irrigation season and irrigation season summary statistics of FC counts for sites in Cowiche Creek.

Average seasonal FC loads were calculated using sampling surveys where concentration and streamflow data were collected at both sites. Data were used from 2 sampling surveys in the non-irrigation season and 9 sampling surveys in the irrigation season. The non-irrigation season loads presented below are estimates due to the lack of data available for average loading calculations. Figure 23 presents the average non-irrigation season and irrigation season FC loads for each reach. Table 24 summarizes the average loads as their percentages of the total load to Cowiche Creek for 2010 if FC die-off and settling are not considered.

The irrigation season FC loads were significantly larger than the non-irrigation season FC loads.

The non-irrigation season FC load to Cowiche Creek was nearly split evenly between the two reaches; the reach between RM 2.7 and 0.7 (56%) and above RM 2.7 (44%).

The entire irrigation season FC load to Cowiche Creek was from above RM 2.7 (100%).

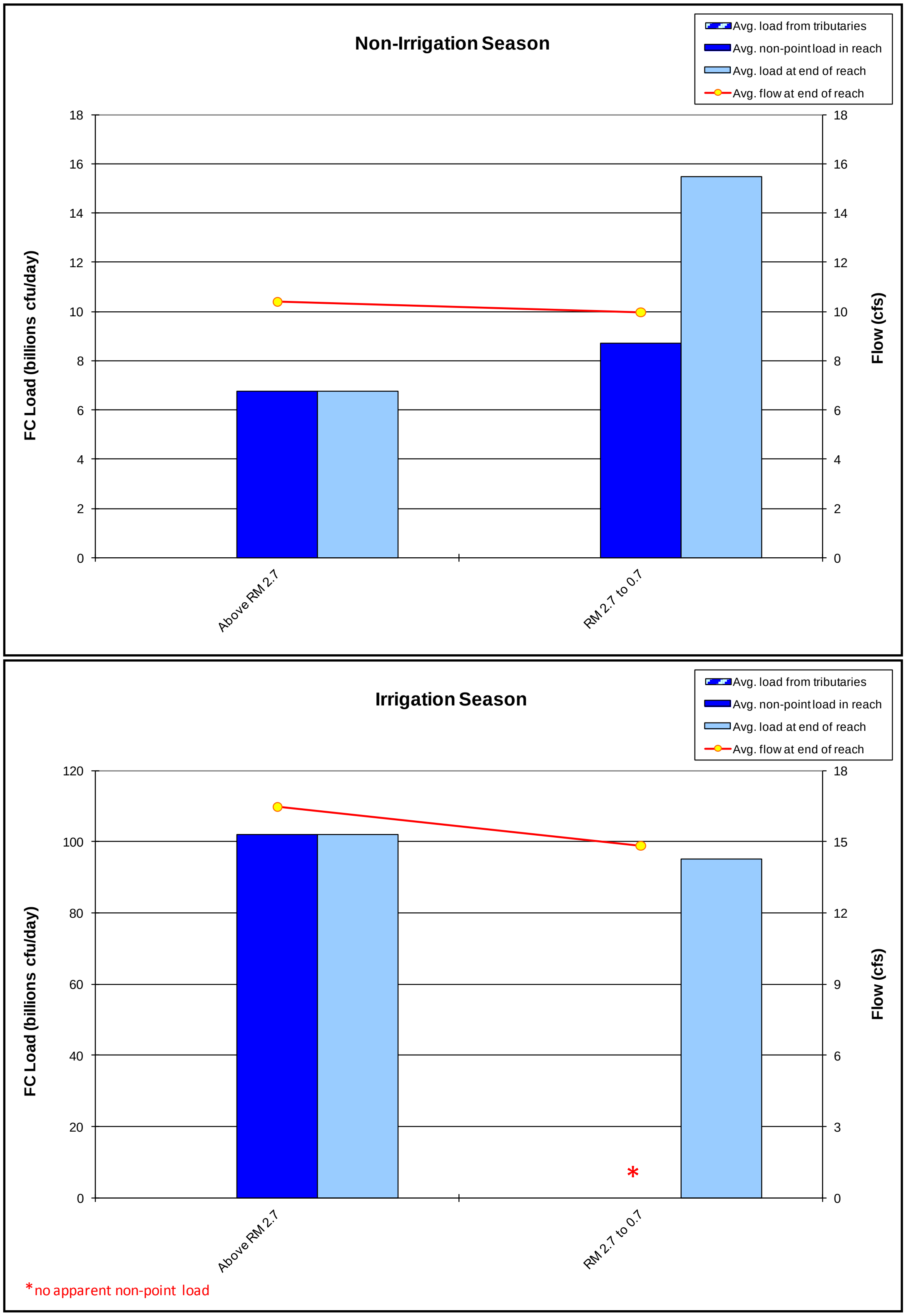


Figure 23. 2010 non-irrigation season and irrigation season average FC loads in Cowiche Creek.

Note the differences in vertical axes scale between the charts.

Table 24. 2010 non-irrigation season and irrigation season FC loading percentages to Cowiche Creek.

Reach (Cowiche RM)	Site (End of Reach)	Non-Irrigation Season	Irrigation Season
Above RM 2.7	38-FC-1.25	43.8%	100.0%
RM 2.7 to 0.7	38-FC-1	56.2%	0.0%

Comparison of 2004 -2006 to 2010 FC Bacteria Results

Overall, the 2010 FC concentrations near the mouth of Cowiche Creek (38-FC-1) appear to be slightly elevated over the 2004-06 study. The comparison is difficult due to the differences in number of samples collected, climate, and hydrology between the two studies. FC concentrations from the two studies were not statistically different at 38-FC-1 according to the Wilcoxon Rank Sum test (EPA, 2006).

Table 25 presents the non-irrigation season and irrigation season TSS load contribution percentages.

For both seasons the entire TSS load to Cowiche Creek appears to be coming from above RM 2.7 (100%).

FC loading percentages were also high above RM 2.7 for both seasons. This suggests that conditions that elevate TSS, such as high flows or runoff processes (causing soil erosion), could also be elevating FC concentrations above RM 2.7 during both seasons.

Figure 24 shows a very weak but positive relationship between irrigation season TSS concentrations and FC concentrations in Cowiche Creek during 2010. This illustrates that conditions that elevate TSS could also be elevating FC concentration in this portion of Cowiche Creek during the irrigation season.

Table 25. 2010 non-irrigation season and irrigation season TSS loading percentages to Cowiche Creek.

Reach (Cowiche RM)	Site (End of Reach)	Non-Irrigation Season	Irrigation Season
Above RM 2.7	38-FC-1.25	100.0%	100.0%
RM 2.7 to 0.7	38-FC-1	0.0%	0.0%

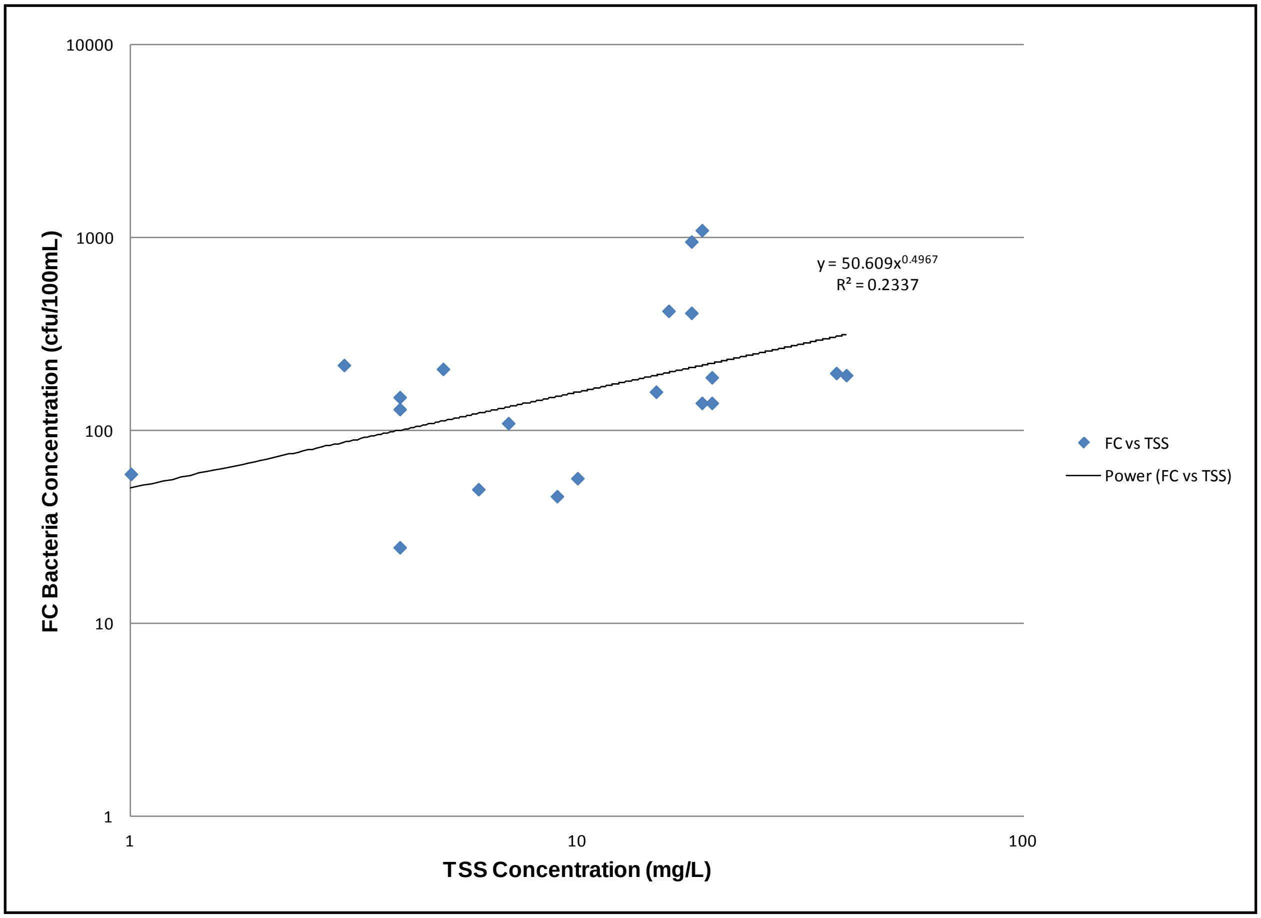


Figure 24. 2010 relationship between irrigation season TSS and FC concentrations in Cowiche Creek.

Wide Hollow Creek

Wide Hollow Creek and its tributaries were monitored from near the headwaters on Stone Road (sites 37-FW-18, 37-FW-17, and 37-FW-16) to just upstream of the confluence with the Yakima River (site 37-FW-0) (Figure 5). During the 2004-06 surveys, Ecology sampled 29 mainstem and tributary sites along Wide Hollow Creek, 2 sites along Cottonwood Creek, 2 sites along Randall Park Pond, and 2 sites along East Spring Creek.

During the 2010 surveys, Ecology sampled 16 mainstem and tributary sites along Wide Hollow Creek and 2 sites along Randall Park Pond.

Below are the non-irrigation and irrigation season summary statistics of FC counts for Wide Hollow Creek, Cottonwood Creek, Randall Park Pond, and East Spring Creek. Also, the target reductions necessary to meet the water quality standards for each site are included.

Wide Hollow Creek

During the 2004-06 surveys, Ecology sampled 12 mainstem Wide Hollow Creek sites and 17 tributary sites. During the 2010 surveys, Ecology sampled 6 mainstem Wide Hollow Creek sites and 10 tributary sites. The 2004-06 and 2010 studies were analyzed separately due to improvements to stormwater conveyances made along Wide Hollow Creek after the 2004-06 study. These improvements were made to reduce bacteria loads in Wide Hollow Creek.

Table 26, Figure 25, and Figure 26 present the non-irrigation season and irrigation season summary statistics of FC counts. Table 26 also presents the target reductions necessary to meet the water quality standards in Wide Hollow Creek.

The three uppermost sites in the watershed (37-FW-18, 37-FW-17, and 37-FW-16) were dry over much of the sampling period. Only two samples were collected during the non-irrigation season at the uppermost Wide Hollow Creek mainstem site (37-FW-18), and these samples met both parts of the criteria. At the unnamed tributaries at Stone Road (37-FW-17 and 37-FW-16) only two samples were collected at each site during the non-irrigation season. Based on the two samples, 37-FW-17 did not meet the 90th percentile part of the criteria. At 37-FW-16 one of the two samples had a concentration of 755 cfu / 100 mL. More samples were taken at Cottonwood Creek (37-FW-13 / 37-SS-18), so this site may more accurately represent the water quality for the headwaters. Cottonwood Creek at the mouth (37-FW-13 / 37-SS-18) met the criteria in the non-irrigation season, but 1 out of the 8 samples (13%) had concentrations above 200 cfu / 100 mL. The elevated counts at these uppermost sites during the non-irrigation season occurred when streamflows increased during a January 2006 rain and thaw event.

FC concentrations during the non-irrigation season appear to increase downstream of 80th Avenue (Yakima city limits) to the mouth. Mainstem Wide Hollow Creek sites in this sub-reach that did not meet water quality criteria were 37-FW-5, 37-FW-1, and 37-FW-0. Tributary and an additional mainstem site in this sub-reach were calculated using two samples or less. Samples collected at 37-SS-38, 37-SS-11, 37-IS-17.5 / 37-SS-9, and 37-SS-6 clearly indicate the presence of high FC concentrations during the non-irrigation season.

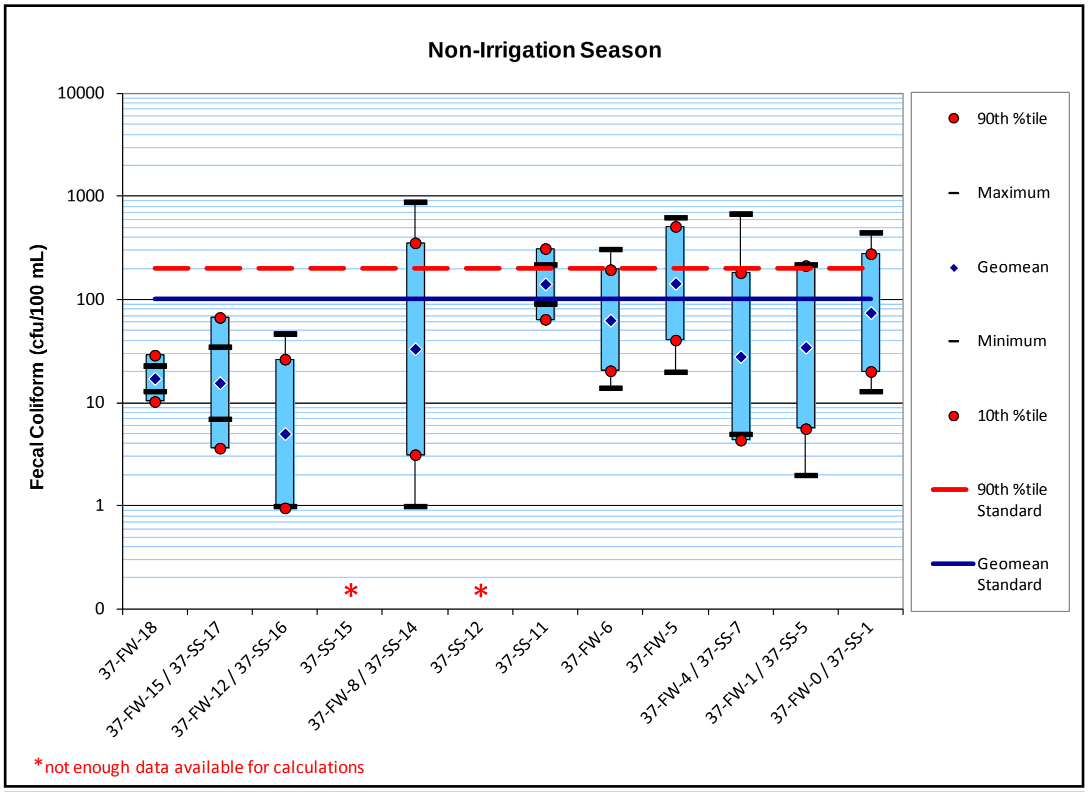
FC concentrations during the irrigation season were elevated versus the non-irrigation season in the sub-reach downstream of 80th Avenue. A drain at 4th Avenue (37-IS-10) was the only site to meet the water quality criteria. The outfall for DID #24 at 3rd Avenue met the geomean part of the criteria but did not meet the 90th percentile part of the criteria. The remaining 21 sites, where samples were collected, did not meet either part of the Primary Contact water quality criteria. The irrigation season statistics for 14 out of the 23 sites were calculated using 4 samples or less, but the samples that were collected clearly indicate the presence of high FC concentrations at these locations.

Table 26. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts and target percent reductions in Wide Hollow Creek.

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
Non-Irrigation Season								
37-FW-18	2	13	10	17	29	23	0%	0%
37-FW-17	2	1	0	8	401	71	0%	50%
37-FW-16	2	8	1	78	4790	755	50%	96%
37-FW-15 / 37-SS-17	2	7	4	16	67	35	0%	0%
37-FW-12 / 37-SS-16	8	1	1	5	27	47	0%	0%
37-FW-13 / 37-SS-18	8	1	1	5	49	240	13%	0%
37-IS-16	0	-	-	-	-	-	-	-
37-SS-15	0	-	-	-	-	-	-	-
37-SS-13	0	-	-	-	-	-	-	-
37-FW-8 / 37-SS-14	12	1	3	33	356	890	8%	44%
37-SS-12	0	-	-	-	-	-	-	-
37-SS-38	1	160	-	160	-	160	0%	38%
37-SS-48	1	10	-	10	-	10	0%	0%
37-IS-19	0	-	-	-	-	-	-	-
37-SS-11	2	92	65	142	314	220	50%	36%
37-FW-6	10	14	20	63	196	310	10%	0%
37-IS-17.5 / 37-SS-9	1	200	-	200	-	200	0%	50%
37-IS-17	0	-	-	-	-	-	-	-
37-SS-8	1	21	-	21	-	21	0%	0%
37-FW-5	10	20	41	144	514	630	50%	61%
37-FW-4 / 37-SS-7	12	5	4	28	183	685	8%	0%
37-IS-15	0	-	-	-	-	-	-	-
37-IS-13	0	-	-	-	-	-	-	-
37-SS-6	2	96	37	315	2720	1035	50%	93%
37-IS-12	0	-	-	-	-	-	-	-
37-IS-10	0	-	-	-	-	-	-	-
37-FW-1 / 37-SS-5	13	2	6	35	214	220	15%	7%
37-FW-0 / 37-SS-1	12	13	20	75	279	450	17%	28%
37-FW-2	11	7	12	42	140	140	0%	0%
Irrigation Season								
37-FW-18	0	-	-	-	-	-	-	-
37-FW-17	0	-	-	-	-	-	-	-
37-FW-16	0	-	-	-	-	-	-	-
37-FW-15 / 37-SS-17	1	2700	-	2700	-	2700	100%	96%
37-FW-12 / 37-SS-16	8	3	7	137	2594	3050	50%	92%

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
37-FW-13 / 37-SS-18	9	41	35	332	3167	8000	56%	94%
37-IS-16	4	90	55	274	1361	1550	50%	85%
37-SS-15	2	1600	935	3098	10265	6000	100%	98%
37-SS-13	2	8000	7558	8579	9738	9200	100%	99%
37-FW-8 / 37-SS-14	16	8	21	164	1275	3600	56%	84%
37-SS-12	2	680	367	1452	5742	3100	100%	97%
37-SS-38	0	-	-	-	-	-	-	-
37-SS-48	0	-	-	-	-	-	-	-
37-IS-19	4	23	15	229	3568	4000	50%	94%
37-SS-11	2	1400	1125	1833	2988	2400	100%	95%
37-FW-6	15	10	29	182	1150	2100	60%	83%
37-IS-17.5 / 37-SS-9	4	870	921	1602	2787	2200	100%	94%
37-IS-17	4	23	23	174	1337	1000	50%	85%
37-SS-8	0	-	-	-	-	-	-	-
37-FW-5	14	20	71	288	1171	1600	71%	83%
37-FW-4 / 37-SS-7	16	25	45	218	1053	3550	56%	81%
37-IS-15	1	1800	-	1800	-	1800	100%	94%
37-IS-13	3	370	335	500	746	690	100%	80%
37-SS-6	2	98	16	896	49540	8200	50%	100%
37-IS-12	3	1	0	6	279	190	0%	28%
37-IS-10	4	1	0	2	8	10	0%	0%
37-FW-1 / 37-SS-5	16	10	53	291	1590	3300	63%	87%
37-FW-0 / 37-SS-1	17	41	73	369	1864	5500	71%	89%
37-FW-2	14	25	54	130	316	300	36%	37%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.
**Cells shaded in this column are values based on less than 5 samples collected at that station.
- Not enough data for calculations



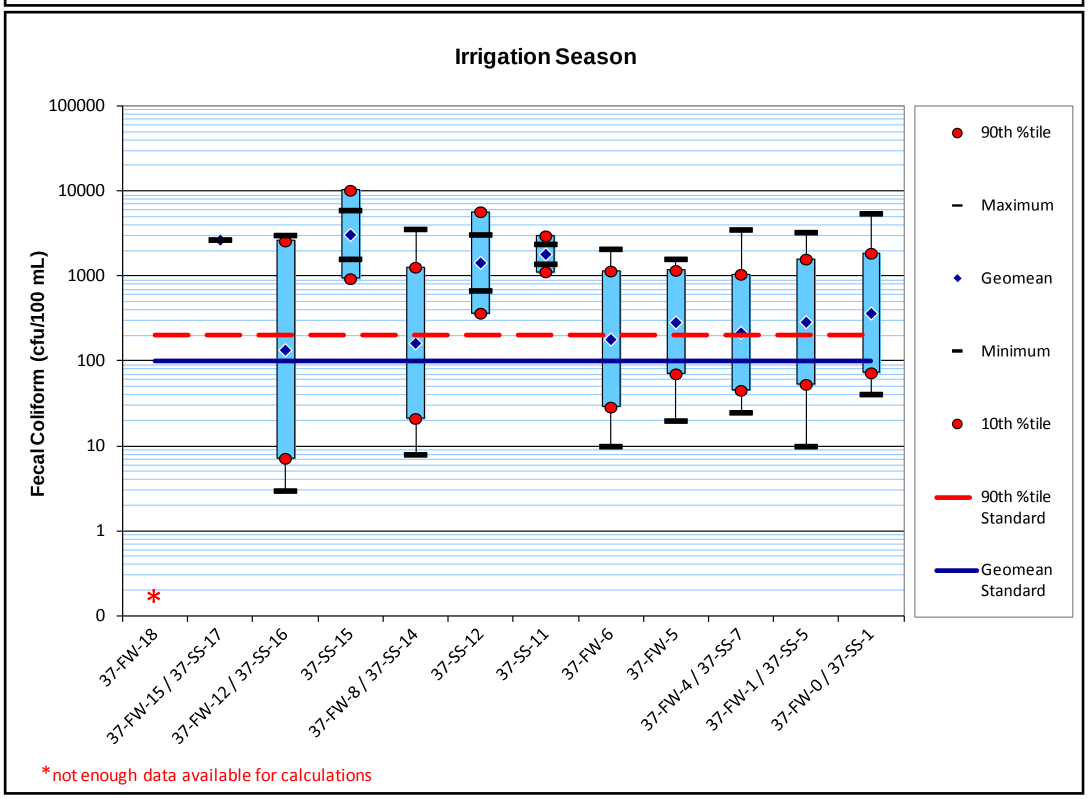


Figure 25. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts for mainstem sites in Wide Hollow Creek.

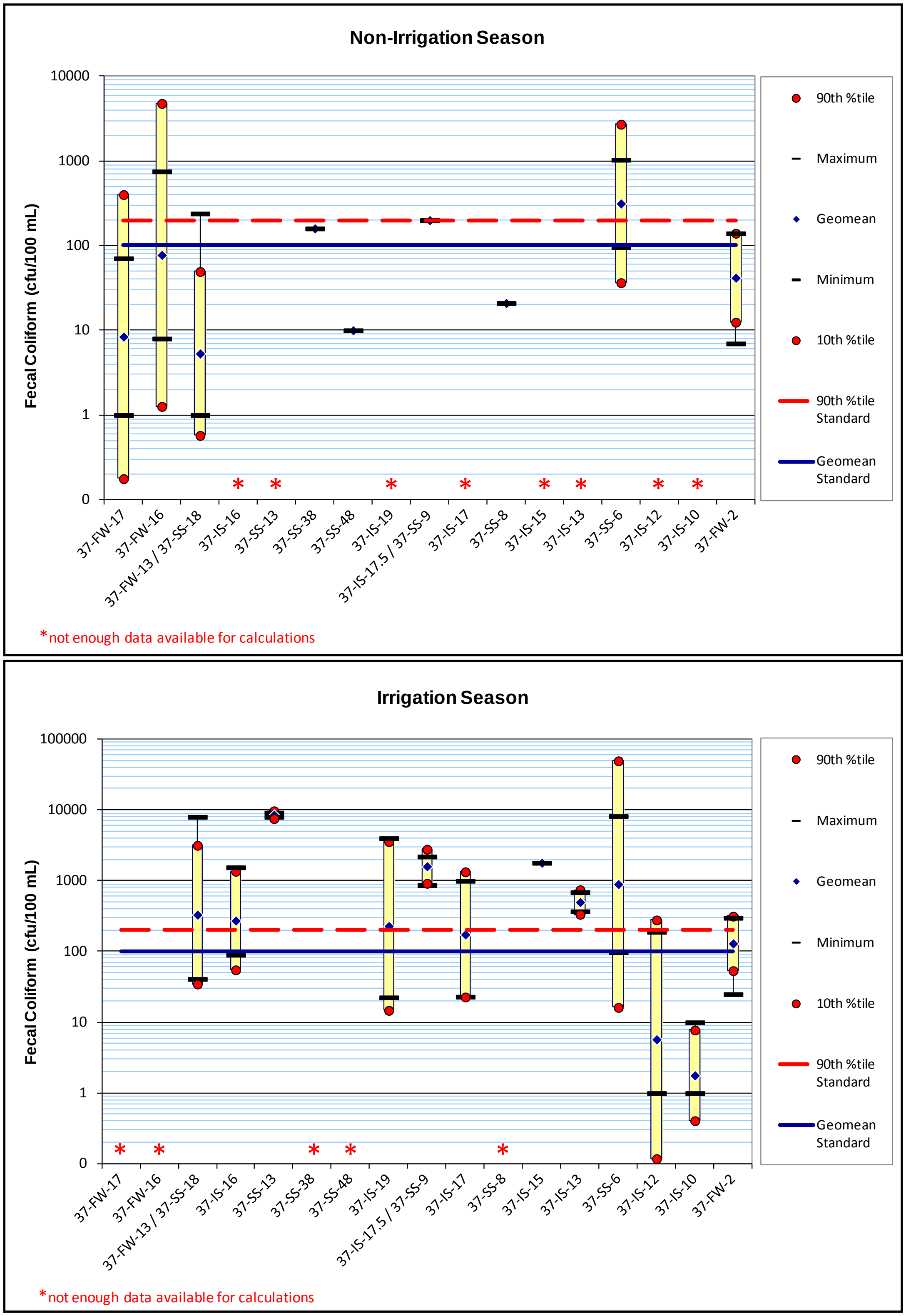


Figure 26. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts for tributary sites in Wide Hollow Creek.

Average seasonal FC loads were calculated using sampling surveys where concentration and streamflow data were available. Data were used from 10 sampling surveys in the non-irrigation season and 14 sampling surveys in the irrigation season. Figure 27 presents the average non-irrigation season and irrigation season FC loads for each reach and tributary. Table 27 summarizes the average loads as their percentages of the total load to Wide Hollow Creek.

If FC die-off is not considered, most of the non-irrigation season FC load to Wide Hollow Creek was from Cottonwood Creek (30%), the reach between RM 0.7 and RM 0.6 (21%), the tributary at Stone Road near Cook Road (18%), and the reach between RM 6.7 and RM 5.3 (10%).

The majority of the irrigation season FC load to Wide Hollow Creek was from the reach between RM 9.6 and RM 6.7 (32%), the reach between RM 4.4 and RM 0.7 (21%), and Congdon Canal (17%).

Eighteen sites in the non-irrigation season and 16 sites in the irrigation season did not have concentration or streamflow data available for the sample surveys where the mainstem fixed-network sites were also sampled. Therefore, these sites were omitted from the loading analysis. More samples and streamflow need to be collected at these sites to characterize their percentages of FC loading to Wide Hollow Creek.

Discussions of FC loads from Randall Park Pond and Cottonwood Creek are included later in this report.

Nearly half (48%) of the non-irrigation TSS loads to Wide Hollow Creek were from Cottonwood Creek (Table 28). The other half of the non-irrigation TSS loads were from the tributary at Stone Road near Cook Road (12%), and East Spring Creek (11%).

Non-irrigation FC loading percentages were also high in Cottonwood Creek and the tributary at Stone Road near Cook Road. This suggests that conditions that elevate TSS, such as high flows or runoff processes (causing soil erosion), could also be elevating FC concentrations in these tributaries.

More than half of the irrigation season TSS loads to Wide Hollow Creek were from the reach between RM 6.7 and RM 5.3 (55%). The majority of the remaining TSS loads were from the reach between RM 9.6 and RM 6.7 (14%), East Spring Creek (11%), and the Congdon Canal (11%).

There is no apparent relationship between irrigation season TSS loads and FC loads in the reach between RM 6.7 and RM 5.3. This suggests that conditions that elevate TSS do not appear to be elevating FC concentrations during the irrigation season in that reach.

Irrigation FC loading percentages were high in the reach between RM 9.6 and RM 6.7 and in Congdon Canal. Therefore, conditions or sources that elevate TSS could also be elevating FC concentrations in these reaches.

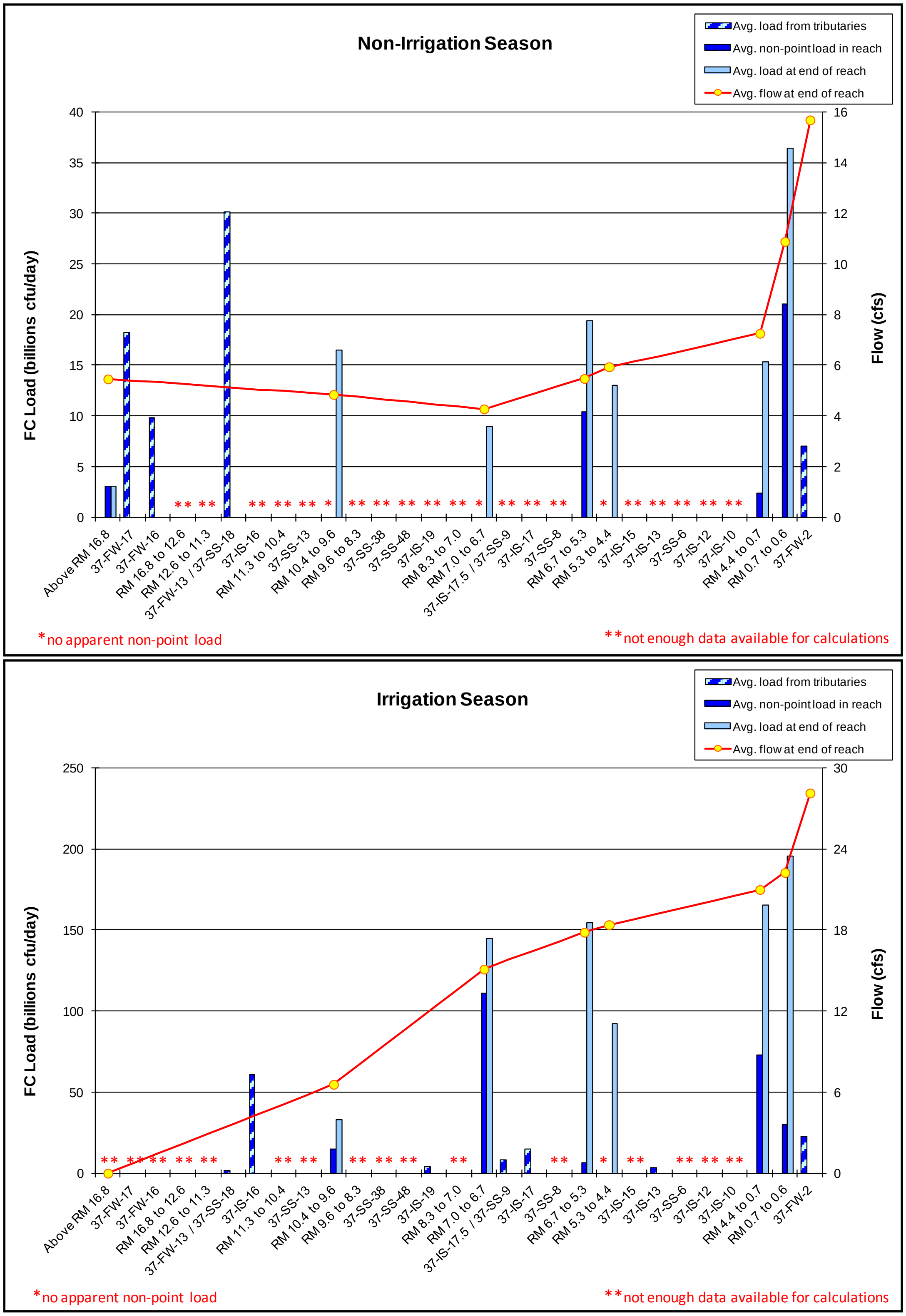


Figure 27. 2004-06 non-irrigation season and irrigation season average FC loads in Wide Hollow Creek.

Note the differences in vertical axes scale between the charts.

Table 27. 2004-06 non-irrigation season and irrigation season FC loading percentages to Wide Hollow Creek.

Reach (Wide Hollow RM or Tributary)	Site (End of Reach)	Non-Irrigation Season	Irrigation Season
Above RM 16.8	37-FW-18	3.0%	-
37-FW-17	37-FW-17	17.9%	-
37-FW-16	37-FW-16	9.6%	-
RM 16.8 to 12.6	37-FW-15 / 37-SS-17	-	-
RM 12.6 to 11.3	37-FW-12 / 37-SS-16	-	-
37-FW-13 / 37-SS-18	37-FW-13 / 37-SS-18	29.5%	0.4%
37-IS-16	37-IS-16	-	17.3%
RM 11.3 to 10.4	37-SS-15	-	-
37-SS-13	37-SS-13	-	-
RM 10.4 to 9.6	37-FW-8 / 37-SS-14	0.0%[1]	4.2%[2]
RM 9.6 to 8.3	37-SS-12	-	-
37-SS-38	37-SS-38	-	-
37-SS-48	37-SS-48	-	-
37-IS-19	37-IS-19	-	1.0%
RM 8.3 to 7.0	37-SS-11	-	-
RM 7.0 to 6.7	37-FW-6	0.0%[3]	31.8%[3]
37-IS-17.5 / 37-SS-9	37-IS-17.5 / 37-SS-9	-	2.3%
37-IS-17	37-IS-17	-	4.2%
37-SS-8	37-SS-8	-	-
RM 6.7 to 5.3	37-FW-5	10.2%	1.9%
RM 5.3 to 4.4	37-FW-4 / 37-SS-7	0.0%	0.0%
37-IS-15	37-IS-15	-	-
37-IS-13	37-IS-13	-	1.0%
37-SS-6	37-SS-6	-	-
37-IS-12	37-IS-12	-	-
37-IS-10	37-IS-10	-	-
RM 4.4 to 0.7	37-FW-1 / 37-SS-5	2.3%	20.8%
RM 0.7 to 0.6	37-FW-0 / 37-SS-1	20.7%	8.6%
37-FW-2	37-FW-2	6.9%	6.4%

[1] This percentage is the sum of all unaccounted for nonpoint loads between RM 16.8 and RM 9.6.
[2] This percentage is the sum of all unaccounted for nonpoint loads above RM 9.6 (outside Yakima city limits).
[3] This percentage is the sum of all unaccounted for nonpoint loads between RM 9.6 and 6.7.
- Not enough data available for calculations

Table 28. 2004-06 non-irrigation season and irrigation season TSS and chloride loading percentages in Wide Hollow Creek.

Reach (Wide Hollow RM or Tributary)	Site	TSS		Chloride	
		Non-Irrigation Season	Irrigation Season	Non-Irrigation Season	Irrigation Season
Above RM 16.8	37-FW-18	3.2%	-	1.8%	-
37-FW-17	37-FW-17	12.3%	-	10.0%	-
37-FW-16	37-FW-16	3.1%	-	5.6%	-
RM 16.8 to 12.6	37-FW-15 / 37-SS-17	-	-	-	-
RM 12.6 to 11.3	37-FW-12 / 37-SS-16	-	-	-	-
37-FW-13 / 37-SS-18	37-FW-13 / 37-SS-18	47.8%	0.1%	7.8%	0.9%
37-IS-16	37-IS-16	-	11.3%	-	7.2%
RM 11.3 to 10.4	37-SS-15	-	-	-	-
37-SS-13	37-SS-13	-	-	-	-
RM 10.4 to 9.6	37-FW-8 / 37-SS-14	8.7%[1]	2.2%[2]	3.4%[1]	5.6%[2]
RM 9.6 to 8.3	37-SS-12	-	-	-	-
37-SS-38	37-SS-38	-	-	-	-
37-SS-48	37-SS-48	-	-	-	-
37-IS-19	37-IS-19	-	1.6%	-	1.0%
RM 8.3 to 7.0	37-SS-11	-	-	-	-
RM 7.0 to 6.7	37-FW-6	0.0%[3]	14.3%[3]	6.1%[3]	12.2%[3]
37-IS-17.5 / 37-SS-9	37-IS-17.5 / 37-SS-9	-	1.0%	-	0.3%
37-IS-17	37-IS-17	-	0.3%	-	2.8%
37-SS-8	37-SS-8	-	-	-	-
RM 6.7 to 5.3	37-FW-5	8.0%	55.8%	12.7%	4.0%
RM 5.3 to 4.4	37-FW-4 / 37-SS-7	0.0%	0.0%	6.4%	5.8%
37-IS-15	37-IS-15	-	-	-	-
37-IS-13	37-IS-13	-	0.0%	-	2.3%
37-SS-6	37-SS-6	-	-	-	-
37-IS-12	37-IS-12	-	-	-	-
37-IS-10	37-IS-10	-	-	-	-
RM 4.4 to 0.7	37-FW-1 / 37-SS-5	2.6%	0.0%	2.6%	21.8%
RM 0.7 to 0.6	37-FW-0 / 37-SS-1	3.1%	2.1%	18.0%	9.9%
37-FW-2	37-FW-2	11.3%	11.3%	25.6%	26.2%

[1] This percentage is the sum of all unaccounted for nonpoint loads between RM 16.8 and RM 9.6.
[2] This percentage is the sum of all unaccounted for nonpoint loads above RM 9.6.
[3] This percentage is the sum of all unaccounted for nonpoint loads between RM 9.6 and 6.7.
- Not enough data available for calculations

The majority of chloride loads to Wide Hollow Creek was from East Spring Creek (26%), the reach between RM 0.7 and RM 0.6 (18%), the reach between RM 6.7 and RM 5.3 (13%), and the tributary at Stone Road near Cook Road (10%).

Non-irrigation FC loading percentages were high for the reach between RM 0.7 and RM 0.6, the reach between RM 6.7 and RM 5.3, and the tributary at Stone Road near Cook Road. This suggests that conditions and nonpoint sources that elevate chloride, such as failing septic tanks, could also be elevating FC concentrations. These sources should be considered for FC contamination in these reaches.

Most of the irrigation season chloride loading to Wide Hollow Creek was from East Spring Creek (26%), the reach between RM 4.4 and RM 0.7 (22%), the reach between RM 9.6 and RM 6.7 (12%), and the reach between RM 0.7 and RM 0.6 (10%).

There appears to be an irrigation season relationship between high chloride loading percentages and FC loading percentages for the reach between RM 9.6 and RM 6.7 and the reach between RM 0.7 and RM 0.6. Conditions and nonpoint sources that elevate chloride could also be elevating FC concentrations. These sources should be considered for FC contamination in these reaches.

2010 FC Bacteria analysis

Table 29, Figure 28, and Figure 29 present the 2010 post-irrigation season (October – December) and partial irrigation season (June – October) summary statistics of FC counts. Table 29 also presents the target reductions necessary to meet the water quality standards in Wide Hollow Creek. Sixteen sites were sampled in 2010 in contrast to 29 during the 2004-06 study. Twelve of these 16 sites were sampled during the 2004-06 study, and 4 of the 16 were new sites added during the 2010 study.

Non-irrigation season statistics were calculated using 2 samples or less at all sites. Non-irrigation FC concentrations in Wide Hollow Creek at 80th, 64th and 40th Avenues met the water quality criteria despite some source loads. Downstream of 40th Avenue, the instream concentrations become elevated. The mainstem Wide Hollow Creek sites at 37-FW-3 and 37-FW-0 probably would not meet criteria. Randall Park Pond, DID #40, and DID #4 (37-IS-17.5 / 37-SS-9, 37-IS-17, and 37-IS-15) also had elevated FC concentrations beyond criteria.

FC concentrations during the irrigation season were elevated versus the non-irrigation season. All seven sites with at least ten samples did not meet either part of the Primary Contact water quality criteria. Six sites had only one sample taken, but the sample clearly indicate the presence of high FC concentrations. DID #48, Shaw Creek, and DID #24 (37-SS-48, 37-IS-13, and 37-IS-12B) each had only one sample collected, but FC counts were very low.

Table 29. 2010 non-irrigation season and irrigation season summary statistics of FC counts and target percent reductions for sites in Wide Hollow Creek.

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile*	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
Non-Irrigation Season								
37-IS-16	0	-	-	-	-	-	-	-
37-SS-13B	0	-	-	-	-	-	-	-
37-FW-8	2	1	0	3	19	8	0%	0%
37-SS-12	2	5	2	12	56	28	0%	0%
37-SS-38	1	3	-	3	-	3	0%	0%
37-SS-48	0	-	-	-	-	-	-	-
37-FW-6B	2	23	13	48	182	100	0%	0%
37-IS-17.5 / 37-SS-9	2	100	25	548	11947	3000	50%	98%
37-IS-17	1	280	-	280	-	280	100%	64%
37-FW-4	2	24	15	44	133	81	0%	0%
37-IS-15	1	4300	-	4300	-	4300	100%	98%
37-IS-13	1	1	-	1	-	1	0%	0%
37-IS-12B	1	1	-	1	-	1	0%	0%
37-FW-3	2	49	25	111	485	250	50%	59%
37-IS-10	0	-	-	-	-	-	-	-
37-FW-0	2	130	98	184	345	260	50%	46%
Irrigation Season								
37-IS-16	1	240	-	240	-	240	100%	58%
37-SS-13B	1	470	-	470	-	470	100%	79%
37-FW-8	10	8	33	159	778	670	40%	74%
37-SS-12	10	14	45	161	571	530	50%	65%
37-SS-38	1	580	-	580	-	580	100%	83%
37-SS-48	1	37	-	37	-	37	0%	0%
37-FW-6B	10	110	99	393	1559	3500	70%	87%
37-IS-17.5 / 37-SS-9	10	230	611	1686	4651	3600	100%	96%
37-IS-17	1	3500	-	3500	-	3500	100%	97%
37-FW-4	10	17	37	215	1255	1300	60%	84%
37-IS-15	1	13000	-	13000	-	13000	100%	99%
37-IS-13	1	3	-	3	-	3	0%	0%
37-IS-12B	1	3	-	3	-	3	0%	0%
37-FW-3	10	140	156	367	864	735	70%	77%
37-IS-10	1	320	-	320	-	320	100%	69%
37-FW-0	10	125	100	349	1219	3150	60%	84%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.

**Cells shaded in this column are values based on less than 5 samples collected at that station.

- Not enough data for calculations

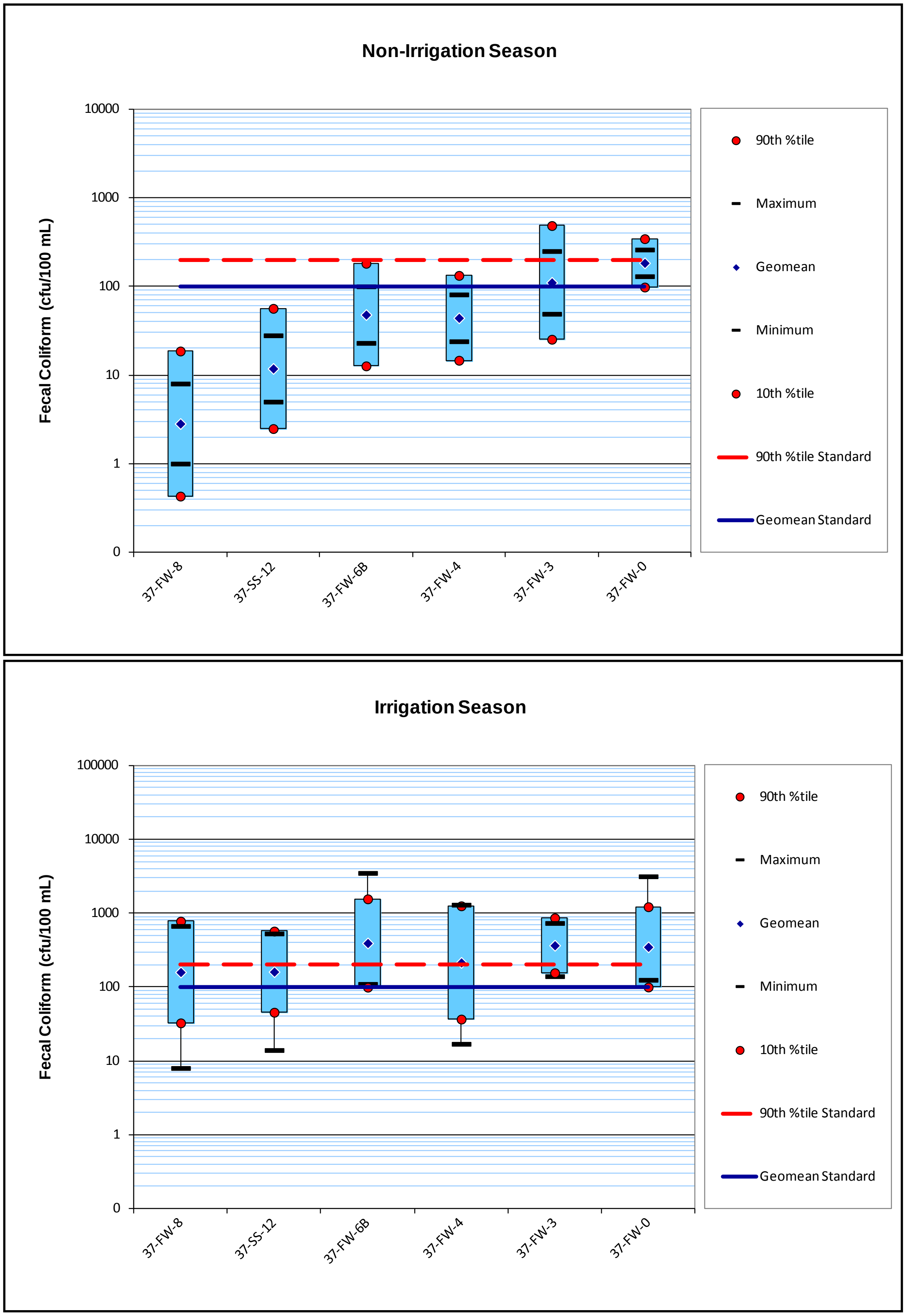
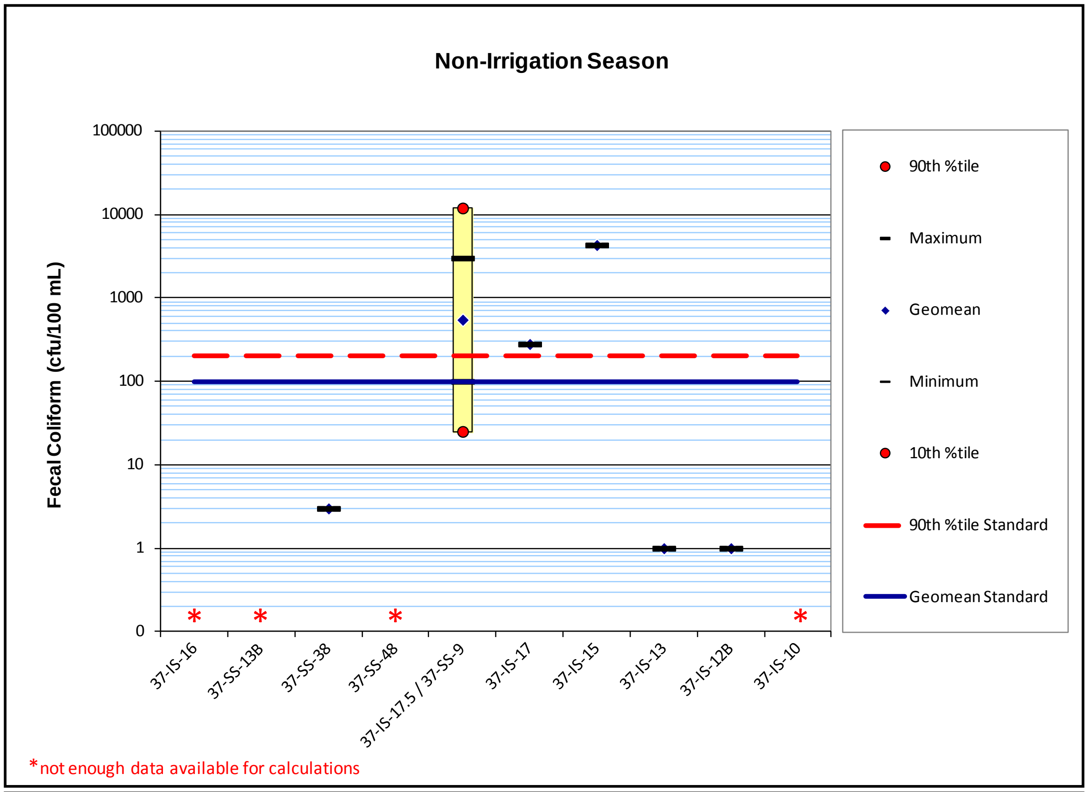


Figure 28. 2010 non-irrigation season and irrigation season summary statistics of FC counts for mainstem sties of Wide Hollow Creek.



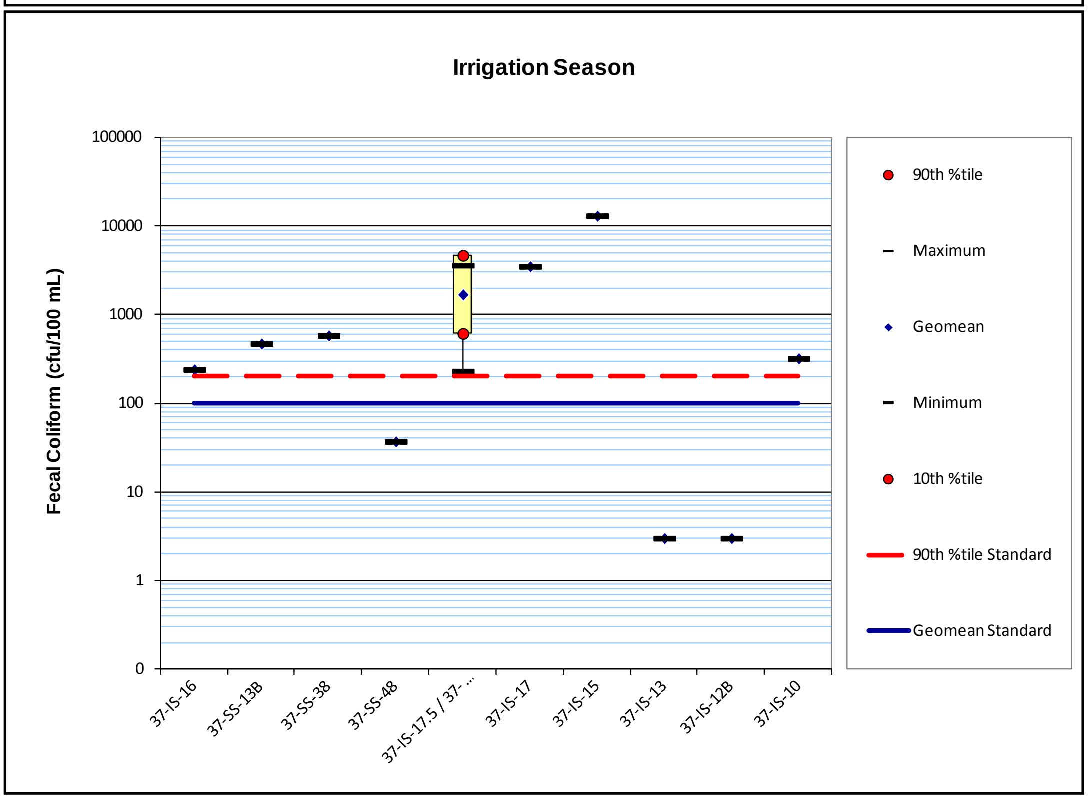


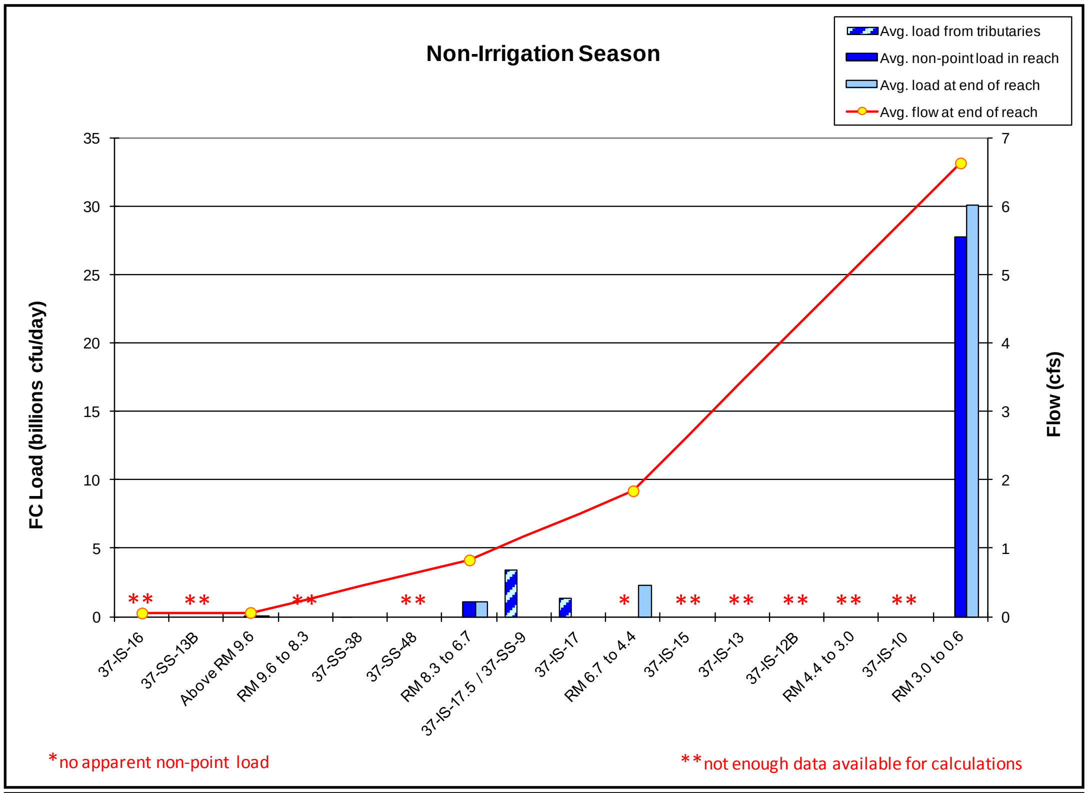
Figure 29. 2010 non-irrigation season and irrigation season summary statistics of FC counts for tributary sites of Wide Hollow Creek.

Average FC loads were calculated for the partial irrigation and non-irrigation seasons using sampling surveys where concentration and streamflow data were available at the majority of fixed-network mainstem sites. Data were used from 3 sampling surveys, fixed-network and irrigation/DID surveys, in the non-irrigation season, as well as 11 sampling surveys, fixed-network and irrigation/DID surveys, in the irrigation season. Figure 30 presents the FC loads for each reach and tributary. Table 30 summarizes the average loads as their percentages of the total load to Wide Hollow Creek if FC die-off and settling are not considered.

The irrigation season FC loads were an order of magnitude higher than the non-irrigation season FC loads (Figure 30).

Over 80% of the non-irrigation FC loads in Wide Hollow Creek were from the reach between RM 4.4 and RM 0.6 (82%). The next largest FC loading percentage during the non-irrigation season was from Randall Park Pond (10%).

Over half of the irrigation season FC loads in Wide Hollow Creek were from the reach between RM 8.3 and RM 6.7 (51%). The majority of the other half of the FC loads was from Congdon Canal (14%) and the reach between RM 4.4 and RM 0.6 (13%). The FC loading percentage at Congdon Canal is an estimate because it was calculated using one sample.



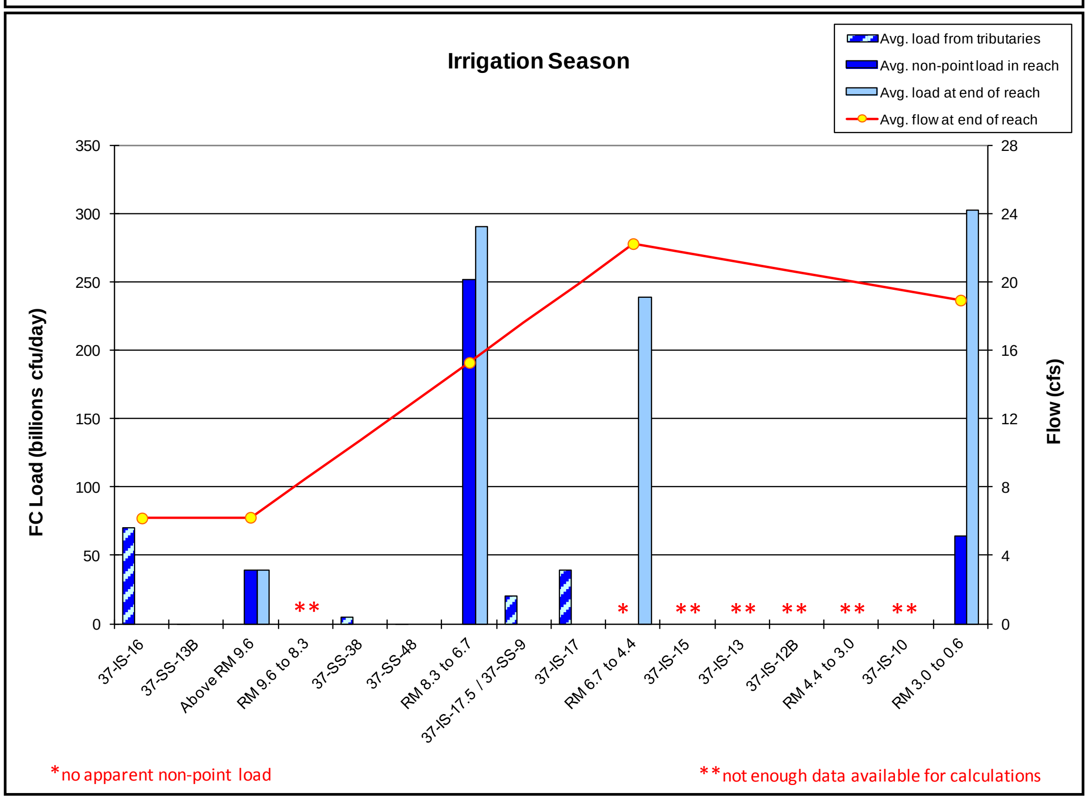


Figure 30. 2010 non-irrigation season and irrigation season average FC loads in Wide Hollow Creek.

Note the differences in vertical axes scale between the charts.

Table 30. 2010 non-irrigation season and irrigation season FC loading percentages to Wide Hollow Creek.

Reach (Wide Hollow RM) or Tributary	Site	Non-Irrigation Season	Irrigation Season
37-IS-16	37-IS-16	-	14.3%
37-SS-13B	37-SS-13B	-	0.1%
Above RM 9.6	37-FW-8	0.0%	8.1%
RM 9.6 to 8.3	37-SS-12	-	-
37-SS-38	37-SS-38	0.0%	0.9%
37-SS-48	37-SS-48	-	0.1%
RM 8.3 to 6.7	37-FW-6B	3.3%[1]	51.3%[1]
37-IS-17.5 / 37-SS-9	37-IS-17.5 / 37-SS-9	10.2%	4.2%
37-IS-17	37-IS-17	4.1%	8.0%
RM 6.7 to 4.4	37-FW-4	0.0%	0.0%
37-IS-15	37-IS-15	-	-
37-IS-13	37-IS-13	-	-
37-IS-12B	37-IS-12B	-	-
RM 4.4 to 3.0	37-FW-3	-	-
37-IS-10	37-IS-10	-	-
RM 3.0 to 0.6	37-FW-0	82.4%[2]	13.1%[2]

[1] This percentage is the sum of all unaccounted for nonpoint loads between RM 9.6 and RM 6.7.
[2] This percentage is the sum of all unaccounted for nonpoint loads between RM 4.4 and RM 0.6.
- Not enough data available for calculations

Comparison of 2004 -2006 to 2010 FC Bacteria Results

Overall the FC concentrations in Wide Hollow Creek during the 2010 study appear to be consistent with the 2004-06 study. The comparison is difficult due to the differences in numbers of samples collected, climate, and hydrology between the two studies. The Wilcoxon Rank Sum test was conducted on each site that was sampled at least twice during each study. FC concentrations at most of the sites were not statistically different between the 2004-06 and 2010 studies. Only the FC concentrations at 37-SS-12 during the irrigation season were statistically different between the 2004-06 and 2010 studies. However, there were only 2 irrigation season samples collected at 37-SS-12 during the 2004-06 study. Therefore, the statistical difference could be due to the low number of samples collected at this site. Since no statistical difference between the 2004-06 and 2010 studies was found, no reductions in seasonal average bacteria concentrations or loads in Wide Hollow Creek from the improvements, put in place after the 2004-06 study, could be detected.

The irrigation season TSS loads were significantly higher than non-irrigation season TSS loads.

FC loading percentage was also the highest from the reach between RM 4.4 and RM 0.6. This suggests that conditions that elevate TSS, such as high flows or runoff processes (causing soil erosion), could also be elevating FC concentrations in this reach during the non-irrigation season.

There does not appear to be a relationship between high FC loads and TSS loads for Randall Park Pond. Therefore, conditions that elevate TSS do not appear to be elevating FC concentrations in the pond.

Half of the irrigation season TSS loading was from the reach between RM 6.7 and RM 4.4 (Table 31). The other half of the TSS loading was from Congdon Canal (24%), above RM 9.6 (10%), and the reach between RM 9.6 and 6.7 (10%).

There does not appear to be a relationship between high FC loads and TSS loads for the reach between RM 6.7 and RM 4.4. Therefore, conditions that elevate TSS do not appear to be elevating FC concentrations in this reach.

Irrigation season FC loading percentages and TSS loading percentages were both high for Congdon Canal, above RM 9.6, and the reach between 9.6 and 6.7. This suggests that conditions that elevate TSS could also be elevating FC concentrations in these reaches during the irrigation season.

Table 31. 2010 non-irrigation season and irrigation season TSS loading percentages to Wide Hollow Creek.

Reach (Wide Hollow RM) or Tributary	Site	Non-Irrigation Season	Irrigation Season
37-IS-16	37-IS-16	-	24.3%
37-SS-13B	37-SS-13B	-	0.2%
Above RM 9.6	37-FW-8	0.7%	10.9%
RM 9.6 to 8.3	37-SS-12	-	-
37-SS-38	37-SS-38	0.1%	0.2%
37-SS-48	37-SS-48	-	1.2%
RM 8.3 to 6.7	37-FW-6B	4.7%[1]	10.8%[1]
37-IS-17.5 / 37-SS-9	37-IS-17.5 / 37-SS-9	2.7%	1.9%
37-IS-17	37-IS-17	0.3%	0.1%
RM 6.7 to 4.4	37-FW-4	0.0%	50.5%
37-IS-15	37-IS-15	-	-
37-IS-13	37-IS-13	-	-
37-IS-12B	37-IS-12B	-	-
RM 4.4 to 3.0	37-FW-3	-	-
37-IS-10	37-IS-10	-	-
RM 3.0 to 0.6	37-FW-0	91.6%[2]	0.0%[2]

[1] This percentage is the sum of all unaccounted for nonpoint loads between RM 9.6 and RM 6.7.
[2] This percentage is the sum of all unaccounted for nonpoint loads between RM 4.4 and RM 0.6.
- Not enough data available for calculations

Cottonwood Creek

Cottonwood Creek was monitored at two sites during 2004-06, at Moore Road and near the mouth at Dazet Road (37-FW-14 and 37-FW-13 / 37-SS-18, respectively). Cottonwood Creek was not monitored during the 2010 surveys.

Table 32 and Figure 31 present the non-irrigation season and irrigation season summary statistics of FC counts. Table 32 also presents the target reductions necessary to meet the water quality standards in Cottonwood Creek.

Non-irrigation season FC concentrations at Moore Road (37-FW-14) and near the mouth at Dazet Road (37-FW-13 / 37-SS-18) met both parts of the criteria. However, the percentage of samples greater than 200 cfu / 100 mL was over 10%. At Moore Road, 1 out of 6 samples was greater than 200 cfu / 100 mL (17%). At Dazet Road, 1 out of 8 samples was greater than 200 cfu / 100 mL (13%). The single elevated sample at both sites occurred during the January 2006 warming and light rain event. All other samples were collected while streamflows were under 1 cfs.

Although streamflows remained under 1 cfs, irrigation season FC concentrations in Cottonwood Creek were much higher than during the non-irrigation season. Both sites did not meet either part of the water quality criteria during the irrigation season.

Table 32. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts and target percent reductions for sites of Cottonwood Creek.

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile*	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
Non-Irrigation Season								
37-FW-14	6	5	4	22	129	270	17%	0%
37-FW-13 / 37-SS-18	8	1	1	5	49	240	13%	0%
Irrigation Season								
37-FW-14	4	21	25	360	5086	2950	75%	96%
37-FW-13 / 37-SS-18	9	41	35	332	3167	8000	56%	94%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.
**Cells shaded in this column are values based on less than 5 samples collected at that station.

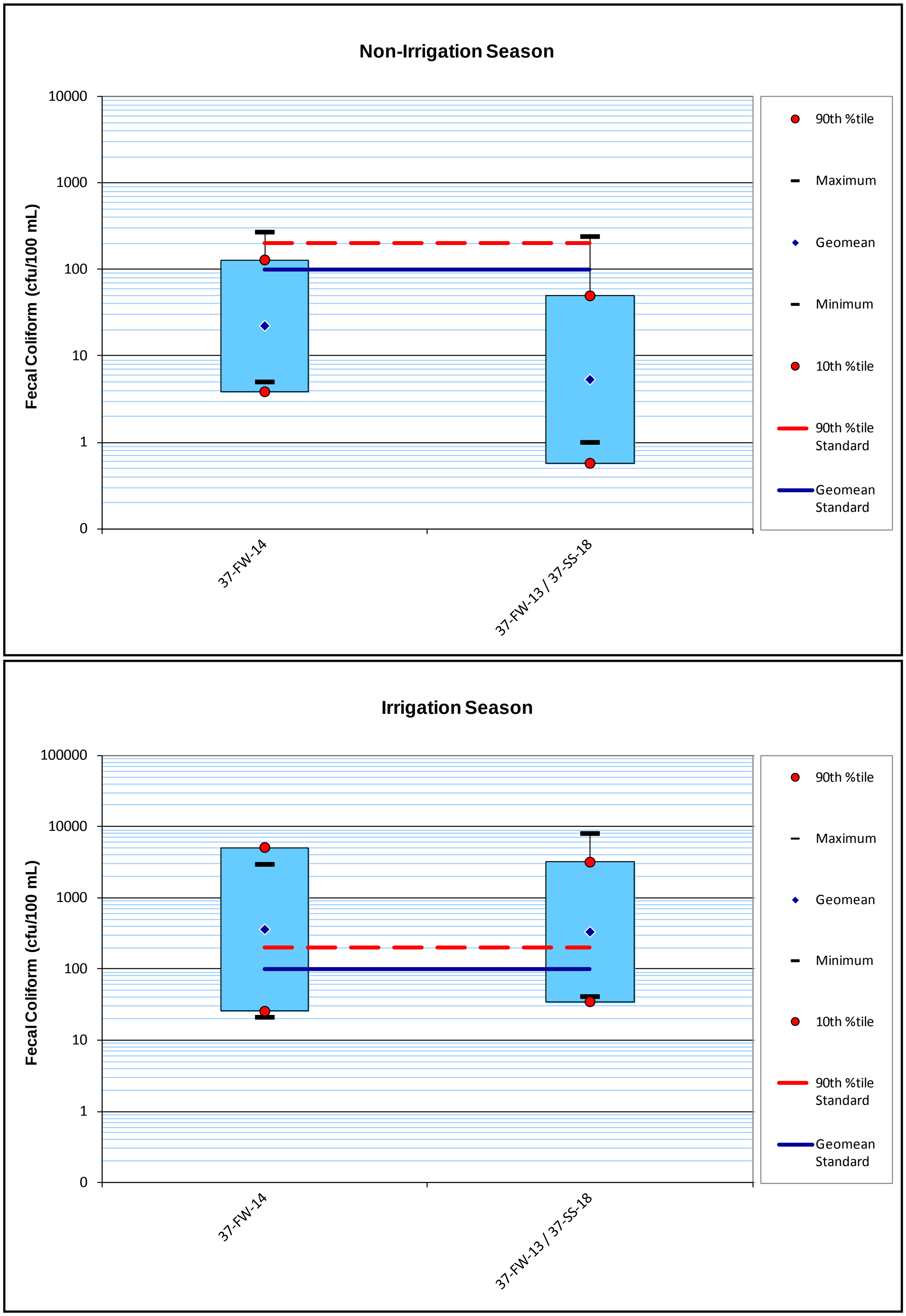


Figure 31. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts for sites in Cottonwood Creek.

Average seasonal FC loads were calculated using sampling surveys where concentration and streamflow data were collected at both Cottonwood Creek sites. Data were used from 6 sampling surveys in the non-irrigation season and 4 sampling surveys in the irrigation season. Figure 32 presents the average non-irrigation season and irrigation season FC loads for each reach and tributary. Table 33 summarizes the average loads as their percentages of the total load to Cottonwood Creek.

Based on seasonal averages, it appears that 100% of the FC loading to Cottonwood Creek was from above the site at Moore Road (37-FW-14). Therefore, the reach downstream of Moore Road to the mouth does not appear to be contributing any additional FC loads to Cottonwood Creek. However, Cottonwood Creek went dry during the irrigation season at Moore Road after May, and high FC concentrations were still present at Dazet Road in June and July. Therefore, a possible source of FC bacteria between Moore Road and Dazet Road cannot be ruled out.

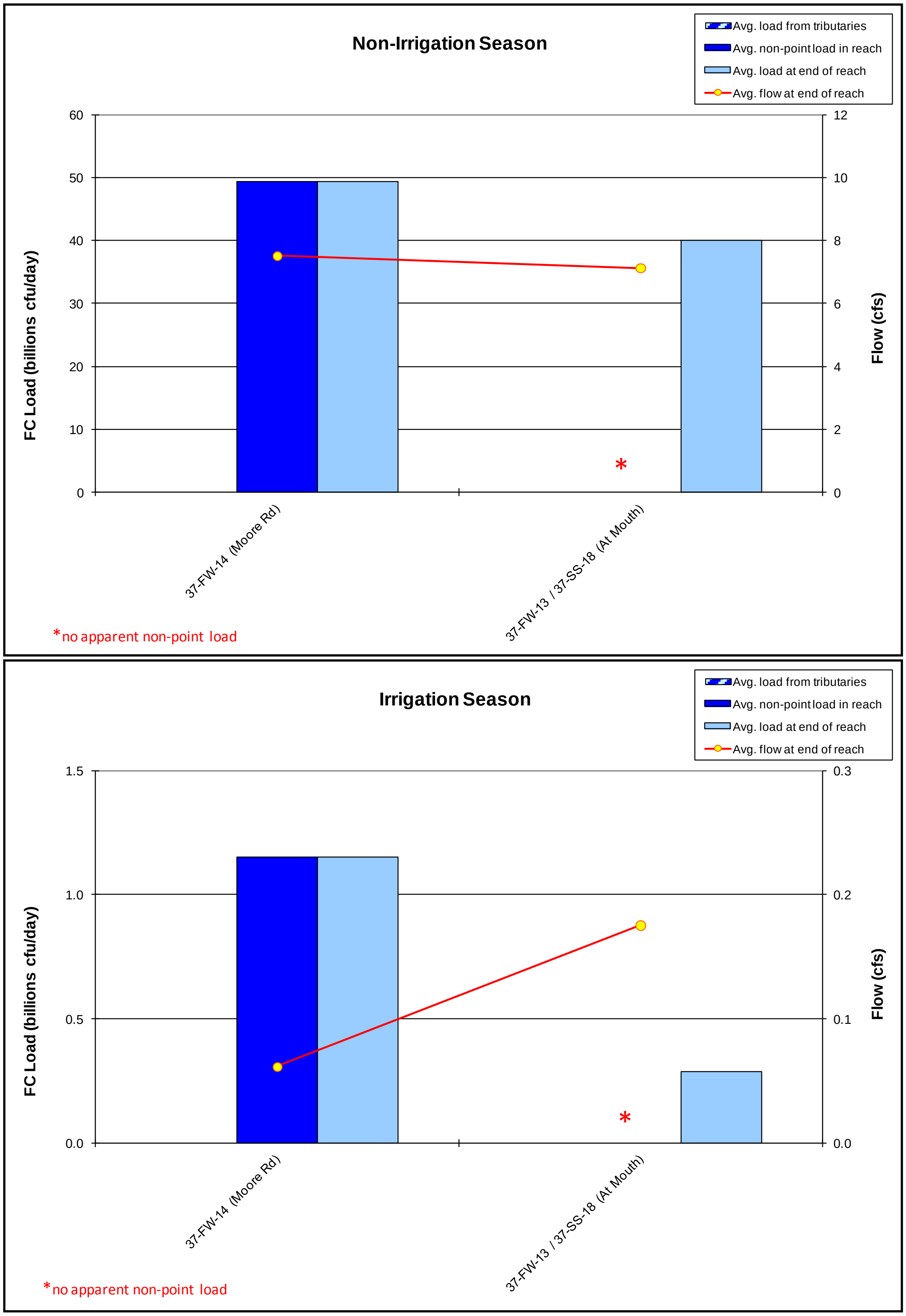


Figure 32. 2004-06 non-irrigation season and irrigation season average FC loads in Cottonwood Creek.

Note the differences in vertical axes scale between the charts.

Table 33. 2004-06 non-irrigation season and irrigation season FC loading percentages to Cottonwood Creek.

Reach (Cottonwood Creek site)	Site (End of Reach)	Non-Irrigation Season	Irrigation Season
37-FW-14 (Moore Rd)	37-FW-14	100.0%	100.0%
37-FW-13 / 37-SS-18 (At Mouth)	37-FW-13 / 37-SS-18	0.0%	0.0%

Table 34 presents the non-irrigation season and irrigation season TSS load contribution percentages.

100% of the non-irrigation TSS loads to Cottonwood Creek appear to be from above Moore Road.

The majority of the irrigation season TSS loads were from the reach between Moore Road and the mouth (75%). Though not the majority, 25% of the irrigation season TSS loads came from above Moore Road.

Figure 33 shows a very weak but positive relationship between irrigation season TSS concentrations and FC concentrations for both sites in Cottonwood Creek. This illustrates that conditions that elevate TSS could also elevate FC concentrations in Cottonwood Creek during the irrigation season.

Table 34 also presents the non-irrigation season and irrigation season chloride load contribution percentages.

There is no apparent relationship between non-irrigation season and irrigation season chloride loads and FC loads in Cottonwood Creek.

Table 34. 2004-06 non-irrigation season and irrigation season TSS and chloride loading percentages to Cottonwood Creek.

Reach (Cottonwood Creek site)	Site	TSS		Chloride	
		Non-Irrigation Season	Irrigation Season	Non-Irrigation Season	Irrigation Season
37-FW-14 (Moore Rd)	37-FW-14	100.0%	24.9%	59.7%	28.0%
37-FW-13 / 37-SS-18 (At Mouth)	37-FW-13 / 37-SS-18	0.0%	75.1%	40.3%	72.0%

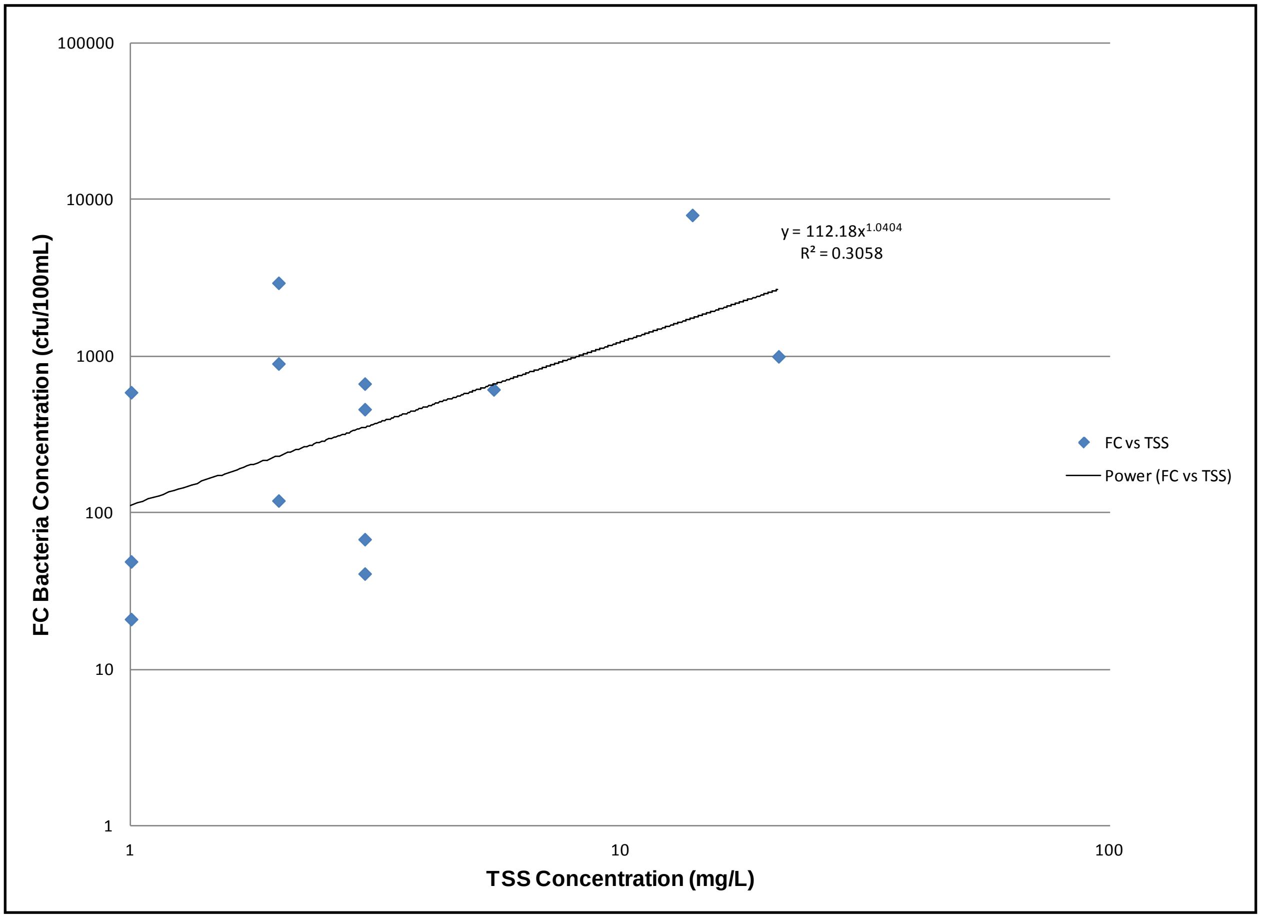


Figure 33. 2004-06 relationship between irrigation TSS and FC concentrations in Cottonwood Creek.

Randall Park Pond

During the 2004-06 surveys, Randall Park Pond was monitored from above the pond at DID #48 near Viola and 48th Avenue (37-IS-18) to the pond outlet on 44th Avenue (37-IS-17.5 / 37-SS-9). In 2010, Randall Park Pond was monitored from above the pond in an open section of DID #48 behind 48th Avenue (37-IS-18B) to the pond outlet on 44th Avenue (37-IS-17.5 / 37-SS-9).

Table 35 and Figure 34 present the non-irrigation season and irrigation season summary statistics of FC counts. Table 35 also presents the target reductions necessary to meet the water quality standards in Randall Park Pond.

No samples were collected at 37-IS-18 during the non-irrigation season. One sample was collected at 37-IS-17.5 / 37-SS-9 during the non-irrigation season. This sample had a concentration of 200 cfu / 100 mL, so it did not meet the water quality criteria. FC concentrations in Randall Park Pond did not meet either part of the criteria. FC concentrations appear to be elevated at the outlet of the pond in comparison to above the pond in DID #48.

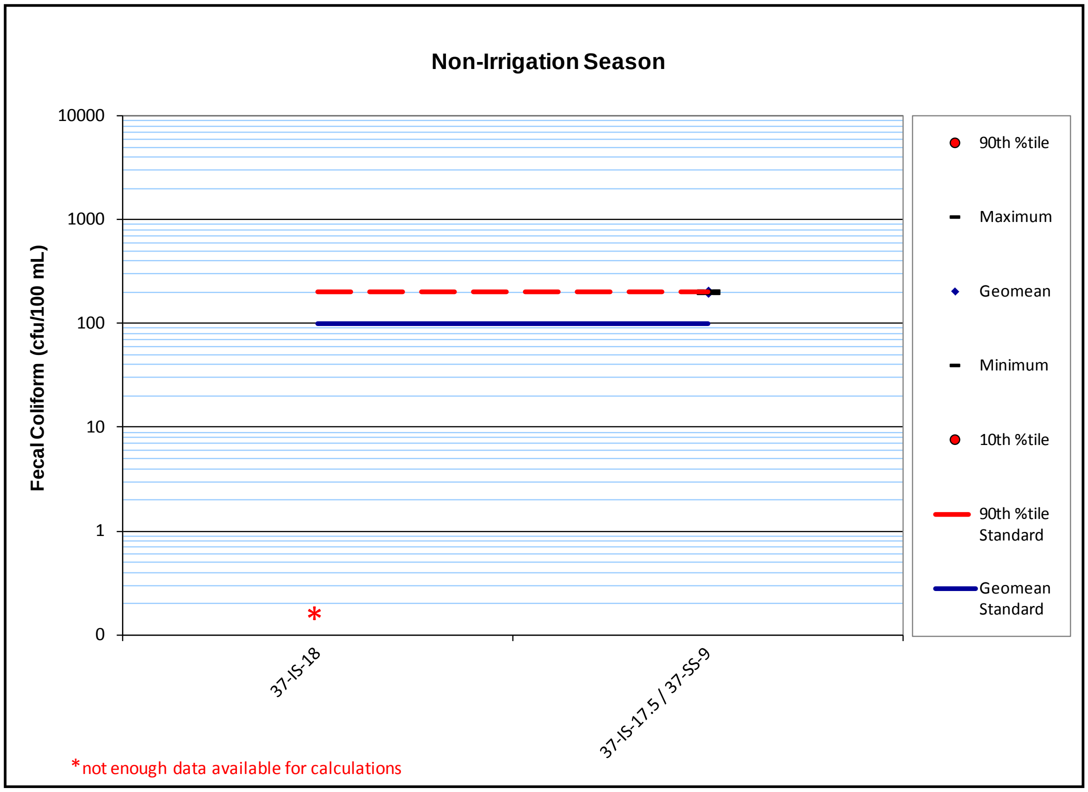
Table 35. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts and target percent reductions for sites of Randall Park Pond.

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile*	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
Non-Irrigation Season								
37-IS-18	0	-	-	-	-	-	-	-
37-IS-17.5 / 37-SS-9	1	200	-	200	-	200	0%	50%
Irrigation Season								
37-IS-18	3	130	107	224	469	410	67%	57%
37-IS-17.5 / 37-SS-9	4	870	921	1602	2787	2200	100%	94%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.

**Cells shaded in this column are values based on less than 5 samples collected at that station.

- Not enough data for calculations



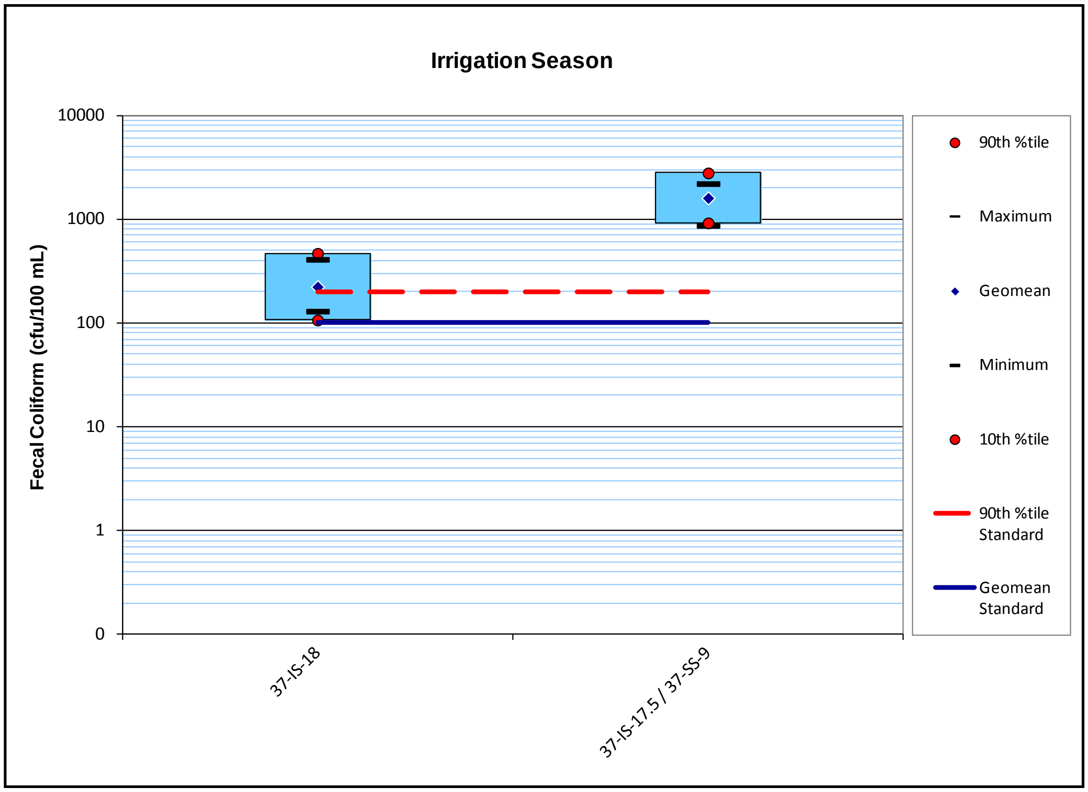


Figure 34. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts for sites of Randall Park Pond.

There were not enough data available for average non-irrigation season FC loads to be calculated for Randall Park Pond. Average irrigation season FC loads were calculated using sampling surveys where concentration and streamflow data were available at both Randall Park Pond sites. Data were used from 2 sampling surveys in the irrigation season, so the FC loads are estimates due to the limited data available. Figure 35 presents the average irrigation season FC loads for both sites in Randall Park Pond. Table 36 summarizes the average loads as their percentages of the total load to Randall Park Pond.

80% of the irrigation season FC loading to Randall Park Pond was from the reach between 48th Avenue and 44th Avenue including the pond. The pond and park have a large duck and goose colony.

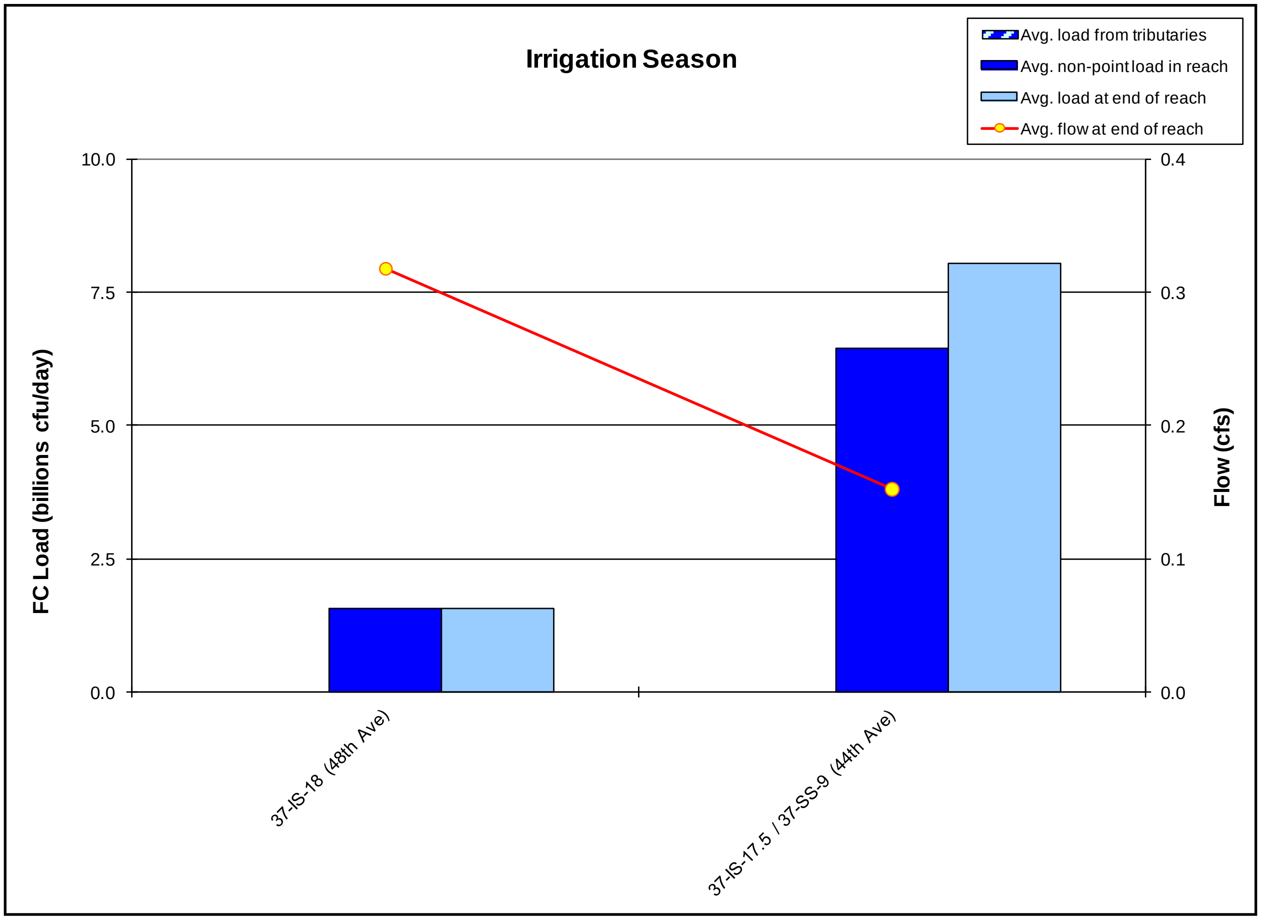


Figure 35. 2004-06 irrigation season average FC loads in Randall Park Pond.

Table 36. 2004-06 non-irrigation season and irrigation season FC loading percentages to Randall Park Pond.

Reach (Randall Park Pond site)	Site (End of Reach)	Non-Irrigation Season	Irrigation Season
37-IS-18 (48th Ave)	37-IS-18	-	19.7%
37-IS-17.5 / 37-SS-9 (44th Ave)	37-IS-17.5 / 37-SS-9	-	80.3%

- Not enough data available for calculations.

Based on the data from the two sampling surveys, there appears to be a relationship between estimated FC loading percentages and estimated TSS loading percentages during the irrigation season in Randall Park Pond (Table 37). Figure 36 shows a strong positive relationship between irrigation season TSS concentrations and FC concentrations in Randall Park Pond. This illustrates that conditions that elevate TSS could also be elevating FC concentration in Randall Park Pond during the irrigation season. The water-fowl feces in the pond are likely contributing nutrients that feed aquatic algae blooms or other aquatic plants. The increase in algae blooms could explain the increase in TSS, while the water fowl feces could explain the increase in FC bacteria. This is a different process than FC bacteria being adsorbed to sediment then being transported to the water body by run-off sources. This process needs to be further investigated in Randall Park Pond.

There is no apparent relationship between the estimated FC loading percentages and the estimated chloride loading percentages.

Table 37. 2004-06 non-irrigation season and irrigation season TSS and chloride loading percentages to Randall Park Pond.

Reach (Randall Park Pond site)	Site	TSS		Chloride	
		Non-Irrigation Season	Irrigation Season	Non-Irrigation Season	Irrigation Season
37-IS-18 (48th Ave)	37-IS-18	-	8.6%	-	100.0%
37-IS-17.5 / 37-SS-9 (44th Ave)	37-IS-17.5 / 37-SS-9	-	91.4%	-	0.0%

- Not enough data available for calculations.

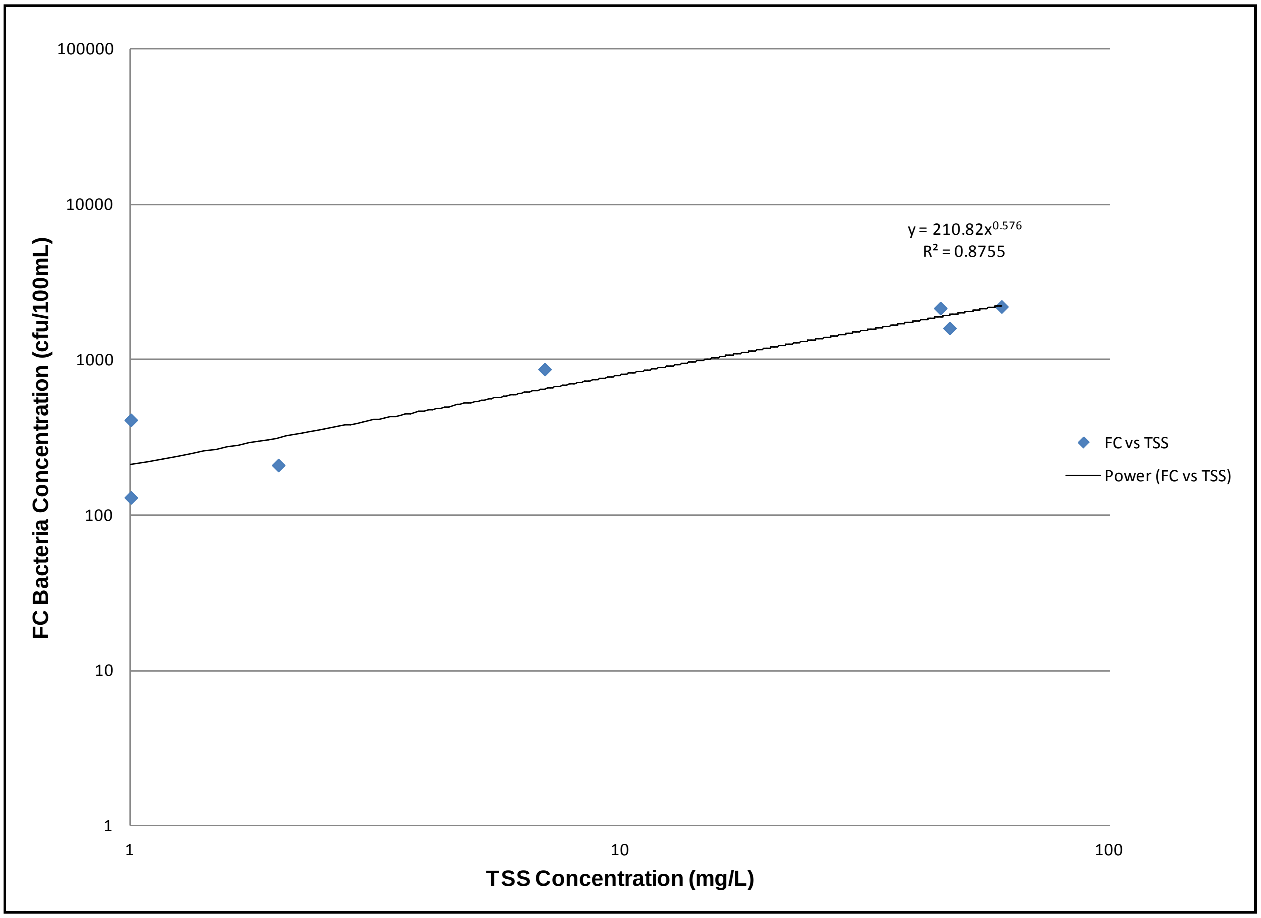


Figure 36. 2004-06 relationship between irrigation season TSS and FC concentrations in Randall Park Pond.

2010 FC Bacteria analysis

Table 38 and Figure 37 present the non-irrigation season and irrigation season summary statistics of FC counts. Table 38 also presents the target reductions necessary to meet the water quality standards in Randall Park Pond.

One sample was collected at the upper site (37-IS-18B) during the non-irrigation season, and two samples were collected at the outlet of the pond (37-IS-17.5 / 37-SS-9) during the non-irrigation season. These samples had concentrations that did not meet the water quality criteria. The non-irrigation summary statistics for these sites are estimates, due to the limited number of samples collected. More samples need to be collected to better establish summary statistics during the non-irrigation season.

One sample was collected at the upper site (37-IS-18B) during the irrigation season, and this sample had a concentration of 730 cfu / 100 mL. This concentration did not meet water quality criteria. The irrigation season summary statistics for this site are estimates, but the high FC concentration in the sample indicates the presence of elevated FC bacteria at the site during the irrigation season.

Ten samples were collected at the outlet of the pond (37-IS-17.5 / 37-SS-9) during the irrigation season, and 100% of the samples were greater than 200 cfu / 100 mL. Therefore, FC concentrations at this site did not meet either part of the water quality criteria.

Average FC loading percentages to Randall Park Pond for 2010 could not be calculated due to the limited data available at the upstream site (37-IS-18B).

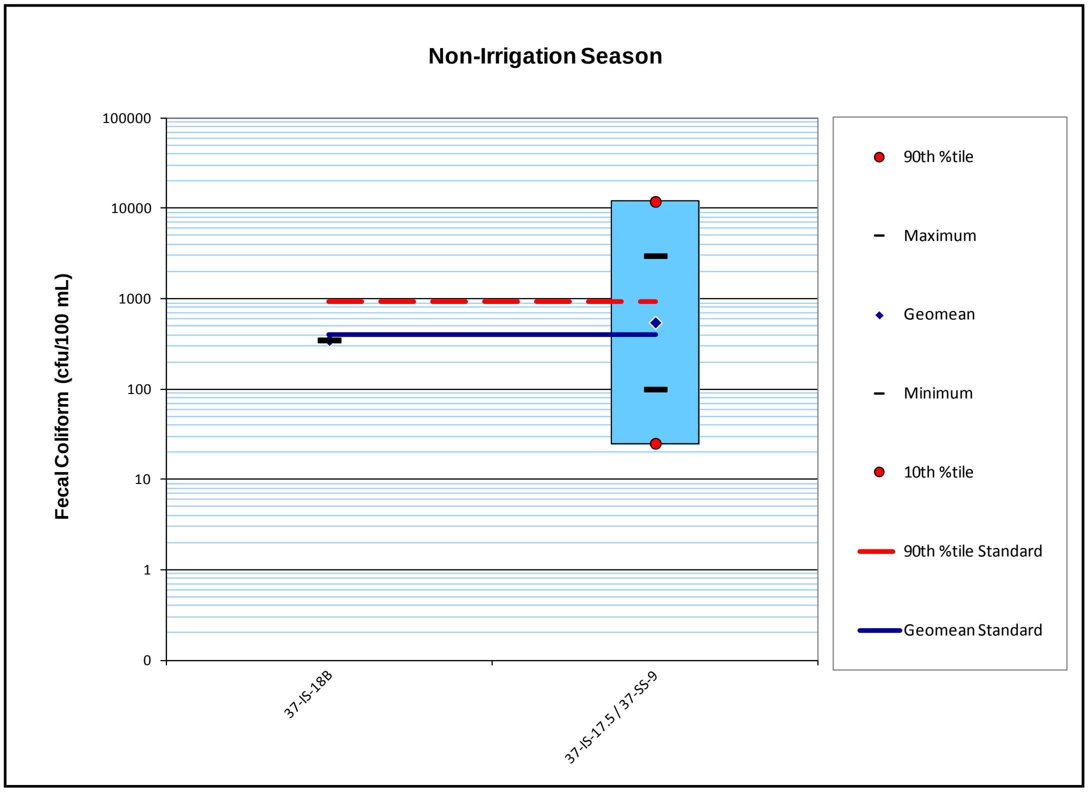
Table 38. 2010 non-irrigation season and irrigation season summary statistics of FC counts and target percent reductions in Randall Park Pond.

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile*	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
Non-Irrigation Season								
37-IS-18B	1	350	-	350	-	350	100%	71%
37-IS-17.5 / 37-SS-9	2	100	25	548	11947	3000	50%	98%
Irrigation Season								
37-IS-18B	1	730	-	730	-	730	100%	86%
37-IS-17.5 / 37-SS-9	10	230	611	1686	4651	3600	100%	96%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.

**Cells shaded in this column are values based on less than 5 samples collected at that station.

- Not enough data for calculations



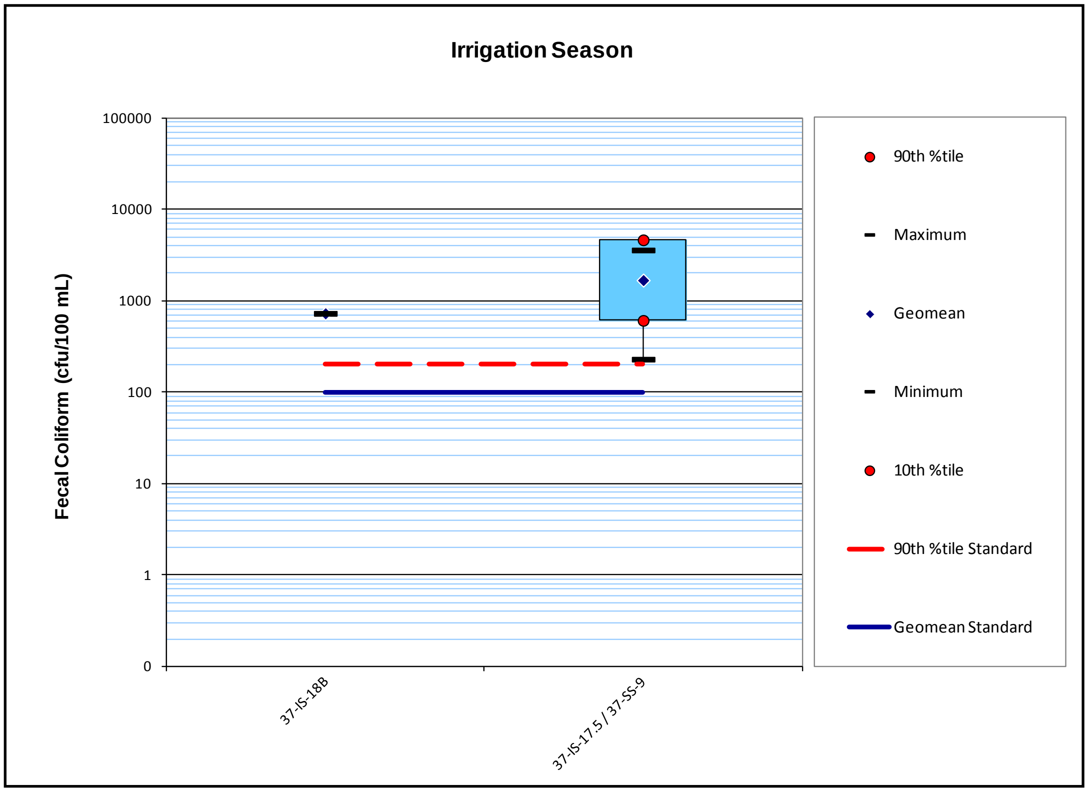


Figure 37. 2010 non-irrigation season and irrigation season summary statistics of FC counts for sites of Randall Park Pond.

Comparison of 2004 -2006 to 2010 FC Bacteria Results

Overall the FC concentrations in Randall Park Pond during the 2010 study appear to be consistent with the 2004-06 study. There was a slight increase in the maximum and 90th percentile at the downstream site (37-IS-17.5/37-SS-9) in 2010, but the geomeans were consistent between the two studies at this site. The comparison is difficult due to the differences in total number of samples collected, climate, and hydrology between the two studies. The Wilcoxon Rank Sum test was conducted for 37-IS-17.5/37-SS-9, and there was no statistical difference between the 2004-06 and 2010 FC concentrations at this site.

Average TSS loading percentages to Randall Park Pond for 2010 could not be calculated due to the limited data available at the upstream site (37-IS-18B). However, there is an apparent weak but positive relationship between irrigation season TSS concentrations and FC concentrations in Randall Park Pond (Figure 38). As mentioned before, this positive relationship was present during 2004-06 study, so conditions that elevate TSS may also be elevating FC concentrations in Randall Park Pond in the irrigation season.

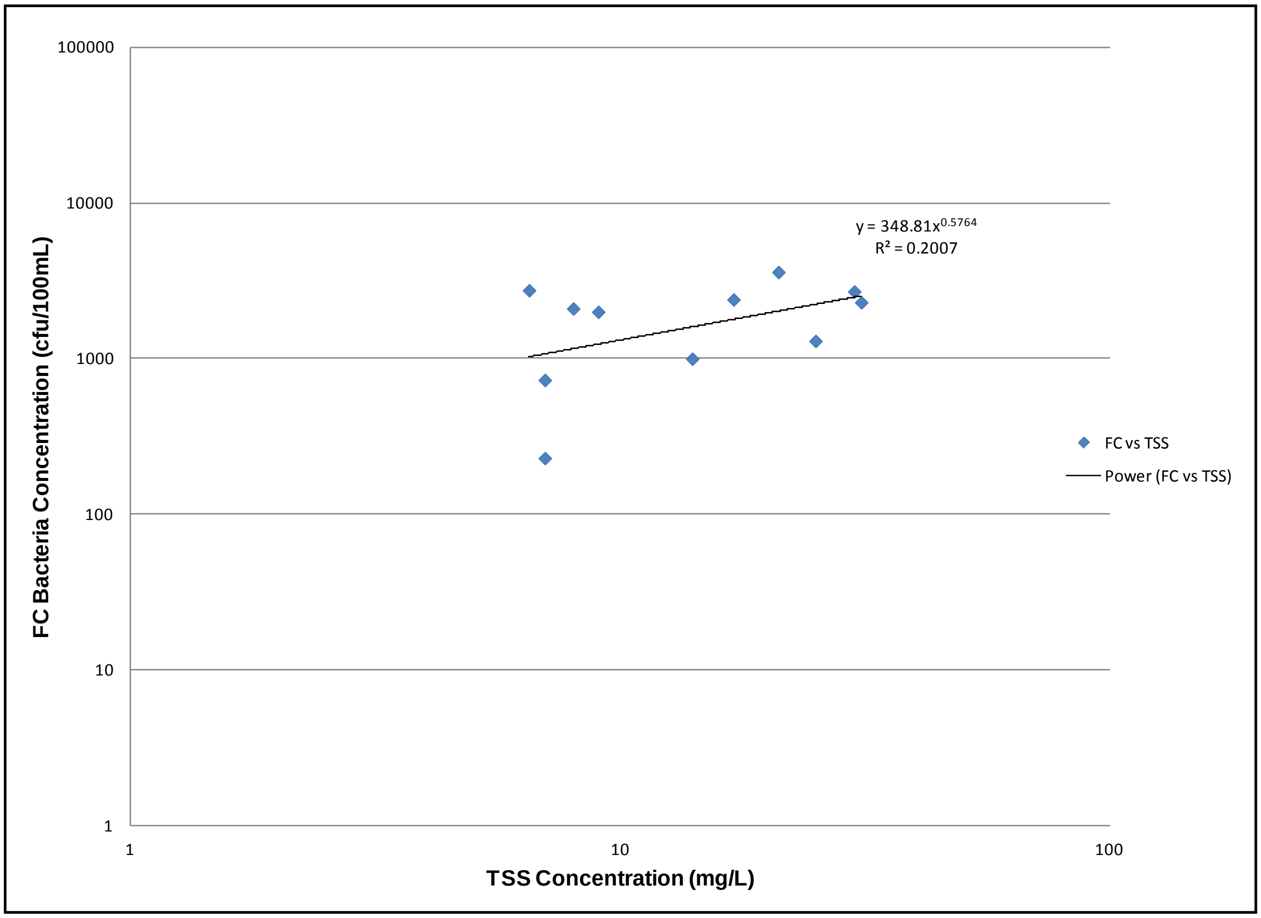


Figure 38. 2010 relationship between irrigation season TSS and FC concentrations in Randall Park Pond.

East Spring Creek

A city stormwater outfall at the end of Ahtanum Road (37-SS-2) and East Spring Creek near the mouth by Union Gap Public Works (37-FW-2) were sampled during the 2004-06 surveys. East Spring Creek was not sampled during the 2010 surveys.

Table 39, Figure 39, and Figure 40 present the non-irrigation season and irrigation season summary statistics of FC counts. Table 39 also presents the target reductions necessary to meet the water quality standards in East Spring Creek.

One sample was collected at the city stormwater outfall at the east end of Ahtanum Road (37-SS-2) during the non-irrigation season, and two were collected during the irrigation season. These samples had a wide range of FC concentration of 31 - 400 cfu / 100 mL, indicating a potential source of FC bacteria to the creek.

FC concentrations at the mouth of East Spring Creek (37-FW-2) were only consistently elevated during the irrigation season. Counts stayed fairly constant from May through August at around 180 – 300 cfu/100 mL. The site failed both parts of the FC criteria during the irrigation season.

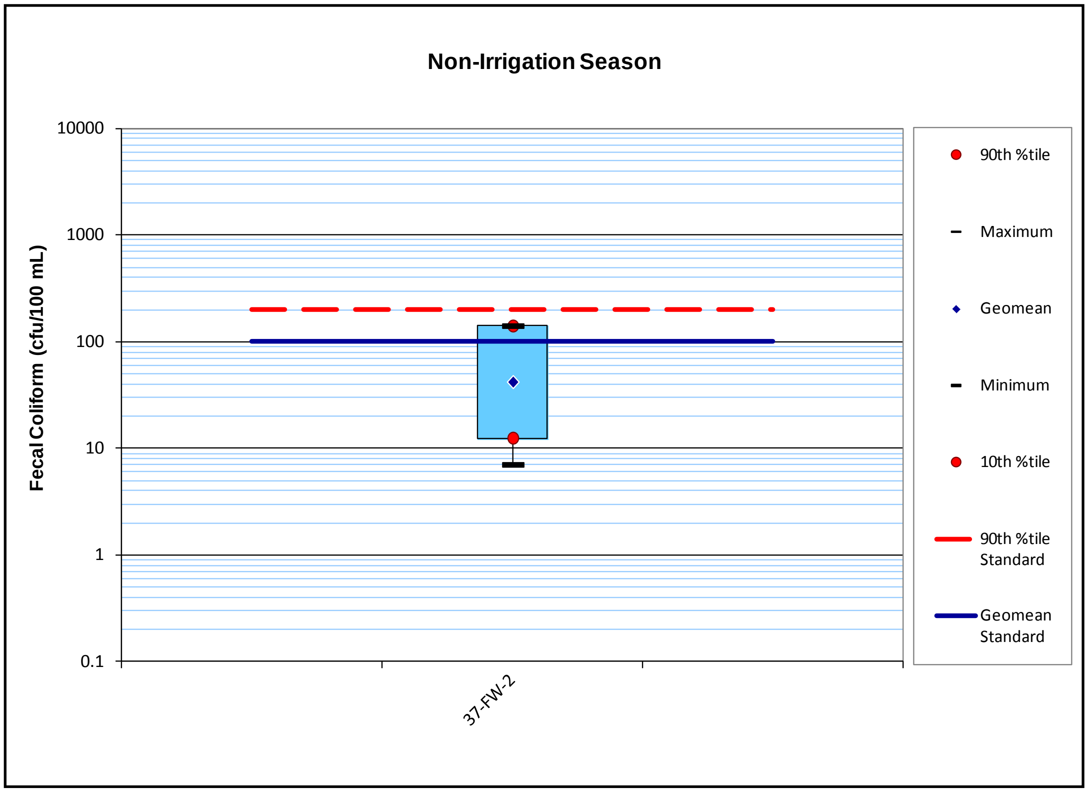
Table 39. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts and target percent reductions for sites in East Spring Creek.

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile*	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
Non-Irrigation Season								
37-SS-2	1	130	-	130	-	130	0%	23%
37-FW-2	11	7	12	42	140	140	0%	0%
Irrigation Season								
37-SS-2	2	31	11	111	1131	400	50%	82%
37-FW-2	14	25	54	130	316	300	36%	37%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.

**Cells shaded in this column are values based on less than 5 samples collected at that station.

- Not enough data for calculations



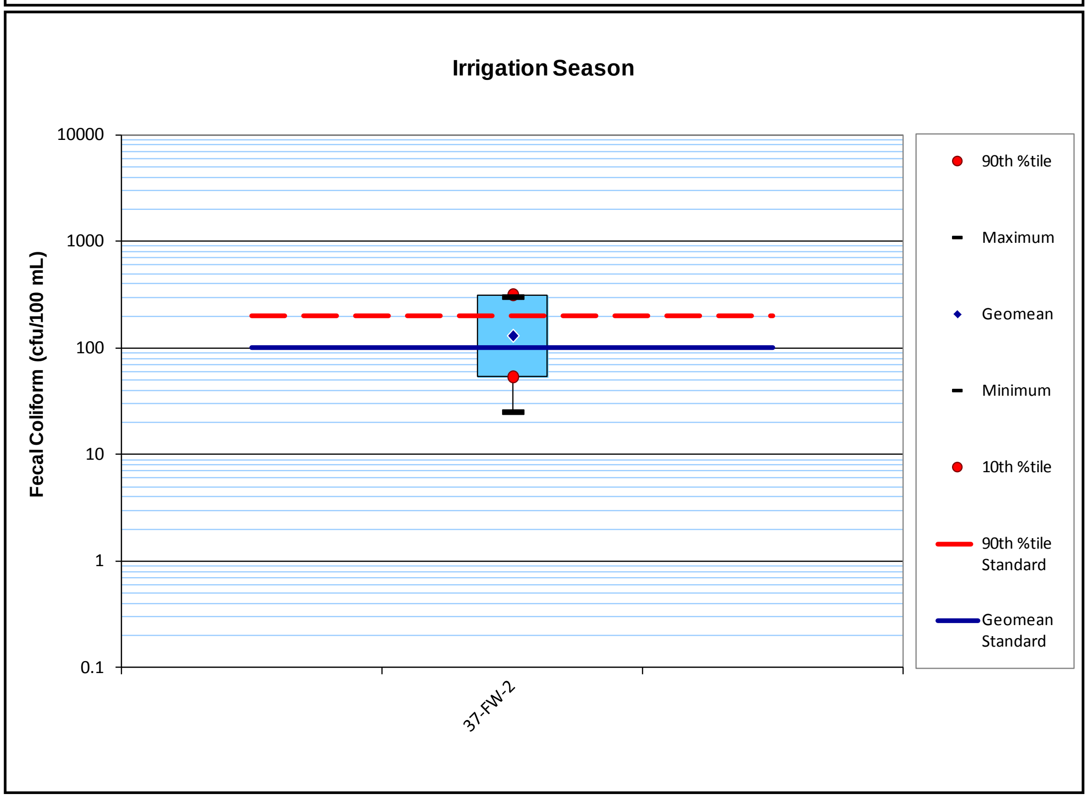
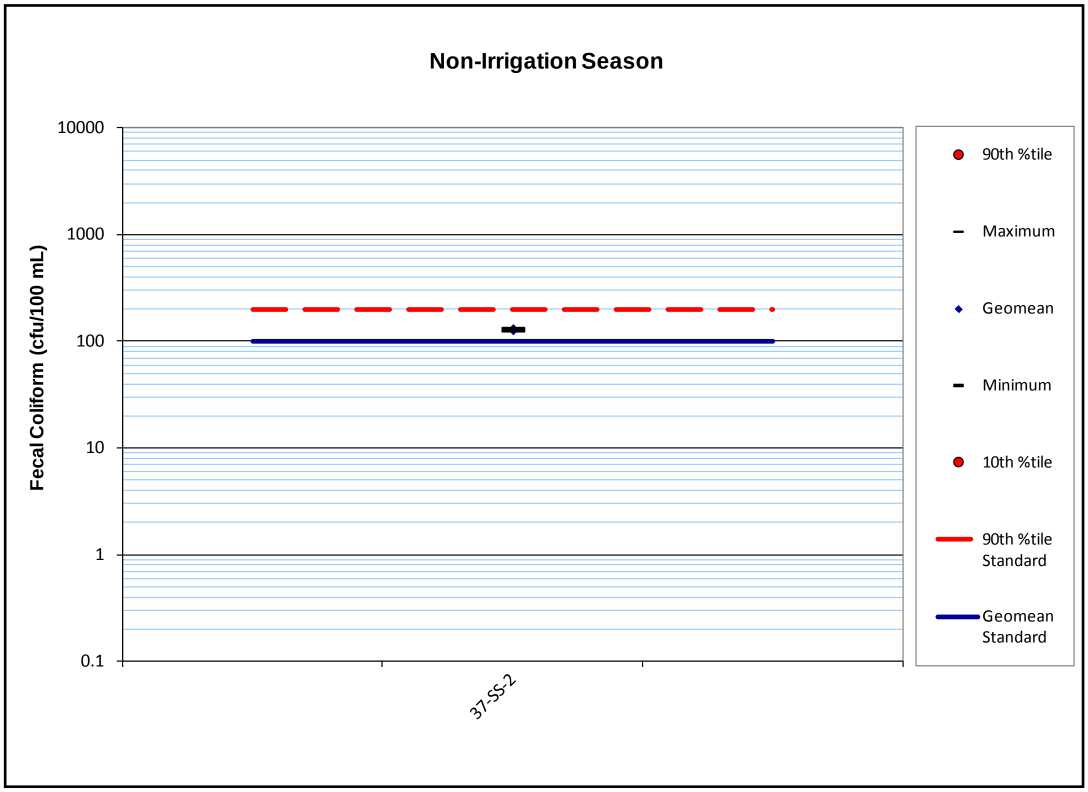


Figure 39. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts for mainstem sites in East Spring Creek.



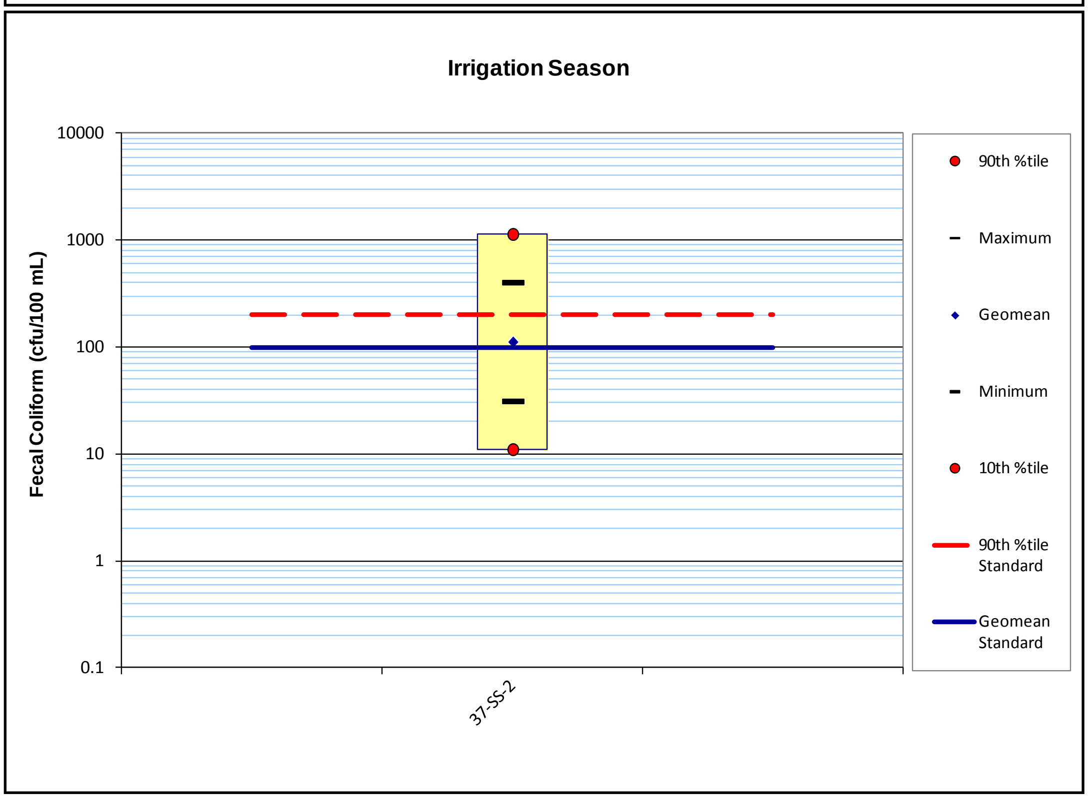


Figure 40. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts for tributary sites in East Spring Creek.

Moxee Drain

Moxee Drain and its tributaries were monitored from the Roza Canal near Beane Road (site 37-IS-5) to just upstream of the confluence with the Yakima River (site 37-FM-1) (Figure 6). During the 2004-06 surveys, Ecology sampled 14 sites along Moxee Drain and 7 sites along DID #11.

During the 2010 surveys, Ecology sampled 3 sites along Moxee Drain. These 3 sites were sampled June through December.

Table 40, Figure 41, and Figure 42 present the non-irrigation season and irrigation season summary statistics of FC counts. Table 40 also presents the target reductions necessary to meet the water quality standards in Moxee Drain.

Five out of the 7 sampled sites during the non-irrigation season did not meet the water quality criteria. Moxee Drain near the mouth (37-FM-1) met both parts of the criteria, but 1 of 8 (13%) of the sample concentrations was greater than 200 cfu / 100 mL. Moxee Drain at Walters Road (37-FM-9) and at Beaudry Road (37-FM-8) met water quality criteria during the non-irrigation season.

FC concentrations appear to be elevated during the irrigation season. Twelve out of the 14 sampled sites during the irrigation season did not meet the water quality criteria. Two of these sites, the irrigation outfall at Beaudry Road (37-IS-4.5) and the irrigation ditch at Beaudry (37-FM-7 / 37-IS-3), met one of the two parts of the criteria.

The outfall from Roza Canal (37-IS-5) and an outfall at Walters Road (37-FM-9.5) met water quality criteria during the irrigation season.

The irrigation season statistics for 6 sites were calculated using 4 samples or less. However, the samples that were collected clearly indicate the presence of high FC concentrations.

Table 40. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts and target percent reductions for sites in Moxee Drain.

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile*	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
Non-Irrigation Season								
37-IS-5	0	-	-	-	-	-	-	-
37-FM-10	9	32	35	105	310	360	22%	36%
37-FM-9	9	4	3	11	40	110	0%	0%
37-FM-9.5	0	-	-	-	-	-	-	-
37-IS-4	0	-	-	-	-	-	-	-
37-FM-8	10	5	5	25	125	122	0%	0%
37-IS-4.6	0	-	-	-	-	-	-	-
37-IS-4.5	0	-	-	-	-	-	-	-
37-FM-7 / 37-IS-3	0	-	-	-	-	-	-	-
37-FM-3.6	5	120	92	256	712	890	40%	72%
37-FM-3.5	5	220	179	318	567	520	100%	69%
37-FM-3	10	33	46	132	372	655	30%	46%
37-IS-0	0	-	-	-	-	-	-	-
37-FM-1	8	9	13	46	165	260	13%	0%
Irrigation Season								
37-IS-5	3	8	7	11	19	17	0%	0%
37-FM-10	14	77	88	366	1511	3800	71%	87%
37-FM-9	14	7	17	72	306	510	7%	35%
37-FM-9.5	1	16	-	16	-	16	0%	0%
37-IS-4	4	1	1	28	594	250	25%	66%
37-FM-8	15	5	29	111	431	560	13%	54%
37-IS-4.6	4	29	34	226	1496	970	75%	87%
37-IS-4.5	4	21	19	69	253	250	25%	21%
37-FM-7 / 37-IS-3	14	15	17	69	279	360	14%	28%
37-FM-3.6	7	235	176	550	1726	3600	100%	88%
37-FM-3.5	7	170	125	301	726	1100	57%	72%
37-FM-3	14	22	64	191	573	615	50%	65%
37-IS-0	4	92	92	137	204	180	0%	27%
37-FM-1	14	17	44	136	425	690	29%	53%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.

**Cells shaded in this column are values based on less than 5 samples collected at that station.

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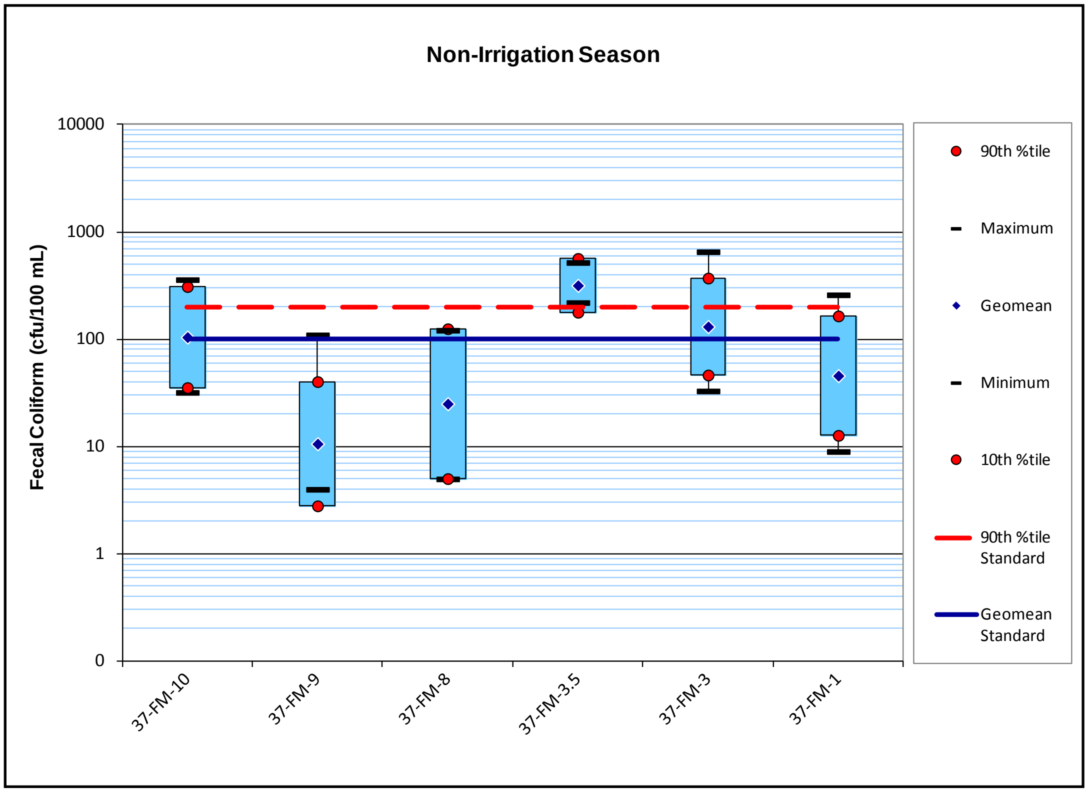


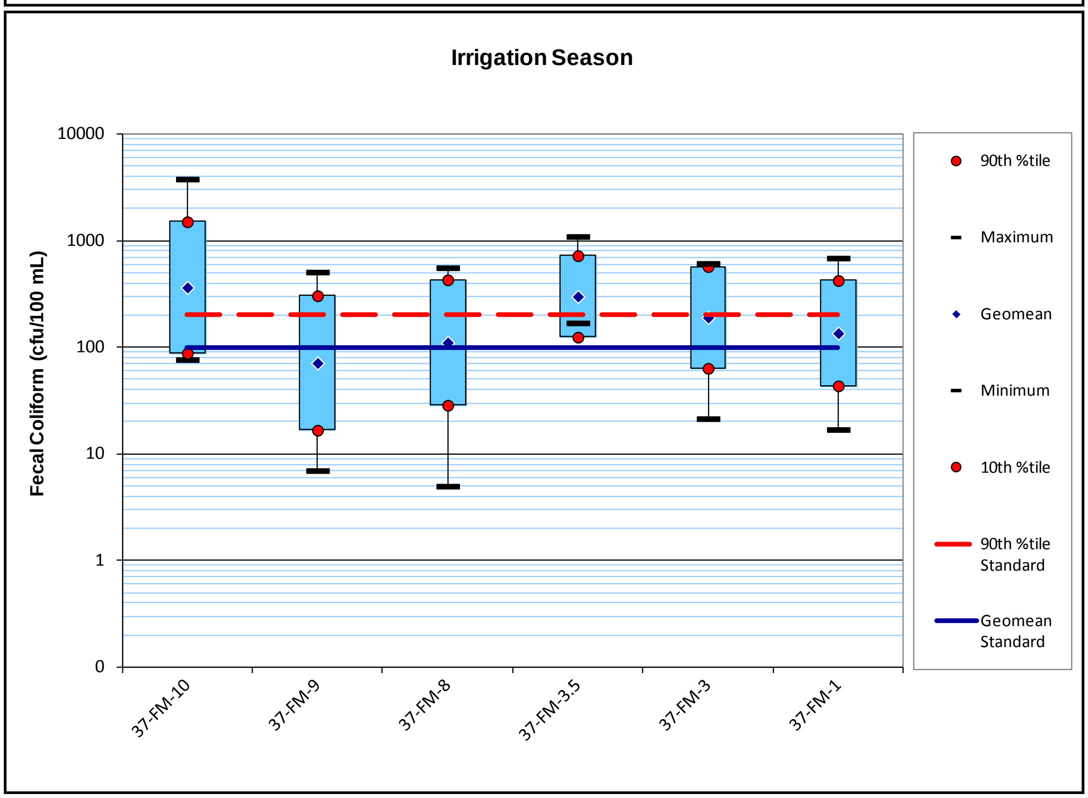


Figure 41. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts for mainstem sites in Moxee Drain.

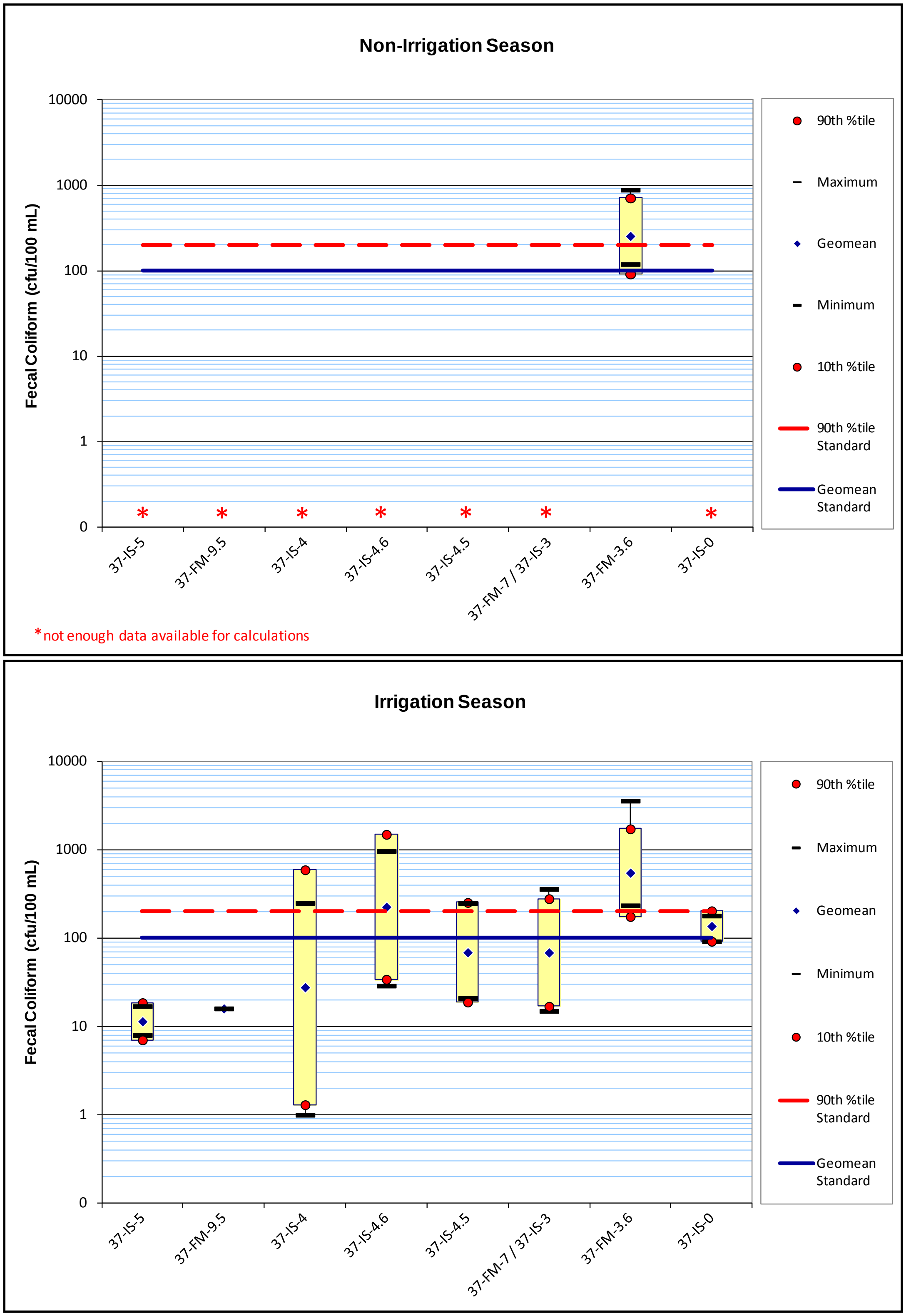


Figure 42. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts for tributary sites in Moxee Drain.

Average seasonal FC loads were calculated using sampling surveys where concentration and streamflow data were available at the majority of fixed-network mainstem sites. Data were used from 7 sampling surveys in the non-irrigation season and 14 sampling surveys in the irrigation season. Figure 43 presents the average non-irrigation season and irrigation season FC loads for each reach and tributary. Table 41 summarizes the average loads as their percentages of the total load to Moxee Drain if FC die-off and settling are not considered.

Based on the analysis in Table 41, nearly three-quarters of the non-irrigation FC loads to Moxee Drain was from the reach between RM 4 and RM 2.1 (72%). The majority of the remaining non-irrigation FC loads was from DID #11 (18%).

Most of the irrigation season FC loads to Moxee Drain was from DID #11 (72%). The majority of the remaining irrigation season loads was from the reach between RM 6.3 and RM 4 (9%) and the reach between RM 8.5 and RM 6.3 (8%).

Eight sites in the non-irrigation season and 2 sites in the irrigation season did not have concentration or streamflow data available for the sample surveys where the mainstem fixed-network sites were also sampled. Therefore, these sites were omitted from the loading analysis. More samples and streamflow need to be collected at these sites to characterize their seasonal percentages of FC loading to Moxee Drain.

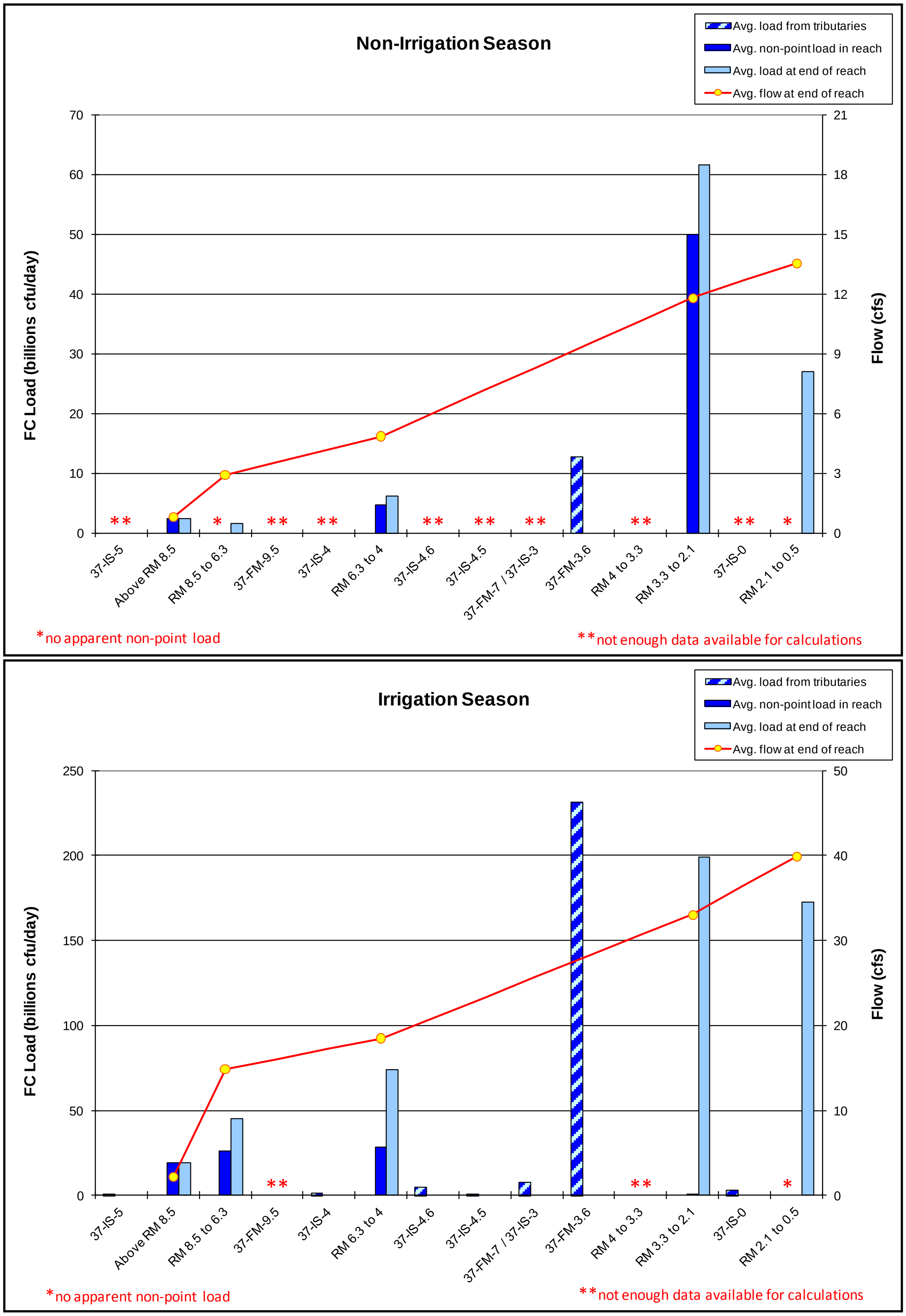


Figure 43. 2004-06 non-irrigation season and irrigation season average FC loads in Moxee Drain.

Note the differences in vertical axes between the charts.

Table 41. 2004-06 non-irrigation season and irrigation season FC loading percentages to Moxee Drain.

Reach (Moxee Drain RM or Tributary)	Site (End of Reach)	Non-Irrigation Season	Irrigation Season
37-IS-5	37-IS-5	-	0.1%
Above RM 8.5	37-FM-10	3.4%	5.9%
RM 8.5 to 6.3	37-FM-9	0.0%	8.0%
37-FM-9.5	37-FM-9.5	-	-
37-IS-4	37-IS-4	-	0.4%
RM 6.3 to 4	37-FM-8	6.7%	8.8%
37-IS-4.6	37-IS-4.6	-	1.5%
37-IS-4.5	37-IS-4.5	-	0.1%
37-FM-7 / 37-IS-3	37-FM-7 / 37-IS-3	-	2.3%
37-FM-3.6	37-FM-3.6	18.2%	71.7%
RM 4 to 3.3	37-FM-3.5	-	-
RM 3.3 to 2.1	37-FM-3	71.7%[1]	0.2%[1]
37-IS-0	37-IS-0	-	1.0%
RM 2.1 to 0.5	37-FM-1	0.0%	0.0%

[1] This percentage is the sum of all unaccounted for nonpoint loads between RM 4 and RM 2.1.

- Not enough data available for calculations.

There does not appear to be a relationship between high FC loads and TSS loads for either season in Moxee Drain (Table 42).

Table 42. 2004-06 non-irrigation season and irrigation season TSS and chloride loading percentages to Moxee Drain.

Reach (Moxee Drain RM or Tributary)	Site	TSS		Chloride	
		Non-Irrigation Season	Irrigation Season	Non-Irrigation Season	Irrigation Season
37-IS-5	37-IS-5	-	0.4%	-	1.4%
Above RM 8.5	37-FM-10	0.7%	0.4%	4.8%	2.8%
RM 8.5 to 6.3	37-FM-9	2.4%	9.8%	14.9%	18.9%
37-FM-9.5	37-FM-9.5	-	-	-	-
37-IS-4	37-IS-4	-	0.2%	-	0.7%
RM 6.3 to 4	37-FM-8	3.0%	40.6%	17.3%	10.7%
37-IS-4.6	37-IS-4.6	-	1.0%	-	0.3%
37-IS-4.5	37-IS-4.5	-	0.0%	-	0.1%
37-FM-7 / 37-IS-3	37-FM-7 / 37-IS-3	-	0.3%	-	5.7%
37-FM-3.6	37-FM-3.6	8.1%	14.9%	20.3%	25.2%
RM 4 to 3.3	37-FM-3.5	-	-	-	-
RM 3.3 to 2.1	37-FM-3	6.2%[1]	10.3%[1]	41.8%[1]	5.6%[1]
37-IS-0	37-IS-0	-	1.4%	-	4.2%
RM 2.1 to 0.5	37-FM-1	79.6%	20.5%	0.9%	24.5%

[1] This percentage is the sum of all unaccounted for nonpoint loads between RM 4 and RM 2.1.
- Not enough data available for calculations.

The reach between RM 4 and RM 2.1 and DID #11 had large FC loading percentages and chloride loading percentages during the non-irrigation season. DID #11, the reach between RM 8.5 and RM 6.3, and the reach between RM 6.3 and RM 4, had the highest FC concentrations during the irrigation season. These reaches also had 3 of the 4 highest chloride loading percentages to Moxee Drain during the irrigation season.

2010 FC Bacteria analysis

Table 43 and Figure 44 present the non-irrigation season and irrigation season summary statistics of FC counts. Table 43 also presents the target reductions necessary to meet the water quality standards in Moxee Drain. Samples were collected during a partial irrigation season (June-October) and a post-irrigation season (November-December). The three sites sampled in 2010 were also sampled during the 2004-06 study.

Moxee Drain at Beane Road (37-FM-10) was the most upstream site for the 2010 surveys. This site was not sampled during the non-irrigation season due to site access constraints. Eight FC concentrations were collected from this site during the irrigation season, and these concentrations did not meet either part of the criteria.

Moxee Drain at Birchfield Road (37-FM-3) did not meet either part of the criteria during both seasons.

Moxee Drain near the mouth (37-FM-1) did not meet either part of the water quality criteria during both seasons.

Non-irrigation summary statistics for 37-FM-3 and 37-FM-1 clearly indicate the continued presence of high FC concentrations at these sites.

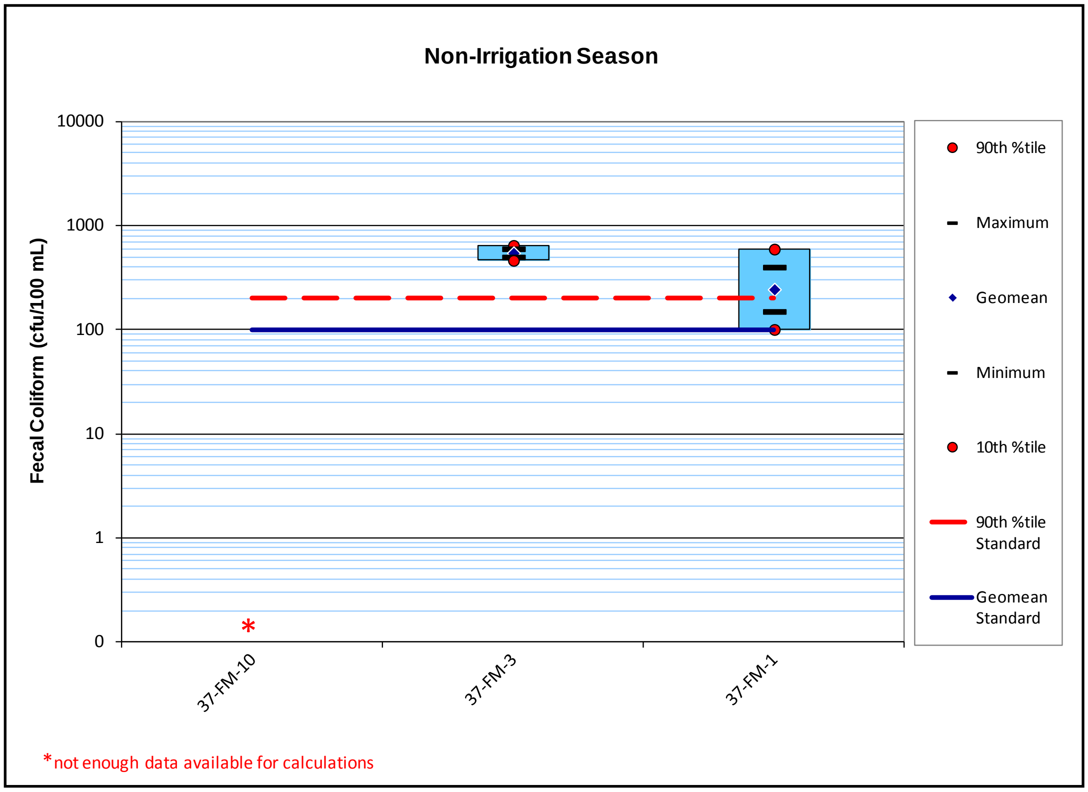
Table 43. 2010 non-irrigation season and irrigation season summary statistics of FC counts and target percent reductions for sites in Moxee Drain.

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile*	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
Non-Irrigation Season								
37-FM-10	0	-	-	-	-	-	-	-
37-FM-3	2	500	464	548	646	600	100%	82%
37-FM-1	2	150	101	245	596	400	50%	66%
Irrigation Season								
37-FM-10	8	88	107	220	453	510	50%	56%
37-FM-3	10	150	106	387	1410	5700	90%	86%
37-FM-1	10	77	117	272	634	1000	70%	68%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.

**Cells shaded in this column are values based on less than 5 samples collected at that station.

- Not enough data for calculations



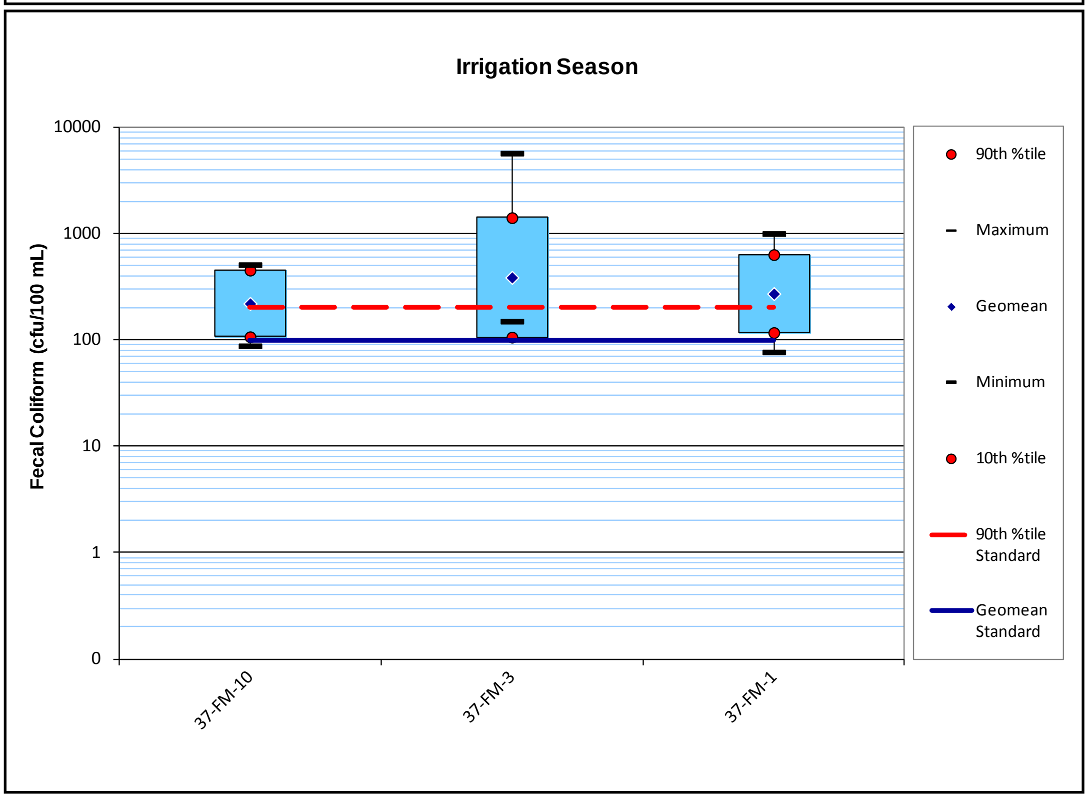
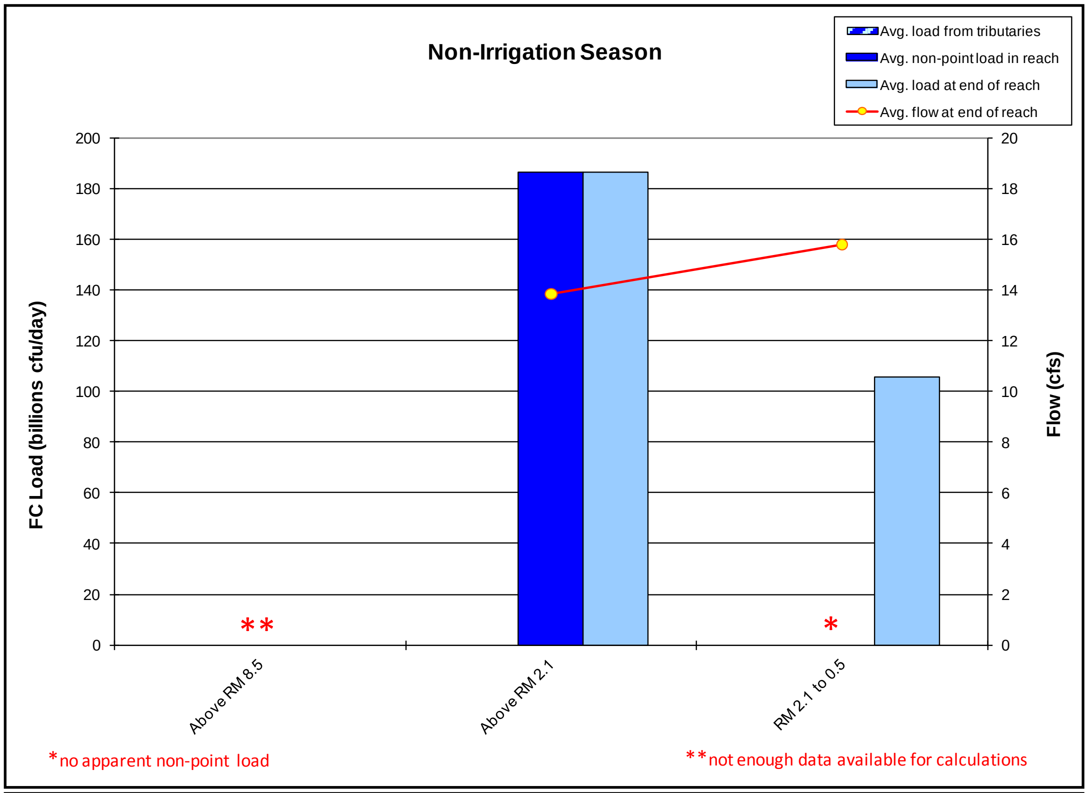


Figure 44. 2010 non-irrigation season and irrigation season summary statistics of FC counts for sites in Moxee Drain.

Average seasonal FC loads were calculated using sampling surveys, where concentration and streamflow data were available at the Moxee Drain sites. Data were used from 2 sampling surveys in the non-irrigation season and 8 sampling surveys in the irrigation season. The non-irrigation season loads presented below are estimates due to the lack of data available for average loading calculations. Figure 45 presents the average non-irrigation season and irrigation season FC loads for each reach. Table 44 summarizes the average loads as their percentages of the total load to Moxee Drain for 2010.

Based on the two sample sets (2004-06 and 2010), there was a decrease in FC loads in the reach between 37-FM-3 and 37-FM-1. During the 2010 non-irrigation season, there were no other mainstem sites monitored upstream of 37-FM-3. During the 2010 irrigation season, there appears to be minimal FC loading from above RM 8.5.



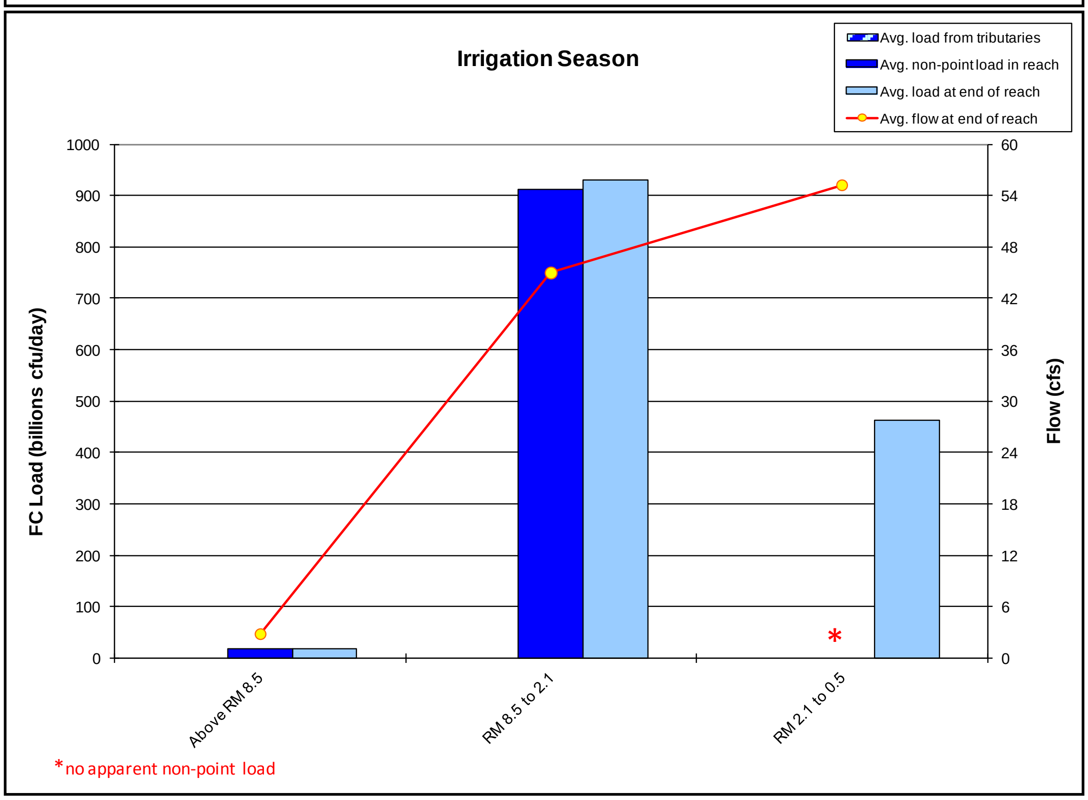


Figure 45. 2010 non-irrigation season and irrigation season average FC loads in Moxee Drain.

Note the differences in vertical axes scale between the charts.

Table 44. 2010 non-irrigation season and irrigation season FC loading percentages to Moxee Drain.

Reach (Moxee Drain RM)	Site (End of Reach)	Non-Irrigation Season	Irrigation Season
Above RM 8.5	37-FM-10	-	2.0%
RM 8.5 to 2.1	37-FM-3	100.0%[1]	98.0%
RM 2.1 to 0.5	37-FM-1	0.0%	0.0%

[1] This percentage is the sum of all unaccounted for nonpoint loads above RM 2.1.
- Not enough data available for calculations.

Comparison of 2004-2006 to 2010 FC Bacteria Results

Overall the FC concentrations and seasonal patterns appear to be consistent between the two studies. 2010 FC concentrations appear to have increased at 37-FM-3 and 37-FM-1. The Wilcoxon Rank Sum test was conducted for all three Moxee Drain sites. 37-FM-1 was the only site to have a statistically significant increase between the 2004-06 and 2010 FC concentrations. Therefore, the increase in FC concentrations at 37-FM-1 in 2010 was statistically significant.

There does not appear to be a relationship between high FC loading percentages and TSS loading percentages during the non-irrigation season. Conditions that elevate TSS do not appear to be elevating FC concentrations during the non-irrigation season.

The reach between RM 8.5 and RM 2.1 had the highest FC loading percentages and highest TSS loading percentages during the irrigation season. Therefore, conditions that elevate TSS may be also elevating FC concentrations during the irrigation season in that reach.

Table 45. 2010 non-irrigation season and irrigation season TSS loading percentages to Moxee Drain.

Reach (Moxee Drain RM)	Site (End of Reach)	Non-Irrigation Season	Irrigation Season
Above RM 8.5	37-FM-10	-	3.0%
RM 8.5 to 2.1	37-FM-3	19.9%[1]	97.0%
RM 2.1 to 0.5	37-FM-1	80.1%	0.0%

[1] This percentage is the sum of all unaccounted for nonpoint loads above RM 2.1.
- Not enough data available for calculations.

Drainage Improvement District (DID) #11

DID #11 and its tributaries were monitored from Beaudry Road (37-FM-5.5) to its confluence with Moxee Drain (37-FM-3.6). During the 2004-06 surveys, Ecology sampled 3 mainstem DID #11 sites, 2 tributary sites, and 2 Moxee POTW sites.

Table 46, Figure 46, and Figure 47 present the non-irrigation season and irrigation season summary statistics of FC counts. Table 46 also presents the target reductions necessary to meet the water quality standards in DID #11.

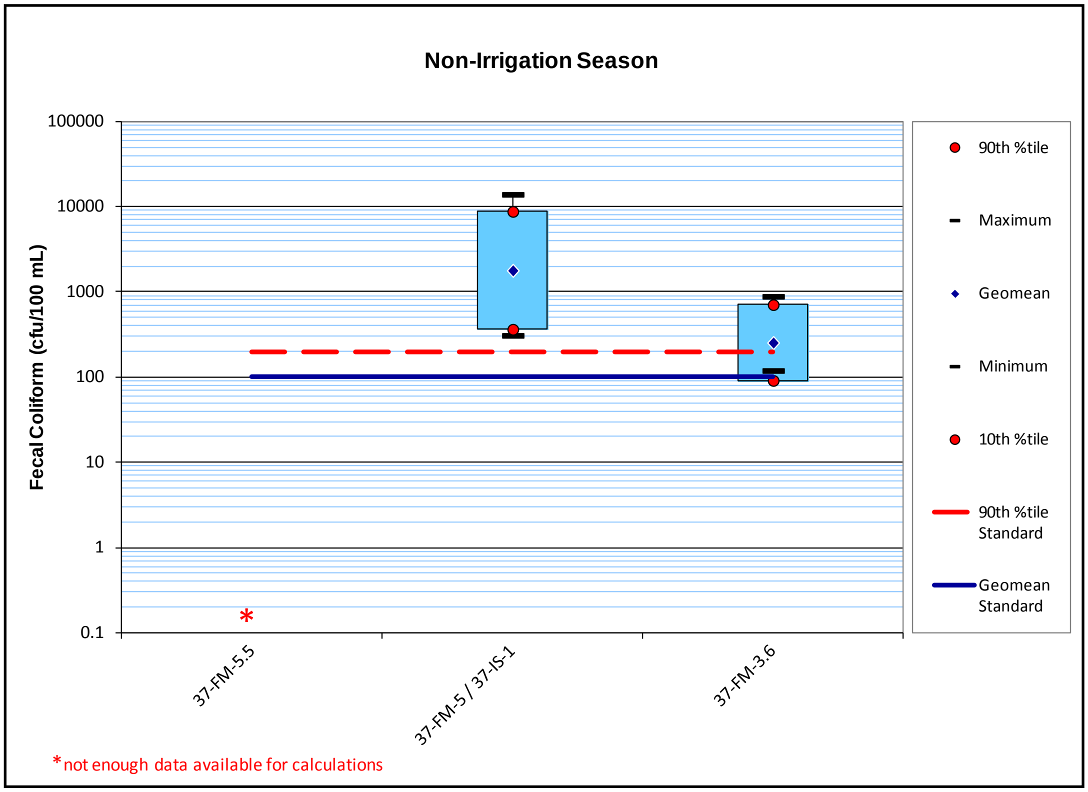
No samples were collected at the Beaudry Road site (37-FM-5.5) during the non-irrigation season. Samples were taken after extremely elevated FC counts were found in samples collected at FM-5. Both samples taken during the irrigation season at this site did not meet the water quality criteria, so this site did not meet either part of the criteria during the irrigation season. The irrigation season summary statistics at 37-FM-5.5 were calculated using 2 samples, so more samples are needed to better establish the seasonal summary statistics. The samples collected at this site clearly indicate the presence of elevated FC concentrations during the irrigation season. However, the primary source of contamination at FM-5 was found downstream of FM-5.5.

FC concentrations in DID #11 at Bell Road (37-FM-5 / 37-IS-1) were significantly elevated. All of the samples collected at this site had FC concentrations from 240 – 17,000 cfu/100 mL. Further investigations showed that a failing onsite system at the mobile home court upstream of the site was leaking into DID #11.

Table 46. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts and target percent reductions for sites in DID #11.

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile*	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
Non-Irrigation Season								
37-FM-5.5	0	-	-	-	-	-	-	-
37-FM-5 / 37-IS-1	9	310	366	1798	8833	14000	100%	98%
37-IS-1.5	0	-	-	-	-	-	-	-
37-FM-WWO[1]	9	1	2	14	111	125	0%	0%
37-FM-4 / 37-IS-2	0	-	-	-	-	-	-	-
37-FM-3.6	5	120	92	256	712	890	40%	72%
Irrigation Season								
37-FM-5.5	2	180	142	240	404	320	50%	58%
37-FM-5 / 37-IS-1	15	240	476	1393	4080	7700	100%	95%
37-IS-1.5	4	58	41	159	613	700	25%	67%
37-FM-WWO[1]	14	1	3	9	27	28	0%	0%
37-FM-4 / 37-IS-2	14	36	48	169	594	1300	50%	66%
37-FM-3.6	7	235	176	550	1726	3600	100%	88%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.
**Cells shaded in this column are values based on less than 5 samples collected at that station.
[1] Permit limits are a monthly geomean of 100 cfu/100 mL and a weekly geomean of 200 cfu/100 mL.
- Not enough data for calculations.



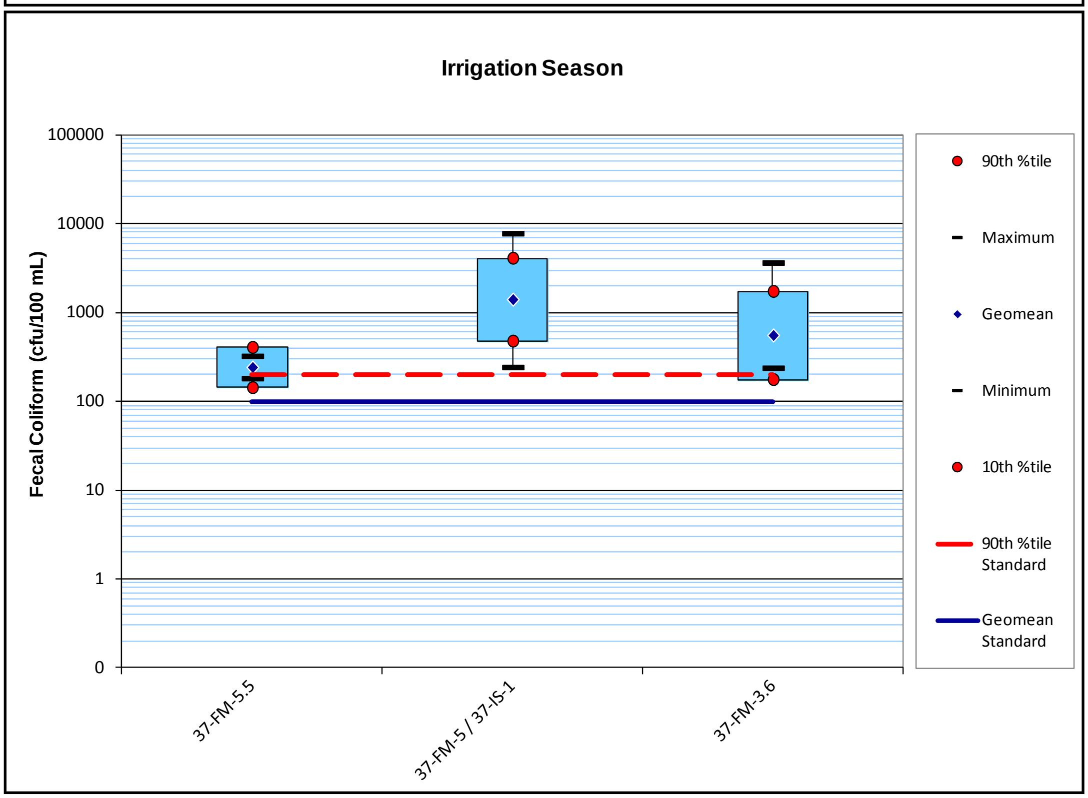
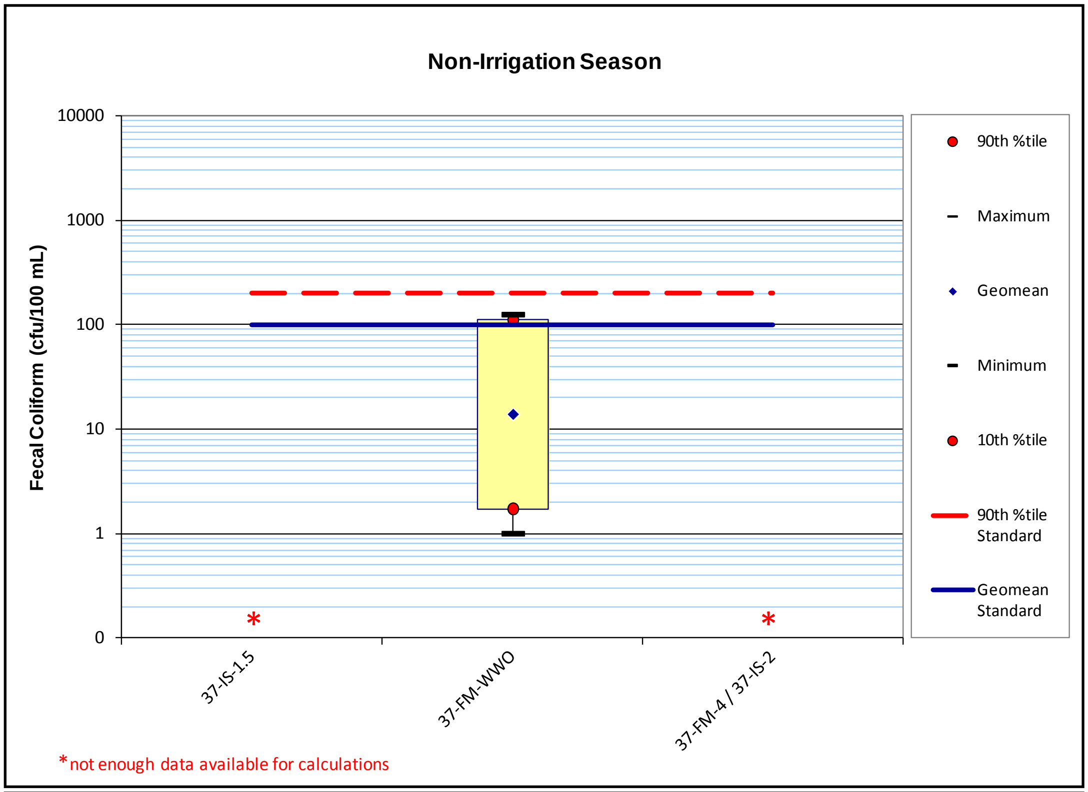


Figure 46. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts for mainstem sites in DID #11.



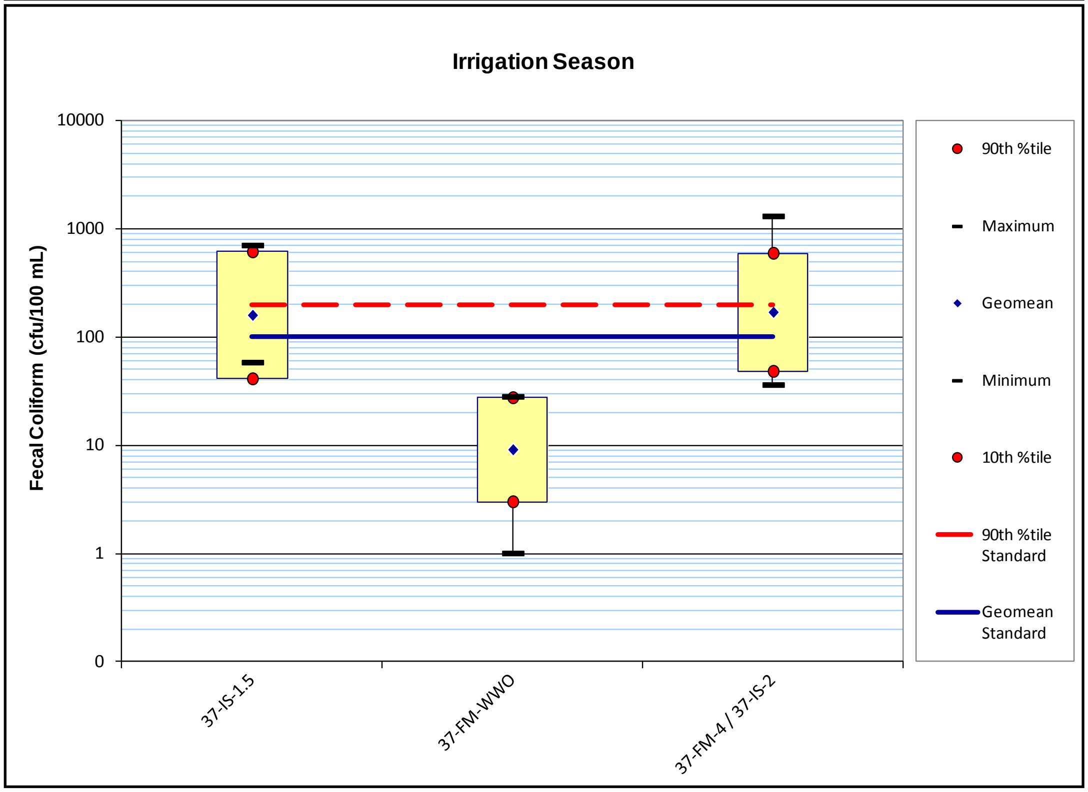


Figure 47. 2004-06 non-irrigation season and irrigation season summary statistics of FC counts for tributary sites in DID #11.

The irrigation outfall at Bell Road (37-IS-1.5) was sampled 4 times during the irrigation season. This outfall had FC concentrations that did not meet either part of the criteria. Irrigation season summary statistics were calculated using the 4 samples, but they clearly indicate the presence of elevated FC concentrations.

The UV disinfected effluent from the Moxee POTW (37-FM-WWO) met both parts of the NPDES permit limits, which are a monthly geomean of 100 cfu/100 mL and a weekly geomean of 200 cfu/100 mL. The Moxee POTW is discussed in more detail later in this report.

Hubbard Canal at Bell Road (37-FM-4 / 37-IS-2) was sampled when it was flowing during the irrigation season. The FC concentrations in the canal did not meet either part of the water quality criteria.

FC counts at the mouth of DID #11 (37-FM-3.6) did not meet either part of the water quality criteria during both seasons.

Average seasonal FC loads were calculated using sampling surveys where concentration and streamflow data were available at all fixed-network DID #11 sites. Data were used from 5 sampling surveys in the non-irrigation season and 7 sampling surveys in the irrigation season. Figure 48 presents the average non-irrigation season and irrigation season FC loads for each reach and tributary. Table 47 summarizes the average loads as their percentages of the total load to DID #11 if die-off and settling are not considered.

Nearly the entire non-irrigation season FC loading to DID #11 was from above Bell Road (99.8%). The load was mainly from the onsite system failure, although sources upstream of FM-5.5 may have contributed. The only other FC load source was the Moxee POTW (0.2%).

Most of the irrigation season FC loading to DID #11 was from the same sources (87%). The irrigation outfall at Bell Road and the Hubbard Canal at Bell Road each accounted for about 7% of the FC loading during the irrigation season.

Three sites during the non-irrigation season and 1 site during the irrigation season were omitted from the loading analysis because they did not have data collected during sample surveys where the mainstem fixed-network sites were also sampled.

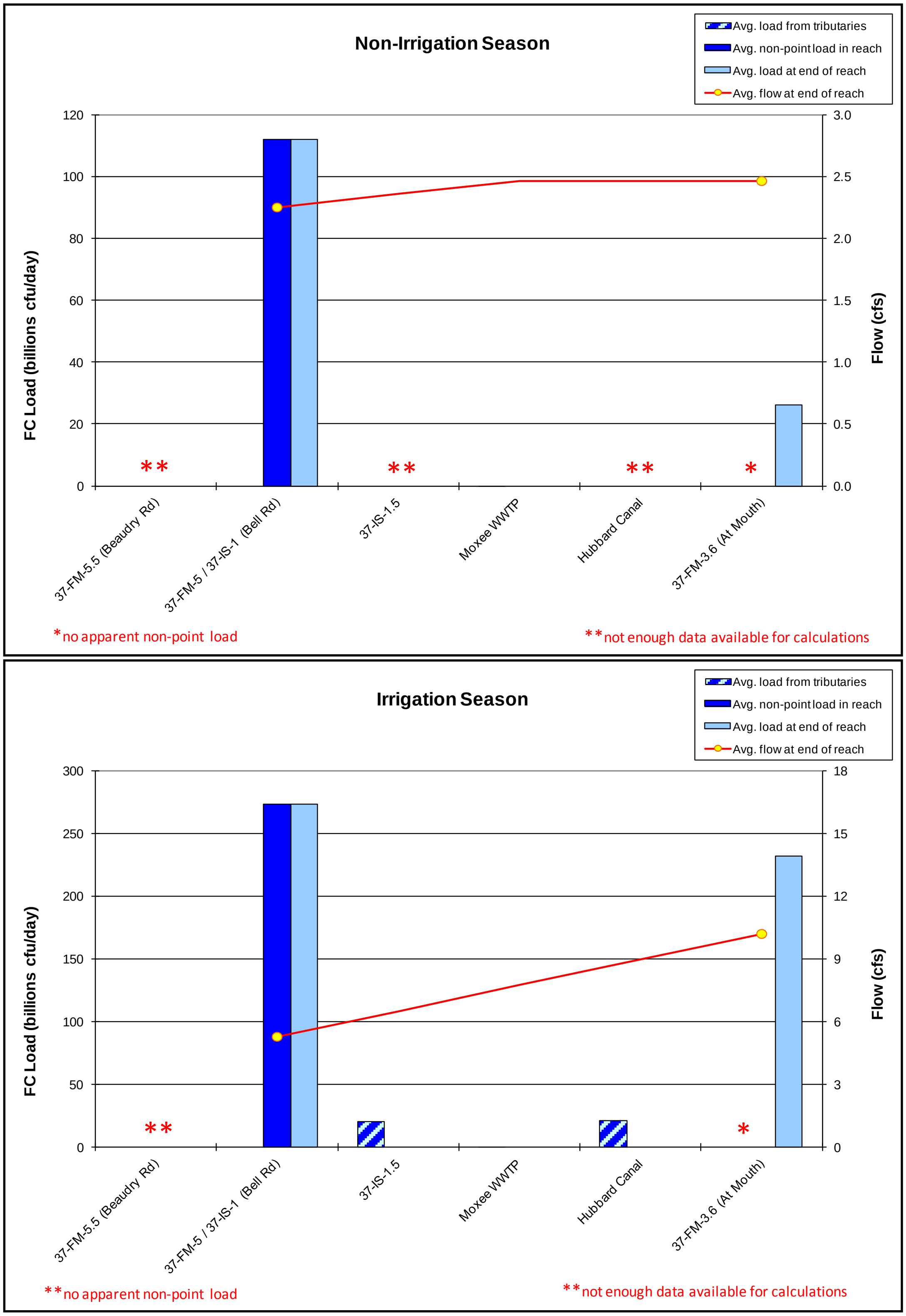


Figure 48. 2004-06 non-irrigation season and irrigation season average FC loads in DID #11.

Note the differences in vertical axes scale between the charts.

Table 47. 2004-06 non-irrigation season and irrigation season FC loading percentages to DID #11.

Reach (DID #11 site or Tributary)	Site (End of Reach)	Non-Irrigation Season	Irrigation Season
37-FM-5.5 (Beaudry Rd)	37-FM-5.5	-	-
37-FM-5 / 37-IS-1 (Bell Rd)	37-FM-5 / 37-IS-1	99.8%[1]	86.9%[1]
37-IS-1.5	37-IS-1.5	-	6.5%
Moxee POTW	37-FM-WWO	0.2%	0.0%
Hubbard Canal	37-FM-4 / 37-IS-2	-	6.6%
37-FM-3.6 (At Mouth)	37-FM-3.6	0.0%	0.0%

[1] This percentage is the sum of all unaccounted for nonpoint loads above Bell Road.
- Not enough data available for calculations.

Table 48 presents the non-irrigation season and irrigation season TSS load contribution percentages.

Figure 49 shows a weak but positive relationship between TSS concentrations and FC concentrations in DID #11. This illustrates that conditions that elevate TSS could also elevate FC concentration in DID #11 during both seasons.

Table 48 presents the non-irrigation season and irrigation season chloride load contribution percentages.

The chloride loading percentage in DID #11 above Bell Road was the highest during the non-irrigation season (71%) and the irrigation season (68%). This further illustrates the presence of the leaky septic source above Bell Road.

Table 48. 2004-06 non-irrigation season and irrigation season TSS and chloride loading percentages to DID #11.

Reach (DID #11 site or Tributary)	Site	TSS		Chloride	
		Non-Irrigation Season	Irrigation Season	Non-Irrigation Season	Irrigation Season
37-FM-5.5 (Beaudry Rd)	37-FM-5.5	-	-	-	-
37-FM-5 / 37-IS-1 (Bell Rd)	37-FM-5 / 37-IS-1	97.1%[1]	72.0%[1]	71.1%[1]	68.3%[1]
37-IS-1.5	37-IS-1.5	-	3.0%	-	3.5%
Moxee POTW	37-FM-WWO	2.9%	0.3%	20.8%	13.0%
Hubbard Canal	37-FM-4 / 37-IS-2	-	4.7%	-	10.0%
37-FM-3.6 (At Mouth)	37-FM-3.6	0.0%	20.0%	8.1%	5.2%

[1] This percentage is the sum of all unaccounted for nonpoint loads above Bell Road.
- Not enough data available for calculations.

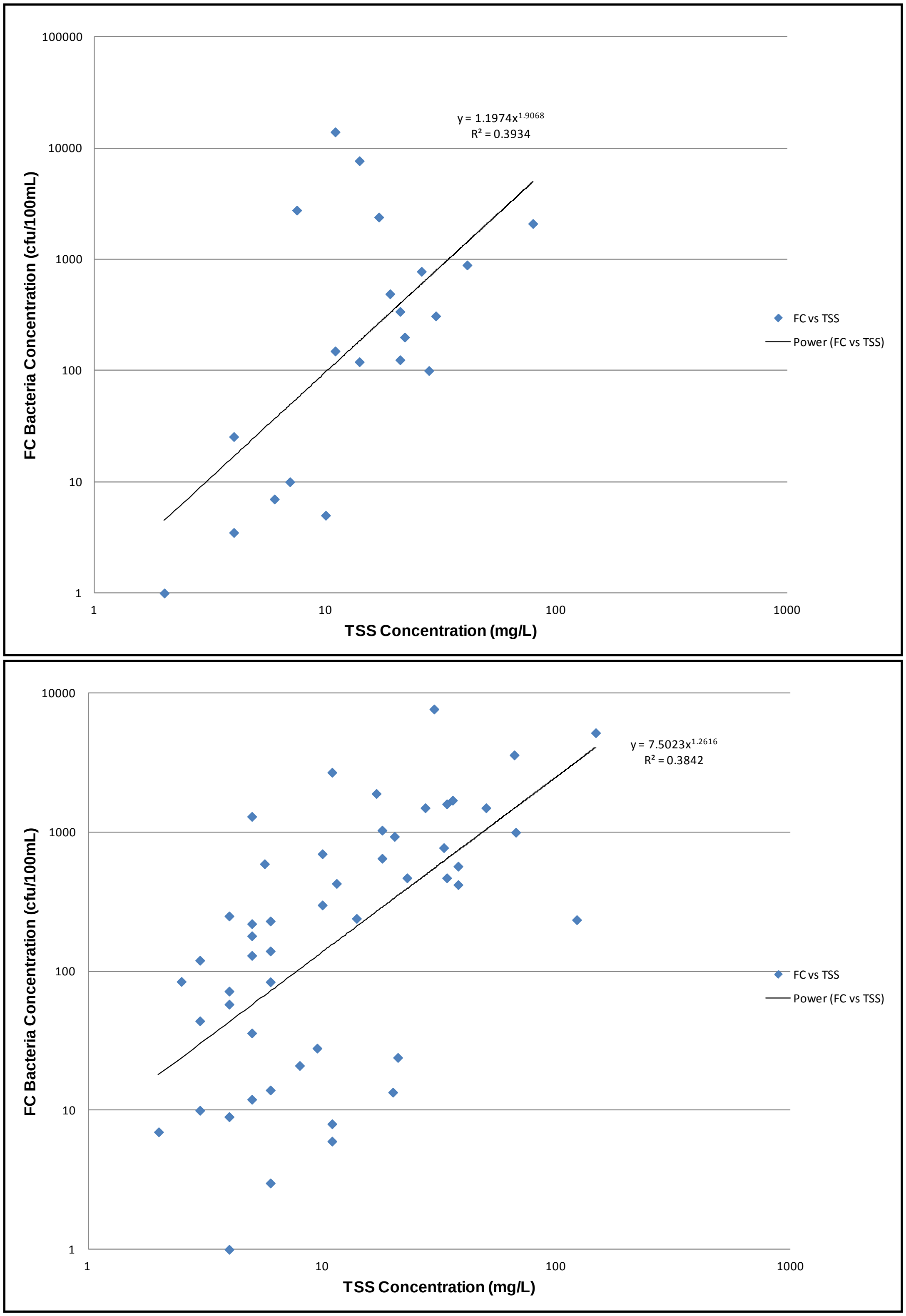


Figure 49. 2004-06 relationships between non-irrigation season and irrigation season TSS and FC concentrations in DID #11.

Moxee POTW

Moxee POTW effluent was monitored after the UV chamber (site 37-FM-WWE) and again at the outfall discharge to DID #11 (site 37-FM-WWO). These two sites were monitored only during the 2004-06 survey and not during the 2010 survey because the POTW was no longer discharging into DID #11. The FC counts are to meet permit limits at the latter site prior to discharge into DID #11. The discharge does not have a mixing zone. The FC bacteria permit limits for the POTW effluent are a monthly geomean of 100 cfu/100 mL and a weekly geomean of 200 cfu/100 mL.

Table 49 and Figure 50 present the monthly summary statistics based on samples collected by Ecology.

One sample was collected at each of the POTW sites during the week of a sampling survey. Therefore, the weekly geomean is also the weekly maximum.

Both sites at the POTW met both parts of the permit criteria for all months except January 2006. There was one sample in January 2006 that had a concentration of 125 cfu/100 mL. Since this sample was the only one collected during the month, the monthly geomean criterion was exceeded. The FC concentrations were often elevated downstream at 37-FM-WWO, but the site still met the criteria.

Table 49. 2004-06 monthly summary statistics of FC counts based on Ecology samples for stations at Moxee POTW.

Station ID	Month	Total # of Samples	Monthly Geomean > 100 cfu/ 100 mL*	Weekly Maximum/ Geomean > 200 cfu/ 100 mL*
38-FC-WWE	Dec-04	0	-	-
	Jan-05	1	22	22
	Feb-05	1	1	1
	Mar-05	1	1	1
	Apr-05	2	1	1
	May-05	2	4	16
	Jun-05	2	1	1
	Jul-05	2	2	3
	Aug-05	2	2	4
	Sep-05	2	4	13
	Oct-05	2	1	1
	Nov-05	2	6	35
	Dec-05	2	1	1
	Jan-06	1	3	3
	Feb-06	0	-	-
	Mar-06	0	-	-
38-FC-WWO	Dec-04	1	49	49
	Jan-05	1	5	5
	Feb-05	1	10	10
	Mar-05	1	4	3.5
	Apr-05	2	4	6
	May-05	2	8	10
	Jun-05	2	18	24
	Jul-05	2	14	21
	Aug-05	2	16	28
	Sep-05	2	13	14
	Oct-05	2	3	8
	Nov-05	2	50	100
	Dec-05	2	3	7
	Jan-06	1	125	125
	Feb-06	0	-	-
	Mar-06	0	-	-

*Cells shaded in these columns are values that do not meet (exceed) permit numeric criteria.
- No samples available for calculations.

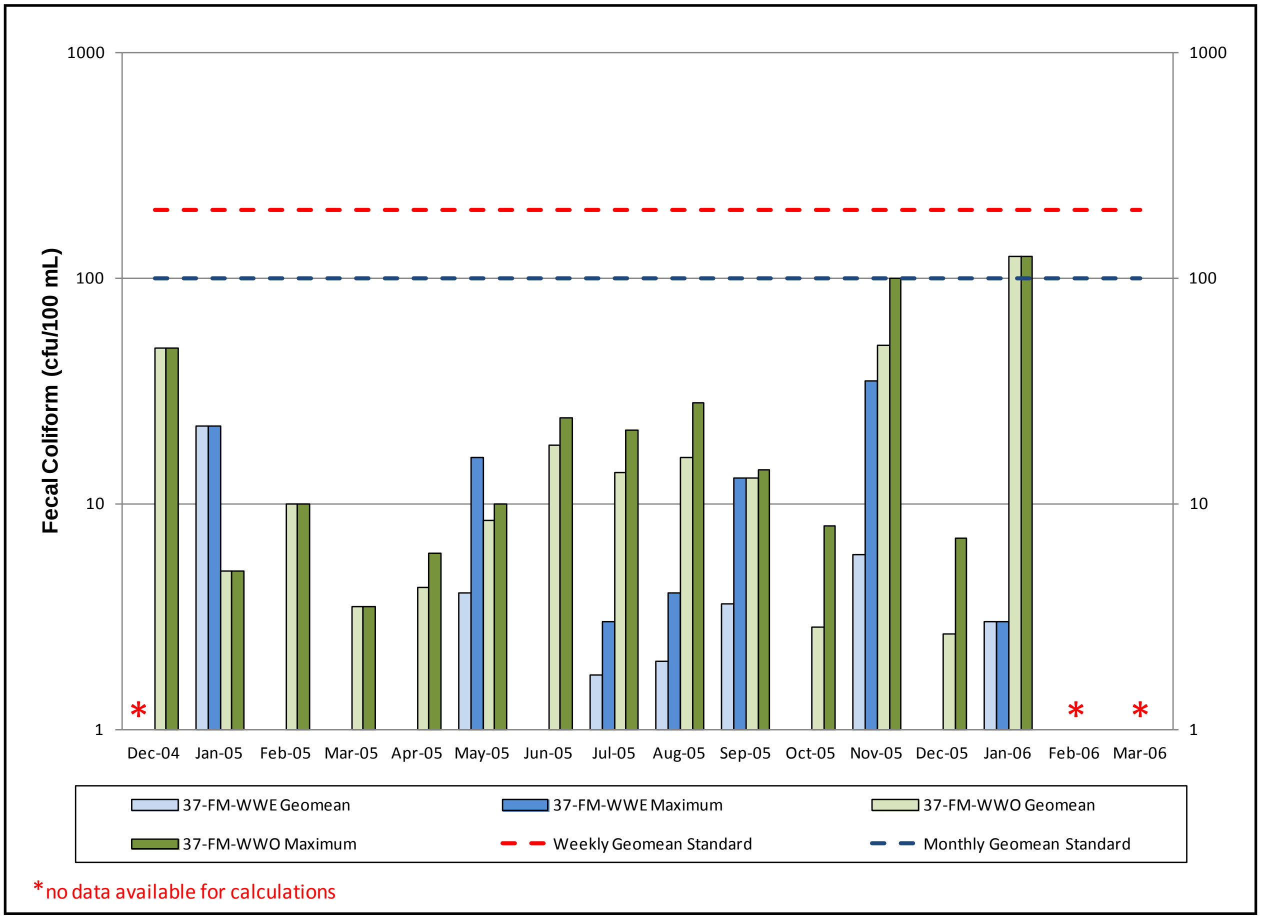


Figure 50. 2004-06 monthly summary statistics of FC counts based on Ecology samples for stations at Moxee POTW.

Average seasonal FC loads were calculated using sampling surveys where concentration and streamflow data were available at both sites. Therefore, data were used from 8 sampling surveys in the non-irrigation season and 14 sampling surveys in the irrigation season. Figure 51 presents the average non-irrigation season and irrigation season FC loads at the POTW. Table 50 summarizes the average loads as their percentages of the total load at the POTW.

The majority of non-irrigation season and irrigation season FC loading at the Moxee POTW was from the reach between the UV chamber and the outfall to DID #11 (79% and 71%, respectively). Only about a quarter of the FC loads at the POTW are from after the UV chamber for both seasons.

The majority of non-irrigation season and irrigation season TSS loading at the Moxee POTW was from above to just below the UV chamber (69% and 87%, respectively).

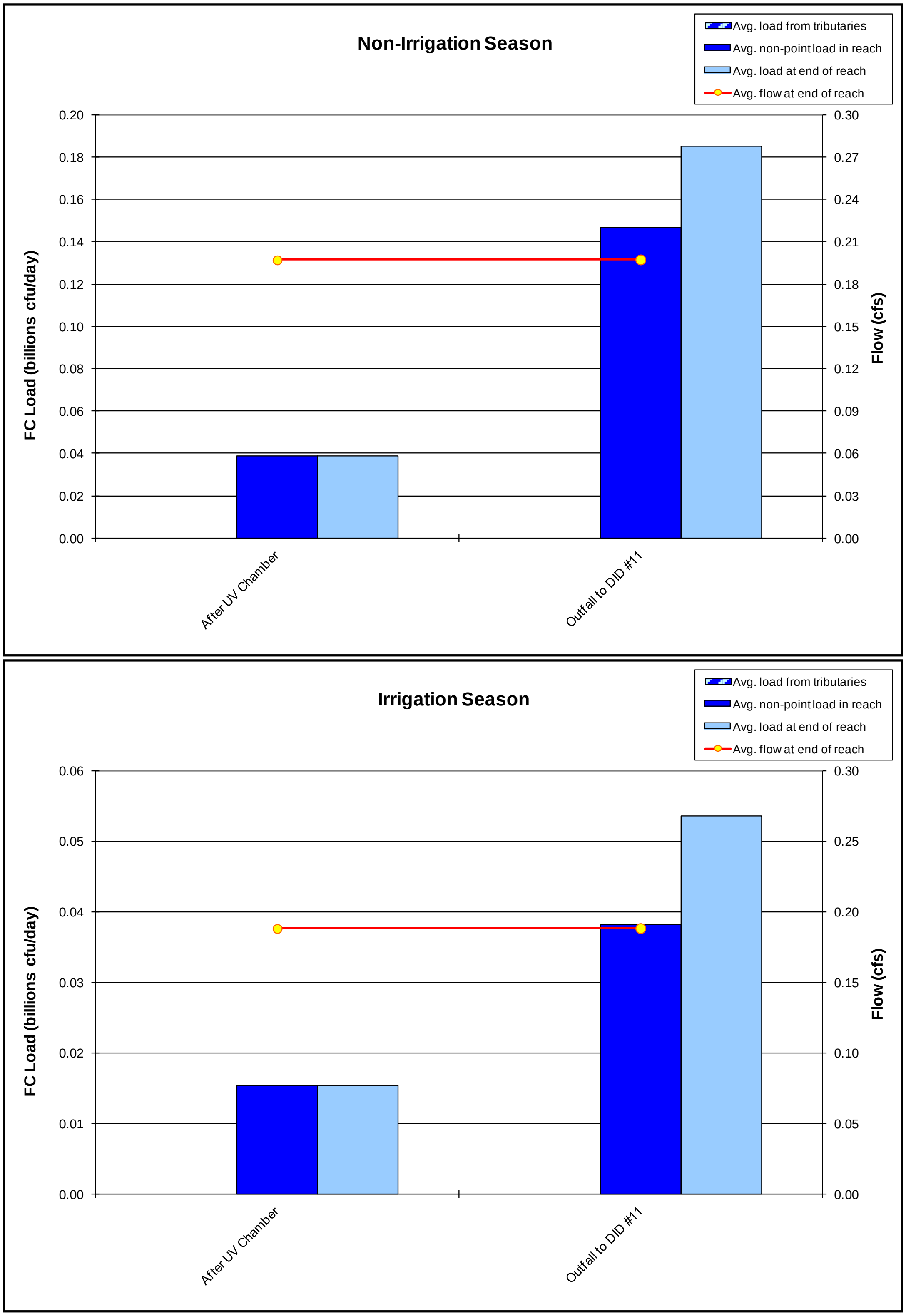


Figure 51. 2004-06 non-irrigation season and irrigation season average FC loads in Moxee POTW.

Note the differences in vertical axes scale between the charts.

Table 50. 2004-06 non-irrigation season and irrigation season FC loading percentages to Moxee POTW.

Reach (POTW)	Site (End of Reach)	Non-Irrigation Season	Irrigation Season
After UV Chamber	37-FM-WWE	20.9%	28.7%
Outfall to DID #11	37-FM-WWO	79.1%	71.3%

There is no apparent relationship between irrigation season TSS loads and FC loads at the Moxee POTW.

Table 51 presents the non-irrigation season and irrigation season TSS and chloride load contribution percentages.

Table 51. 2004-06 non-irrigation season and irrigation season TSS and chloride loading percentages to Moxee POTW.

Reach (POTW)	Site (End of Reach)	TSS		Chloride	
		Non-Irrigation Season	Irrigation Season	Non-Irrigation Season	Irrigation Season
After UV Chamber	37-FM-WWE	68.5%	87.2%	100.0%	100.0%
Outfall to DID #11	37-FM-WWO	31.5%	12.8%	0.0%	0.0%

It appears that the entire non-irrigation season and irrigation season chloride loading was from the site immediately after the UV chamber (100%). Therefore, the reach after the UV chamber to the outfall to DID #11 does not appear to be contributing any additional chloride loads.

There is no apparent relationship between irrigation season chloride loads and FC loads at the Moxee POTW.

Stormwater Sampling

The stormwater sampling sites were distributed among several outfalls under NPDES industrial and Phase II permits in the Wide Hollow Creek Watershed. The resources for this TMDL project were not adequate to cover all of the permit holders in the study area. Wide Hollow Creek has the most complex combination of stormwater and industrial permits. In contrast to Cowiche and Moxee Watersheds, historical data from Wide Hollow Watershed also suggest that winter FC counts do not meet state criteria (Joy, 2005).

The stormwater sample sites, outfalls and Wide Hollow Creek, were visited on 4 dates during the 2004-06 surveys: May 9 and 10, 2005; February 28, 2006; and March 5, 2006. Stormwater sites were not sampled during the 2010 surveys.

The stormwater outfalls are expected to meet the FC concentration criteria of the water body they discharge to, Wide Hollow Creek. Therefore, this TMDL expresses target percent reductions necessary to achieve concentration levels which are in accordance with the water quality standards. Table 52 presents the summary statistics, geomeans and 90th percentiles, for the stormwater sample sites that were compared to the Primary Contact Recreation water quality standards.

Table 52. 2004-06 stormwater sampling statistics of FC counts and target percent reductions for stormwater sites.

Station ID	Total # of Samples	Min	10th %tile	Geomean > 100 cfu/ 100 mL*	90th %tile*	Max	% Samples > 200 cfu/ 100 mL*	Target % Reduction**
Yakima County								
37-SS-17	1	2700	-	2700	-	2700	100%	96%
37-SS-16	3	2	1	214	38805	3050	67%	99%
37-SS-18	1	8000	-	8000	-	8000	100%	99%
37-SS-15	2	1600	935	3098	10265	6000	100%	98%
37-SS-14	4	3	2	121	7051	3600	50%	97%
37-SS-38	1	160	-	160	-	160	0%	38%
37-SS-48	1	10	-	10	-	10	0%	0%
City of Yakima								
37-SS-13	2	8000	7558	8579	9738	9200	100%	99%
37-SS-12	2	680	367	1452	5742	3100	100%	97%
37-SS-11	4	92	72	511	3647	2400	75%	95%
37-SS-9	2	200	86	566	3724	1600	50%	95%
37-SS-8[1]	1	21	-	21	-	21	0%	0%
37-SS-7	4	29	21	335	5263	3550	50%	96%
37-SS-4[1]	2	110	37	420	4748	1600	50%	96%
City of Union Gap								
37-SS-6[1]	4	96	34	532	8239	8200	50%	98%
37-SS-5	4	30	18	350	6619	3300	50%	97%
37-SS-1	3	25	16	626	24224	5500	67%	99%
37-SS-2[1]	3	31	23	117	606	400	33%	67%

*Cells shaded in these columns are values that do not meet (exceed) Washington State numeric standards.
**Cells shaded in this column are values based on less than 5 samples collected at that station.
[1] Stormwater outfall.
- Not enough data for calculations.

FC concentrations at 15 of the 18 stormwater sites did not meet either part of the Primary Contact Recreation criteria. The FC concentration at DID #38 outfall (37-SS-38) did not meet the geomean part of the criteria. The FC concentrations at DID #48 outfall (37-SS-48) and at the city storm outfall at the end of 34th Avenue (37-SS-8) met both parts of the water quality criteria.

FC loading percentages were calculated for the May 9, 2005; February 28, 2006; and March 5, 2006 storm surveys (Table 53). The May 10, 2005 survey was omitted because the stormwater streamflow had yet to make it to the mouth of Wide Hollow Creek at the time of sampling, resulting in inappropriately low FC loads for the City of Union Gap. The total FC loading percentages in Table 53 are the estimated stormwater loads assigned to the three jurisdictions: Yakima County, City of Yakima, and City of Union Gap. DID #38 and DID #48 are currently owned and maintained by Yakima County; therefore, the FC loading at these outfalls were included in Yakima County's total FC loading percentage.

Table 53. 2004-06 jurisdictional stormwater FC loading percentages to Wide Hollow Creek.

Jurisdiction	Reach	May 9, 2005	February 28, 2006	March 5, 2006
Yakima County	Above RM 9.6	19%	5%	1%
City of Yakima	RM 9.6 to RM 4.4	32%	74%	53%
City of Union Gap	Below RM 4.4	50%	21%	46%

Yakima County appears to have the lowest FC loading percentage for all three surveys. The City of Yakima appears to be the primary loading source during the winter/non-irrigation season storm events. Union Gap appears to be the primary loading source during the spring/irrigation season storm event.

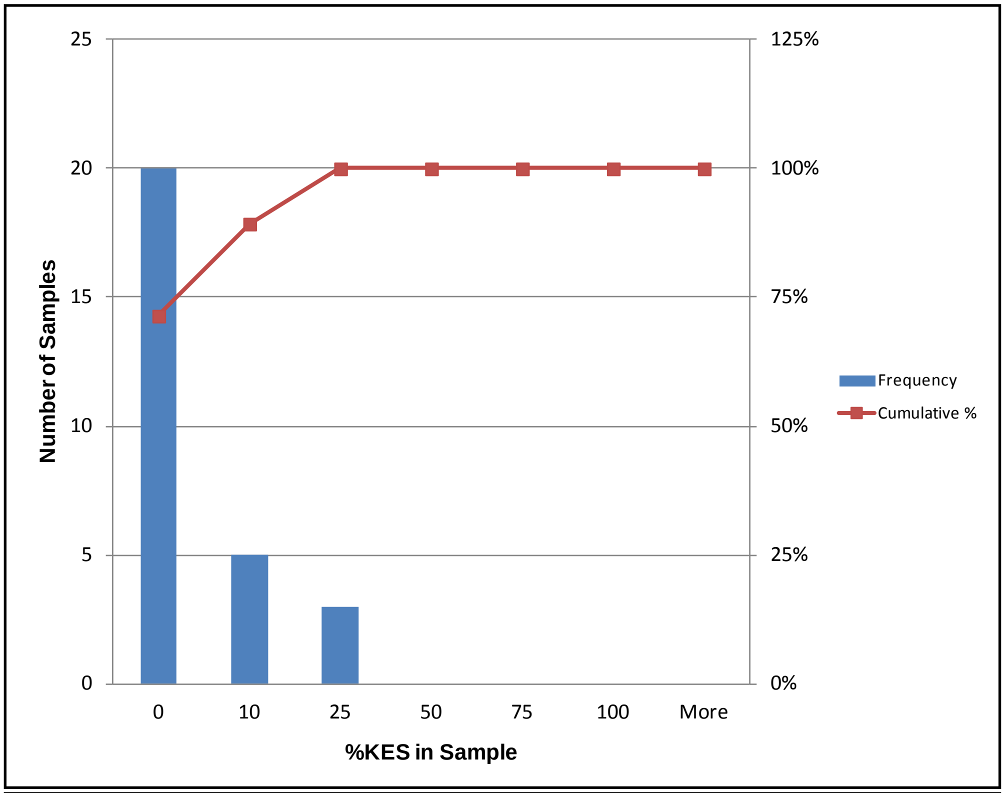
Escherichia coli (E. coli) and % KES (Klebsiella, Enterobacter, and Serratia)

Randomly selected samples were tested for *E. coli* and % KES to help characterize wastes from various sources. For example, samples with a large number of *E. coli* would more likely come from an animal source than those with a high percentage of KES. A high percentage KES would indicate bacteria from decaying vegetation. Conclusions from this data are difficult when *E. coli* concentrations and % KES are both low or both high. However, future decisions about the types of best management practices (BMPs) and specific source-identification procedures could depend on this information.

Percent KES and *E. coli* samples were collected at 29 sites throughout the study area during the 2004-06 study. There were no % KES samples collected during the 2010 survey.

Cowiche Creek

Eight sites in the Cowiche Creek basin were sampled for % KES and *E. coli* during the 2004-06 study. The frequency distributions and summary statistics are shown in Figure 52 and Table 54, respectively.



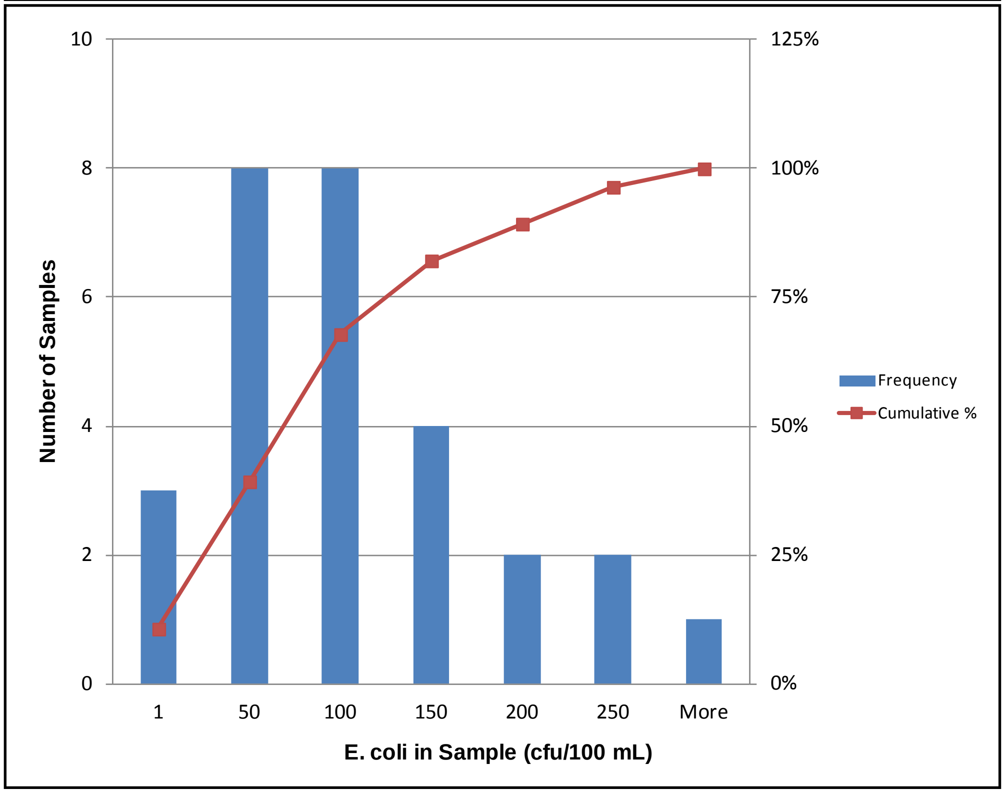


Figure 52. 2004-06 % KES and *E. coli* frequency distribution for the Cowiche Creek basin.

Note the differences in axes scales between the charts.

Table 54. 2004-06 % KES and *E. coli* summary statistics for sites in the Cowiche Creek basin.

Station ID	% KES				*E. coli*			
	Total Number of Samples	Number of Detects	Min	Max	Total Number of Samples	Number of Detects	Min	Max
Non-Irrigation Season								
38-FC-4	1	0	0	0	1	1	14	14
38-FC-2.5	0	-	-	-	0	-	-	-
38-FC-2	2	0	0	0	2	0	1	1
38-FC-7	1	0	0	0	1	1	29	29
38-FC-6	2	0	0	0	2	2	57	61
38-FC-3	1	0	0	0	1	0	1	1
38-FC-1.5	1	0	0	0	1	1	110	110
38-FC-1	3	1	0	14	3	3	6	11
Irrigation Season								
38-FC-4	3	0	0	0	3	3	49	69
38-FC-2.5	1	0	0	0	1	1	100	100
38-FC-2	4	0	0	0	4	4	49	200
38-FC-7	0	-	-	-	0	-	-	-
38-FC-6	0	-	-	-	0	-	-	-
38-FC-3	2	1	0	2	2	2	110	140
38-FC-1.5	4	3	0	22	4	4	37	260
38-FC-1	3	3	4	20	3	3	54	210

- No data available for calculations.

Six of the 7 sampled sites had no % KES detects during the non-irrigation season. The only one to have a detection was Cowiche Creek near the mouth at Powerhouse Road (38-FC-1). However, the single detection at 38-FC-1 was small (14% KES), and the *E. coli* concentration at this site was also small.

During the irrigation season, 3 of the 6 sampled sites had no % KES detects and moderate to high E. coli concentrations. These three sites were in the upper part of the basin, similar to the non-irrigation season. Cowiche Creek at Zimmerman Road and Powerhouse Road (38-FC-1.5 and 38-FC-1, respectively) had a maximum % KES over 20%. However, both these sites also had elevated *E. coli* concentrations.

Wide Hollow Creek

Eleven sites in the Wide Hollow Creek basin were sampled for % KES and *E. coli* during the 2004-06 study. The frequency distributions and summary statistics are shown in Figure 53 and Table 55.

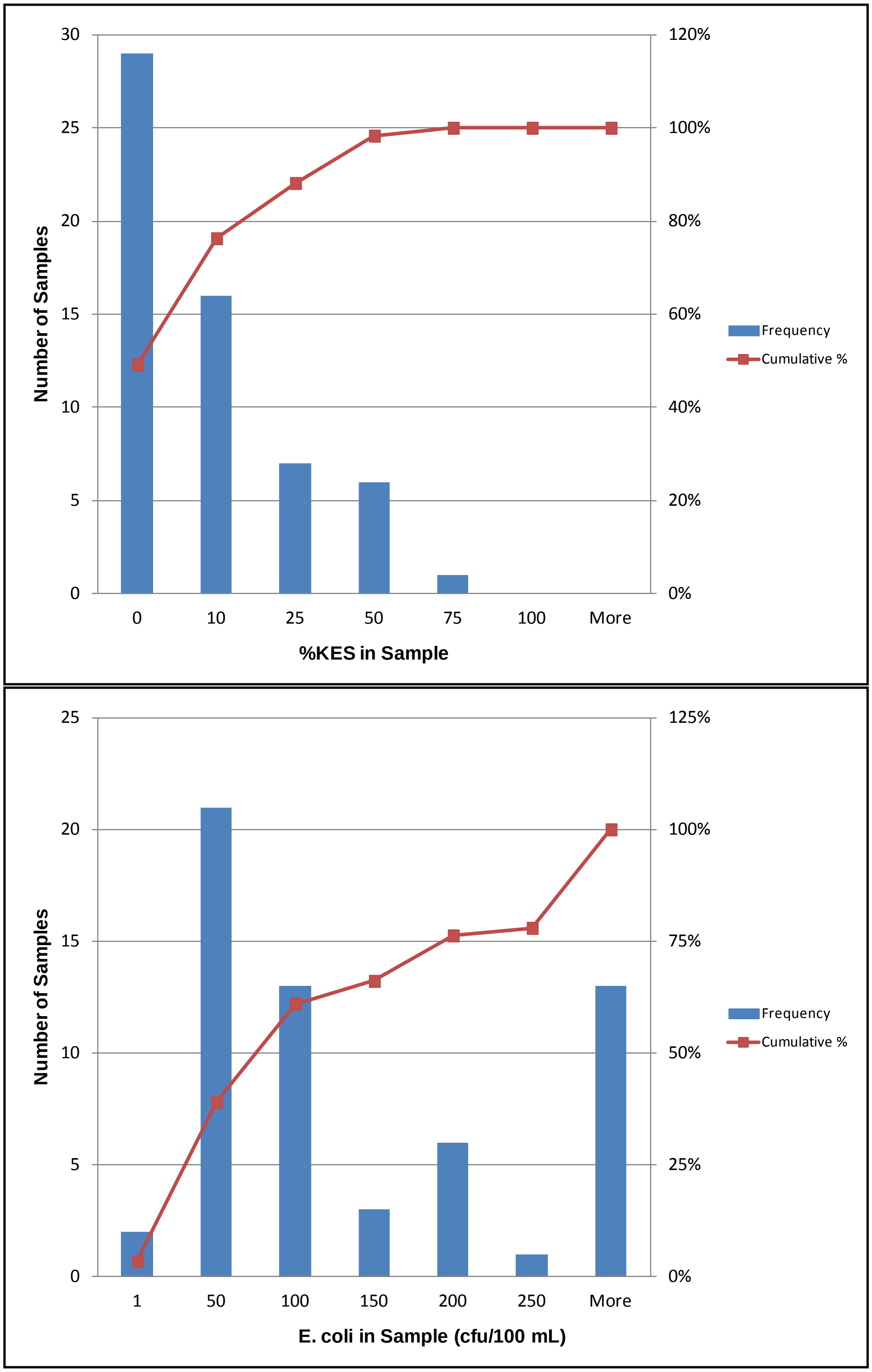


Figure 53. 2004-06 % KES and *E. coli* frequency distribution for the Wide Hollow Creek basin.

Note the differences in axes scales between the charts.

Table 55. 2004-06 % KES and *E. coli* summary statistics for sites in the Wide Hollow Creek basin.

Station ID	% KES				*E. coli*			
	Total Number of Samples	Number of Detects	Min	Max	Total Number of Samples	Number of Detects	Min	Max
Non-Irrigation Season								
37-FW-16	2	0	0	0	2	2	490	510
37-FW-12 / 37-SS-16	2	0	0	0	2	1	1	170
37-FW-14	1	0	0	0	1	1	1100	1100
37-FW-13 / 37-SS-18	1	1	66	66	1	0	1	1
37-FW-8 / 37-SS-14	0	-	-	-	0	-	-	-
37-FW-6	3	1	0	40	3	3	3	9
37-FW-5	4	2	0	8	4	4	86	240
37-FW-4 / 37-SS-7	5	2	0	17	5	5	2	12
37-FW-1 / 37-SS-5	0	-	-	-	0	-	-	-
37-FW-0 / 37-SS-1	3	3	3	13	3	3	40	130
37-FW-2	1	1	3	3	1	1	40	40
Irrigation Season								
37-FW-16	0	-	-	-	0	-	-	-
37-FW-12 / 37-SS-16	6	1	0	2	6	6	57	200
37-FW-14	2	0	0	0	2	2	660	2400
37-FW-13 / 37-SS-18	3	0	0	0	3	3	320	710
37-FW-8 / 37-SS-14	5	2	0	37	5	5	2	370
37-FW-6	4	3	0	36	4	4	46	970
37-FW-5	3	1	0	29	3	3	16	1100
37-FW-4 / 37-SS-7	2	2	2	10	2	2	61	190
37-FW-1 / 37-SS-5	3	2	0	38	3	3	59	200
37-FW-0 / 37-SS-1	6	6	3	23	6	6	12	830
37-FW-2	3	3	3	12	3	3	41	60

- No data available for calculations.

The three upper basin sites (37-FW-16, 37-FW-12 / 37-SS-16, and 37-FW-14) had no % KES detects and high *E. coli* concentrations in the non-irrigation season. The single sample taken at Cottonwood Creek at the mouth (37-FW-13) had a high % KES detection (66%). The single *E. coli* sample collected at 37-FW-13 did not have a detection, so it appears that bacteria at the mouth of Cottonwood Creek could be from decaying vegetation during the non-irrigation season. One of the three samples collected at Wide Hollow Creek at 44th Ave (37-FW-6) resulted in a detection for % KES (40%). All three of the *E. coli* samples for this site had low concentrations. It appears that some of the bacteria at this site may be from decaying vegetation. Wide Hollow Creek at and downstream of 16th Ave (37-FW-4 / 37-SS-7 and 37-FW-0 / 37-SS-1) and East Spring Creek at the mouth (37-FW-2) appear to have low to moderate % KES during the non-irrigation season. These sites also had low to moderate *E. coli* concentrations during the non-irrigation season.

Wide Hollow Creek at Dazet Road (37-FW-12 / 37-SS-16) and Cottonwood Creek (37-FW-14 and 37-FW-13 / 37-SS-18) had low % KES and high *E. coli* concentrations during the irrigation season. It appears that bacteria may be from an animal source, and not decaying vegetation, at these sites during the irrigation season. Wide Hollow Creek sites between 80th Ave (37-FW-8 / 37-SS-14) and the Union Gap Public Works (37-FW-0 / 37-SS-1) had low to moderate % KES detections and moderate to high *E. coli* concentrations. It appears that decaying vegetation may only be a minor source of bacteria in this reach during the irrigation season. East Spring Creek at the mouth (37-FW-2) had low % KES detections and low to moderate *E. coli* concentrations during the irrigation season.

Moxee Drain

Ten sites in the Moxee Drain basin were sampled for % KES and *E. coli* during the 2004-06 study. The frequency distributions and summary statistics are shown in Figure 54 and Table 56.

Moxee Drain at Beane Road (37-FM-10) had 1 out of 3 non-irrigation season samples result in a % KES detection (31%). However, moderate *E. coli* concentrations were also present at this site. Moxee Drain at Beaudry Road (37-FM-8) had a wide range of % KES during the non-irrigation season (0% to 63%). *E. coli* concentrations also had a wide range at this site (8 to 130 cfu/100 mL). Moxee Drain and its tributaries from Beaudry Road to Birchfield Road, including DID #11, had low % KES and high *E. coli* concentrations during the non-irrigation season. Moxee Drain near the mouth (37-FM-1) had low to moderate % KES during the non-irrigation season, but this site also had low to moderate *E. coli* concentrations. It does not appear that decaying vegetation is the main source of bacteria in Moxee Drain and DID #11 during the non-irrigation season.

In comparison to the non-irrigation samples, the *E. coli* concentrations appear elevated at all sites during the irrigation season in the Moxee Drain basin. Two sites, the irrigation ditch to Moxee Drain at Beaudry (37-FM-7 / 37-IS-3) and the Hubbard canal at Bell Road (37-FM-4), had moderate to high % KES detections. These 2 sites also had moderate to high *E. coli* concentrations during the irrigation season. The Hubbard Canal had 92 % KES in the single sample collected at this site. Even though the *E. coli* concentration was also high at this site, decaying vegetation may be a significant source of bacteria in the canal during the irrigation season.

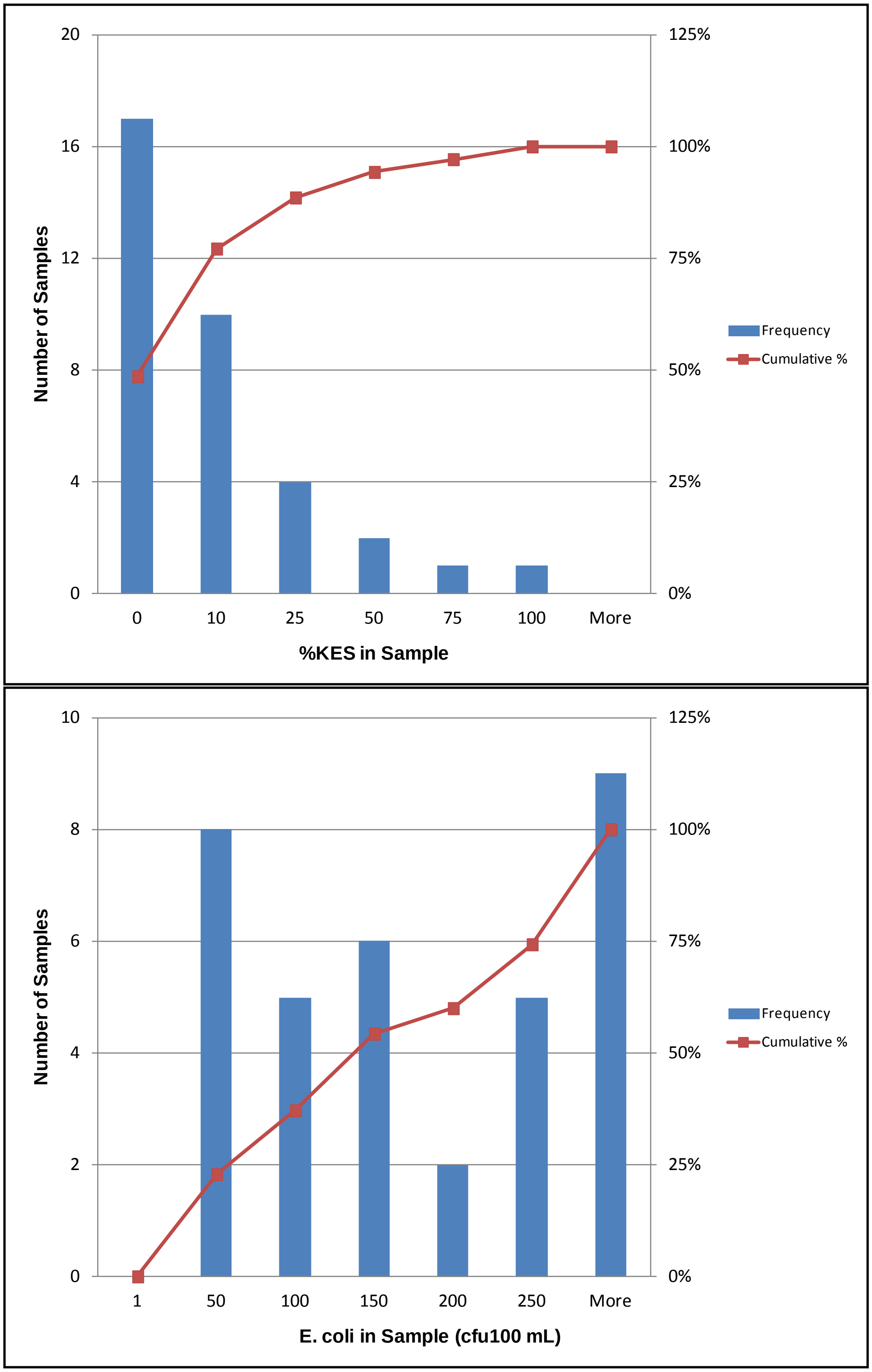


Figure 54. 2004-06 % KES and *E. coli* frequency distribution for the Moxee Drain basin.

Note the differences in axes scales between the charts.

Table 56. 2004-06 % KES and *E. coli* summary statistics for sites in the Moxee Drain basin.

Station ID	% KES				*E. coli*			
	Total Number of Samples	Number of Detects	Min	Max	Total Number of Samples	Number of Detects	Min	Max
Non-Irrigation Season								
37-FM-10	3	1	0	31	3	3	23	66
37-FM-9	3	0	0	0	3	3	8	110
37-FM-8	3	2	0	63	3	3	8	130
37-FM-7 / 37-IS-3	0	-	-	-	0	-	-	-
37-FM-5 / 37-IS-1	1	0	0	0	1	1	9200	9200
37-FM-4 / 37-IS-2	0	-	-	-	0	-	-	-
37-FM-3.6	0	-	-	-	0	-	-	-
37-FM-3.5	1	0	0	0	1	1	110	110
37-FM-3	2	2	2	3	2	2	210	260
37-FM-1	2	2	5	16	2	2	33	56
Irrigation Season								
37-FM-10	6	0	0	0	6	6	150	1300
37-FM-9	2	0	0	0	2	2	84	160
37-FM-8	1	1	4	4	1	1	240	240
37-FM-7 / 37-IS-3	2	2	1	40	2	2	49	170
37-FM-5 / 37-IS-1	1	1	7	7	1	1	1100	1100
37-FM-4 / 37-IS-2	1	1	92	92	1	1	110	110
37-FM-3.6	3	3	4	7	3	3	210	270
37-FM-3.5	1	0	0	0	1	1	520	520
37-FM-3	1	1	19	19	1	1	140	140
37-FM-1	2	2	2	15	2	2	61	69

- No data available for calculations.

TMDL Analysis

Fecal coliform bacteria

Compliance with standards and loading capacity

"Loading capacity" means the maximum amount of FC bacteria pollution a water body can assimilate and still meet the Washington State water quality standard. In this TMDL report, the goal is for the individual tributaries and various segments (reaches) of Cowiche Creek, Wide Hollow Creek, and Moxee Drain to meet the water quality standard, so that then each creek as a whole would be expected to meet the standard prior to its confluence with the Naches and Yakima Rivers.

Because the applicable FC bacteria water quality standard is based on statistical targets, and because FC loading is not relevant to meeting standards or implementation, this FC bacteria TMDL uses statistical targets as surrogate measures to define loading capacities. The applicable statistics from the two-part FC criteria for the TMDL study are:

- A geometric mean less than 100 cfu/100 mL for Cowiche Creek, Wide Hollow Creek, Moxee Drain, and their tributaries.
- No more than 10% of the samples to exceed 200 cfu/100 mL for Cowiche Creek, Wide Hollow Creek, Moxee Drain, and their tributaries. (The 90^{th} percentile of the sample distribution is equivalent and used in this TMDL instead.)

Non-irrigation and irrigation season statistics were developed for each site using current data collected from the 2004-06 and 2010 TMDL studies. The statistics were compared to the water quality criteria, and the percent reduction required to meet the water quality criteria was calculated. The statistic that needed the greatest percent reduction was chosen for each site as the basis for compliance.

Many sites were sampled during both the 2004-06 and 2010 studies, and only one set of target percent reductions are presented for these sites. The 2004-06 target percent reductions were used for sites that had data sets that were not statistically different between the two studies. In these cases, the 2004-06 study data were more robust, resulting in more representative statistics for both seasons.

An exception to this approach was that the 2010 study statistics were used for both seasons for 37-SS-12 and 37-IS-17.5 / 37-SS-9, and 2010 irrigation season statistics were used for 37-FM-1. There were no samples collected at 37-SS-12 during the 2004-06 study non-irrigation season and 5 times as many samples collected in 2010 during the irrigation season. There were twice as many samples collected at 37-IS-17.5 / 37-SS-9 during both seasons for the 2010 study. The increased number of samples collected at these two sites during 2010 resulted in more representative statistics. The Wilcoxon Rank Sum test showed that the 2010 irrigation season concentrations were significantly higher than the 2004-06 irrigation season data set at 37-FM-1.

Therefore, the more stringent target percent reduction (2010) was used for the irrigation season for 37-FM-1.

The percent reduction values in Tables 57 - 59 indicate the relative degree the water body is currently out of compliance with the above water quality criteria (i.e., how far it is over its capacity to receive FC loads and still provide Primary Contact Recreation). Sites representing reaches or tributaries that are meeting their loading capacity have a zero percent reduction value. Sites that require aggressive reductions in FC sources have high target percent reductions, while sites with minor problems have lower target percent reductions.

Table 57. Seasonal FC loading capacities at sites in North Fork Cowiche Creek, South Fork Cowiche Creek, and Cowiche Creek expressed as percentage reduction and statistical target values.

Station ID	Station Description	Non-Irrigation Season Target % Reduction	Non-Irrigation Season FC Target Capacity (cfu/100 mL)		Irrigation Season Target % Reduction	Irrigation Season FC Target Capacity (cfu/100 mL)	
			Geomean	90th percentile		Geomean	90th percentile
NF Cowiche Creek							
38-FC-7	NF Cowiche Ck at French Rd above reservoir	0%	6	185	-	-	-
38-FC-6	NF Cowiche Ck at Rozenkranz Rd bridge	0%	17	166	76%	38	200
38-FC-WWE	Cowiche POTW effluent from UV chamber	94%	see permit limits		78%	see permit limits	
38-FC-WWR	POTW effluent after cooling channel	90%	see permit limits		94%	see permit limits	
38-IS-7	Loop return to NF Cowiche off Thompson Rd	-	-	-	88%	100	-
38-FC-3.5	NF Cowiche Ck at Thompson Rd	19%	27	200	0%	93	189
38-FC-3	NF Cowiche Ck at Mahoney Rd	0%	7	30	64%	17	200
SF Cowiche Creek							
38-FC-4	SF Cowiche Ck at Cowiche Mill Rd	0%	8	36	0%	19	103
38-FC-2.5	SF Cowiche Ck at WDFW bridge	0%	12	74	65%	49	200
38-IS-7.6	SF Cowiche Ck at Pioneer Way	-	-	-	85%	13	200
38-IS-7.5	SF Cowiche Ck at Summitview Rd	-	-	-	76%	100	199
38-IS-8.5	Irrigation return to SF Cowiche Ck at FC-2	-	-	-	86%	23	200
38-FC-2	SF Cowiche Ck at Pioneer Rd/confluence	53%	14	200	85%	27	200
Cowiche Creek							
38-FC-2	SF Cowiche Ck at Pioneer Rd/confluence	53%	14	200	85%	27	200
38-FC-3	NF Cowiche Ck at Mahoney Rd	0%	7	30	64%	17	200
38-FC-1.5	Cowiche Ck at Zimmerman Rd Bridge	0%	22	78	68%	58	200
38-IS-8	Branch return to Cowiche Ck at Weikel Rd	-	-	-	75%	62	200
38-FC-1.25*	Cowiche Ck at the end of Cowiche Ck Rd	0%	21	71	63%	60	200
38-FC-1	Cowiche Ck at Powerhouse Rd	0%	8	59	55%	27	200

Shaded cells are estimates due to insufficient # of samples.

* Based on 2010 data.

- Not enough data available for the calculations.

Table 58. Seasonal FC loading capacities at sites in Wide Hollow Creek, Cottonwood Creek, Randall Park Pond, and East Spring Creek expressed as percentage reduction and statistical target values.

Station ID	Station Description	Non-Irrigation Season Target % Reduction	Non-Irrigation Season FC Target Capacity (cfu/100 mL)		Irrigation Season Target % Reduction	Irrigation Season FC Target Capacity (cfu/100 mL)	
			Geomean	90th percentile		Geomean	90th percentile
Wide Hollow Creek							
37-FW-18	Wide Hollow Ck at Stone Rd near Burnham Rd	0%	17	29	-	-	-
37-FW-17	Trib to Wide Hollow Ck at Stone Rd	50%	4	200	-	-	-
37-FW-16	Trib to Wide Hollow Ck at Stone Rd near school	96%	3	200	-	-	-
37-FW-15 / 37-SS-17	Wide Hollow Ck at Wide Hollow Rd	0%	16	67	96%	100	-
37-FW-12 / 37-SS-16	Wide Hollow Ck at Dazet Rd	0%	5	27	92%	11	200
37-FW-13 / 37-SS-18	Cottonwood Ck at Dazet Rd	0%[1]	5	49	94%	21	200
37-IS-16	Congdon Canal east of 101st Ave	-	-	-	85%	40	200
37-SS-15	Wide Hollow Ck at 91st Ave and Wide Hollow Rd	-	-	-	98%	60	200
37-SS-13	Shaw Ck west of 80th Ave and north of Nob Hill	-	-	-	99%	100	114
37-FW-8 / 37-SS-14	Wide Hollow Ck at park off 80th Ave	44%	19	200	84%	26	200
37-SS-12*	Wide Hollow Ck at 64th Ave	0%	12	56	65%	56	200
37-SS-38	DID #38 outfall at 64th Ave	38%	100	-	-	-	-
37-SS-48	DID #48 outfall at 64th Ave	0%	10	-	-	-	-
37-IS-19	Large blue culvert under 64th Ave bridge	-	-	-	94%	13	200
37-SS-11	Wide Hollow Ck at 48th Ave/Randall Park	36%	91	200	95%	100	163
37-FW-6	Wide Hollow Ck at 44th Ave/Randall Park	0%	63	196	83%	32	200
37-FW-6B*	Wide Hollow Ck behind Bergren Screen Printing	0%	48	182	87%	51	200
37-IS-17.5 / 37-SS-9*	Randall Park Pond outlet on 44th Ave	98%	9	200	96%	72	200
37-IS-17	DID #40 outfall at 38th Ave and Logan Ave	-	-	-	85%	26	200
37-SS-8	City storm outfall at end of 34th Ave	0%	21	-	-	-	-
37-FW-5	Wide Hollow Ck at gas station near airport	61%	56	200	83%	49	200
37-FW-4 / 37-SS-7	Wide Hollow Ck at 16th Ave	0%	28	183	81%	42	200
37-IS-15	DID #4 outfall at Gardner's Nursery	-	-	-	94%	100	-
37-IS-13	DID #24 outfall L2; Pioneer Ln and Cornell Ave	-	-	-	80%	100	149
37-SS-6	City stormwater outfall at 3rd Ave	93%	23	200	100%	4	200
37-IS-12	DID #24 outfall L1 at 3rd Ave	-	-	-	28%	4	200
37-FW-3*	Wide Hollow Ck downstream of 3rd Ave	59%	45	200	77%	84	200

Station ID	Station Description	Non-Irrigation Season Target % Reduction	Non-Irrigation Season FC Target Capacity (cfu/100 mL)		Irrigation Season Target % Reduction	Irrigation Season FC Target Capacity (cfu/100 mL)	
			Geomean	90th percentile		Geomean	90th percentile
37-IS-10	Drain at 4th St and Pine St in Union Gap	-	-	-	0%	2	8
37-FW-1 / 37-SS-5	Wide Hollow Ck at Main St in Union Gap	7%	32	200	87%	37	200
37-FW-0 / 37-SS-1	Wide Hollow Ck at Union Gap Public Works	28%	54	200	89%	40	200
37-FW-2	East Spring Ck at Union Gap Public Works	0%	42	140	37%	82	200
Cottonwood Creek							
37-FW-14	Cottonwood Ck at Moore Rd	0%[1]	22	129	96%	14	200
37-FW-13 / 37-SS-18	Cottonwood Ck at Dazet Rd	0%[1]	5	49	94%	21	200
Randall Park Pond							
37-IS-18	DID #48 near Viola Ave & 48th Ave	-	-	-	57%	95	200
37-IS-17.5 / 37-SS-9	Randall Park Pond outlet on 44th Ave	50%	100	-	94%	100	174
East Spring Creek							
37-SS-2	City storm outfall at east end of Ahtanum Rd	23%	100	-	82%	20	200
37-FW-2	East Spring Ck at Union Gap Public Works	0%	42	140	37%	82	200

Shaded cells are estimates due to insufficient # of samples.

[1] Site had too many seasonal high counts.

* Based on 2010 data.

- Not enough data available for the calculations.

Table 59. Seasonal FC loading capacities at sites in Moxee Drain and DID #11 expressed as percentage reduction and statistical target values.

Station ID	Station Description	Non-Irrigation Season Target % Reduction	Non-Irrigation Season FC Target Capacity (cfu/100 mL)		Irrigation Season Target % Reduction	Irrigation Season FC Target Capacity (cfu/100 mL)	
			Geomean	90th percentile		Geomean	90th percentile
Moxee Drain							
37-IS-5	Outfall from Roza Canal to Moxee Drain	-	-	-	0%	11	19
37-FM-10	Moxee Drain at Beane Rd	36%	68	200	87%	48	200
37-FM-9	Moxee Drain at Walters Rd	0%	11	40	35%	47	200
37-FM-9.5	Outfall to Moxee Drain at Walters Rd	-	-	-	0%	16	-
37-IS-4	Irrigation outfall to Moxee Drain at Walters	-	-	-	66%	9	200
37-FM-8	Moxee Drain at Beaudry near Beauchene Rd	0%	25	125	54%	52	200
37-IS-4.6	North irrigation outfall to Moxee Drain at FM-8	-	-	-	87%	30	200
37-IS-4.5	Irrigation outfall to Moxee Drain at FM-8	-	-	-	21%	55	200
37-FM-7 / 37-IS-3	Irrigation ditch to Moxee Drain at Beaudry Rd	-	-	-	28%	49	200
37-FM-3.6	DID #11 at mouth	72%	72	200	88%	64	200
37-FM-3.5	Moxee Drain just below DID #11	69%	100	178	72%	83	200
37-FM-3	Moxee Drain at Birchfield Rd	46%	71	200	65%	67	200
37-IS-0	Irrigation return to Moxee Drain near FM-1	-	-	-	27%	100	149
37-FM-1*	Moxee Drain near mouth off Thorp Rd	0%[1]	46	165	68%	87	200
DID #11							
37-FM-5.5	DID #11 at Beaudry Rd	-	-	-	58%	100	168
37-FM-5 / 37-IS-1	DID #11 at Bell Rd	98%	41	200	95%	68	200
37-IS-1.5	Irrigation outfall to DID #11 at FM-5	-	-	-	67%	52	200
37-FM-4 / 37-IS-2	Hubbard canal at Bell Rd	-	-	-	66%	57	200
37-FM-3.6	DID #11 at mouth	72%	72	200	88%	64	200

Shaded cells are estimates due to insufficient # of samples.

[1] Site had too many seasonal high counts.

* Irrigation season based on 2010 data.

- Not enough data available for the calculations.

In addition, to meet EPA reporting requirements, Tables 60 - 62 express the estimated seasonal FC load capacity at each evaluated site in number of FC bacteria per day. The loading calculations are based on the estimated average seasonal streamflow. Since the load capacity is flow dependent, it changes as the flow changes. The reported load capacities are specific to the average seasonal flow measured at each station. Higher flow at a station would result in a higher load capacity, while a lower flow would result in a lower load capacity. Compliance with the water quality standard and this TMDL should compare monitoring results to the concentration-based standard and not the average seasonal loading capacity indicated in Tables 60 - 62 since it is unlikely the flow conditions will be the same.

Table 60. Estimated seasonal FC loading capacities for sites evaluated in North Fork Cowiche Creek, South Fork Cowiche Creek, and Cowiche Creek.

Station ID	Station Description	Non-Irrigation Season Target % Reduction	Irrigation Season Target % Reduction	Average Daily FC Loading Capacity (billions cfu/day) based on average seasonal flow	
				Non-Irrigation Season	Irrigation Season
NF Cowiche Creek					
38-FC-7	NF Cowiche Ck at French Rd above reservoir	0%	-	4.7	-
38-FC-6	NF Cowiche Ck at Rozenkranz Rd bridge	0%	76%	7.5	1.1
38-FC-WWE	Cowiche POTW effluent from UV chamber	94%	78%	see permit limits	
38-FC-WWR	POTW effluent after cooling channel	90%	94%	see permit limits	
38-IS-7	Loop return to NF Cowiche off Thompson Rd	-	88%	-	0.1
38-FC-3.5	NF Cowiche Ck at Thompson Rd	19%	0%	5.9	6.6
38-FC-3	NF Cowiche Ck at Mahoney Rd	0%	64%	0.4	0.4
SF Cowiche Creek					
38-FC-4	SF Cowiche Ck at Cowiche Mill Rd	0%	0%	3.5	3.4
38-FC-2.5	SF Cowiche Ck at WDFW bridge	0%	65%	6.0	2.5
38-IS-7.6	SF Cowiche Ck at Pioneer Way	-	85%	-	0.1
38-IS-7.5	SF Cowiche Ck at Summitview Rd	-	76%	-	3.8
38-IS-8.5	Irrigation return to SF Cowiche Ck at FC-2	-	86%	-	0.0
38-FC-2	SF Cowiche Ck at Pioneer Rd/confluence	53%	85%	6.2	4.0
Cowiche Creek					
38-FC-2	SF Cowiche Ck at Pioneer Rd/confluence	53%	85%	6.2	4.0
38-FC-3	NF Cowiche Ck at Mahoney Rd	0%	64%	0.4	0.4
38-FC-1.5	Cowiche Ck at Zimmerman Rd Bridge	0%	68%	13.6	11.2
38-IS-8	Branch return to Cowiche Ck at Weikel Rd	-	75%	-	1.4
38-FC-1.25*	Cowiche Ck at the end of Cowiche Ck Rd	0%	63%	5.3	24.0
38-FC-1	Cowiche Ck at Powerhouse Rd	0%	55%	6.0	4.9

Shaded cells are estimates due to insufficient # of samples.

* Based on 2010 data.

- Not enough data available for the calculations.

Table 61. Estimated seasonal FC loading capacities for sites evaluated in Wide Hollow Creek, Cottonwood Creek, Randall Park Pond, and East Spring Creek.

Station ID	Station Description	Non-Irrigation Season Target % Reduction	Irrigation Season Target % Reduction	Average Daily FC Loading Capacity (billions cfu/day) based on average seasonal flow	
				Non-Irrigation Season	Irrigation Season
Wide Hollow Creek					
37-FW-18	Wide Hollow Ck at Stone Rd near Burnham Rd	0%	-	2.3	-
37-FW-17	Trib to Wide Hollow Ck at Stone Rd	50%	-	1.1	-
37-FW-16	Trib to Wide Hollow Ck at Stone Rd near school	96%	-	0.1	-
37-FW-15 / 37-SS-17	Wide Hollow Ck at Wide Hollow Rd	0%	96%	6.1	-
37-FW-12 / 37-SS-16	Wide Hollow Ck at Dazet Rd	0%	92%	0.5	0.0
37-FW-13 / 37-SS-18	Cottonwood Ck at Dazet Rd	0%[1]	94%	0.7	0.1
37-IS-16	Congdon Canal east of 101st Ave	-	85%	-	12.4
37-SS-15	Wide Hollow Ck at 91st Ave and Wide Hollow Rd	-	98%	-	-
37-SS-13	Shaw Ck west of 80th Ave and north of Nob Hill	-	99%	-	0.4
37-FW-8 / 37-SS-14	Wide Hollow Ck at park off 80th Ave	44%	84%	2.1	4.6
37-SS-12*	Wide Hollow Ck at 64th Ave	0%	65%	-	8.3
37-SS-38	DID #38 outfall at 64th Ave	38%	-	0.3	-
37-SS-48	DID #48 outfall at 64th Ave	0%	-	0.0	-
37-IS-19	Large blue culvert under 64th Ave bridge	-	94%	-	0.5
37-SS-11	Wide Hollow Ck at 48th Ave/Randall Park	36%	95%	13.4	64.2
37-FW-6	Wide Hollow Ck at 44th Ave/Randall Park	0%	83%	6.6	11.7
37-FW-6B*	Wide Hollow Ck behind Bergren Screen Printing	0%	87%	1.0	19.1
37-IS-17.5 / 37-SS-9*	Randall Park Pond outlet on 44th Ave	98%	96%	0.0	0.8
37-IS-17	DID #40 outfall at 38th Ave and Logan Ave	-	85%	-	0.6
37-SS-8	City storm outfall at end of 34th Ave	0%	-	0.0	-
37-FW-5	Wide Hollow Ck at gas station near airport	61%	83%	7.5	21.5
37-FW-4 / 37-SS-7	Wide Hollow Ck at 16th Ave	0%	81%	4.4	20.7
37-IS-15	DID #4 outfall at Gardner's Nursery	-	94%	-	-
37-IS-13	DID #24 outfall L2; Pioneer Ln and Cornell Ave	-	80%	-	0.7
37-SS-6	City stormwater outfall at 3rd Ave	93%	100%	0.1	-
37-IS-12	DID #24 outfall L1 at 3rd Ave	-	28%	-	-
37-FW-3*	Wide Hollow Ck downstream of 3rd Ave	59%	77%	-	38.8
37-IS-10	Drain at 4th St and Pine St in Union Gap	-	0%	-	-
37-FW-1 / 37-SS-5	Wide Hollow Ck at Main St. in Union Gap	7%	87%	6.7	20.1
37-FW-0 / 37-SS-1	Wide Hollow Ck at Union Gap Public Works	28%	89%	14.5	23.3
37-FW-2	East Spring Ck at Union Gap Public Works	0%	37%	5.0	11.9
Cottonwood Creek					
37-FW-14	Cottonwood Ck at Moore Rd	0%[1]	96%	4.1	0.0
37-FW-13 / 37-SS-18	Cottonwood Ck at Dazet Rd	0%[1]	94%	0.7	0.1
Randall Park Pond					
37-IS-18	DID #48 near Viola Ave & 48th Ave	-	57%	-	0.7
37-IS-17.5 / 37-SS-9	Randall Park Pond outlet on 44th Ave	50%	94%	0.2	0.4
East Spring Creek					
37-SS-2	City storm outfall at east end of Ahtanum Rd	23%	82%	14.9	-
37-FW-2	East Spring Ck at Union Gap Public Works	0%	37%	5.0	11.9

Shaded cells are estimates due to insufficient # of samples.

[1] Site had too many seasonal high counts.

* Based on 2010 data.

- Not enough data available for the calculations.

Table 62. Estimated seasonal FC loading capacities for sites evaluated in Moxee Drain and DID #11.

Station ID	Station Description	Non-Irrigation Season Target % Reduction	Irrigation Season Target % Reduction	Average Daily FC Loading Capacity (billions cfu/day) based on average seasonal flow	
				Non-Irrigation Season	Irrigation Season
Moxee Drain					
37-IS-5	Outfall from Roza Canal to Moxee Drain	-	0%	-	0.4
37-FM-10	Moxee Drain at Beane Rd	36%	87%	1.3	2.5
37-FM-9	Moxee Drain at Walters Rd	0%	35%	0.8	17.0
37-FM-9.5	Outfall to Moxee Drain at Walters Rd	-	0%	-	-
37-IS-4	Irrigation outfall to Moxee Drain at Walters	-	66%	-	0.2
37-FM-8	Moxee Drain at Beaudry near Beauchene Rd	0%	54%	3.0	24.4
37-IS-4.6	North irrigation outfall to Moxee Drain at FM-8	-	87%	-	0.3
37-IS-4.5	Irrigation outfall to Moxee Drain at FM-8	-	21%	-	0.2
37-FM-7 / 37-IS-3	Irrigation ditch to Moxee Drain at Beaudry Rd	-	28%	-	2.9
37-FM-3.6	DID #11 at mouth	72%	88%	4.3	15.9
37-FM-3.5	Moxee Drain just below DID #11	69%	72%	16.9	63.9
37-FM-3	Moxee Drain at Birchfield Rd	46%	65%	20.8	53.9
37-IS-0	Irrigation return to Moxee Drain near FM-1	-	27%	-	2.4
37-FM-1*	Moxee Drain near mouth off Thorp Rd	0%[1]	68%	15.2	112.7
DID #11					
37-FM-5.5	DID #11 at Beaudry Rd	-	58%	-	-
37-FM-5 / 37-IS-1	DID #11 at Bell Rd	98%	95%	2.1	8.3
37-IS-1.5	Irrigation outfall to DID #11 at FM-5	-	67%	-	1.5
37-FM-4 / 37-IS-2	Hubbard canal at Bell Rd	-	66%	-	3.7
37-FM-3.6	DID #11 at mouth	72%	88%	4.3	15.9

Shaded cells are estimates due to insufficient # of samples.

[1] Site had too many seasonal high counts.

* Irrigation season based on 2010 data.

\- Not enough data available for the calculations.

Margin of Safety

A margin of safety to account for scientific uncertainty must be considered in all TMDLs to ensure that the targets will protect water quality. The margin of safety for this FC bacteria TMDL analysis is implicit through the use of conservative assumptions in project design and analysis.

Target reductions generally were based on the 90th percentile of FC concentrations. The roll-back method assumes that the variance of the post-management data set will be equivalent to the variance of the pre-management data set. As pollution sources are managed, the frequency of high FC values is likely to decrease, which should reduce the variance and 90th percentile of the post-management condition.

Conclusions

Cowiche Creek

North Fork Cowiche Creek

2004-06 analysis

- The sites at the Cowiche POTW (38-FC-WWE and 38-FC-WWR) and at 38-FC-3.5 were the only sites to not meet the water quality criteria during the non-irrigation season.
- All the sites sampled during the irrigation season did not meet the criteria, except 38-FC-3.5. Three of the sites did not meet either part of the criteria: 38-FC-6, 38-FC-WWR, and 38-IS-7.
- Most of the non-irrigation season load to NF Cowiche Creek was from the reach between river mile (RM) 8.7 and RM 6.7 (48%), above RM 8.7 (36%), and the reach between RM 6.7 and RM 1.1 (10%).
- The entire irrigation season load to NF Cowiche Creek was from the Cowiche POTW (60%) and above RM 6.7 (40%).
- Non-irrigation total suspended solids (TSS) loading percentages were also high in the reach between RM 6.7 and RM 1.1 and above RM 8.7. This suggests that conditions that elevate TSS, such as direct manure sources, or high flows or runoff processes (causing soil erosion), could also be elevating fecal coliform (FC) bacteria concentrations in these reaches.
- Non-irrigation chloride loading percentages were also high above RM 8.7 and in the reach between RM 6.7 and RM 1.1. This suggests that conditions and nonpoint sources that elevate chloride, such as failing septic tanks, could be elevating FC concentrations. These sources should be considered for FC contamination in these reaches.

Cowiche Publicly Owned Treatment Works (POTW)

2004-06 analysis

- Both sites at the POTW did not meet the water quality permit criteria. The POTW had FC concentrations that exceeded (did not meet) permit limits a majority of the months sampled. The concentrations appear to be slightly elevated at the downstream site (38-FC-WWR) between August and December 2005.
- The entire non-irrigation season FC load at the POTW was from the site immediately after the UV chamber (100%). Therefore, the cooling channel appears not to be contributing additional FC loads to NF Cowiche Creek during the non-irrigation season.
- Most of the irrigation season load at the POTW was from within the cooling channel (77%). Therefore, the cooling channel appears to be contributing additional FC loads to NF Cowiche Creek during the irrigation season.

South Fork Cowiche Creek

2004-06 analysis

- During the non-irrigation season, 1 out of the 3 sampled sites (38-FC-2) did not meet the 90th percentile part of the water quality criteria.
- During the irrigation season, 5 out of the 6 sampled sites did not meet the criteria. Of these 5 sites, 38-IS-4.6 was the only one to meet one part, geomean, of the criteria. 38-FC-4 was the only site to meet both parts of the criteria.
- All of the non-irrigation season load to SF Cowiche Creek was from above RM 7.7 (54%) and the reach between RM 4.8 and RM 0.1 (46%).
- Most of the irrigation season load to SF Cowiche Creek was from the reach between RM 4.8 and RM 0.1 (62%), the reach between RM 7.7 and RM 4.8 (18%), and above RM 7.7 (15%).
- Non-irrigation season TSS loads to SF Cowiche Creek were also high above RM 7.7 and for the reach between RM 4.8 and RM 0.1. This suggests that conditions that elevate TSS, such as high flows or runoff processes (causing soil erosion), could also be elevating FC concentrations in these reaches.
- Non-irrigation season chloride loads to SF Cowiche Creek were also high above RM 7.7 and for the reach between RM 4.8 and RM 0.1. This suggests that conditions that elevate chloride, such as failing septic tanks, could also be elevating FC concentrations in these reaches.
- Irrigation season chloride loads to SF Cowiche Creek were also high above RM 7.7 and for the reach between RM 4.8 and RM 0.1. This suggests that conditions that elevate chloride, such as failing septic tanks, could also be elevating FC concentrations during the irrigation season in these reaches.

Cowiche Creek

2004-06 analysis

- During the non-irrigation season, none of the Cowiche Creek or tributary sites downstream of the NF and SF confluence exceeded the water quality criteria.
- All the sites sampled during the irrigation season did not meet the criteria. Two of the sites downstream of the NF and SF confluence did not meet either part of the criteria: 38-FC-1.5, and 38-IS-8.
- Nearly half of the non-irrigation FC loads to Cowiche Creek was from SF Cowiche Creek (48%). The other half of the non-irrigation loads was from the reach between RM 6.3 and RM 0.7 (28%) and NF Cowiche Creek (24%).
- Two-thirds of the irrigation FC loads to Cowiche Creek was from SF Cowiche Creek (75%). The other third of irrigation loads was from the irrigation return at Weikel Road (16%) and NF Cowiche Creek (9%).

- SF Cowiche Creek, the reach between RM 6.3 and RM 0.7, and NF Cowiche Creek, also had the largest non-irrigation TSS loading percentage to Cowiche Creek. This suggests that conditions that elevate TSS, such as high flows or runoff processes (causing soil erosion), could also be elevating FC concentrations in these reaches during the non-irrigation season.
- Irrigation season TSS loading percentages were also high for SF Cowiche Creek, the irrigation return, and NF Cowiche Creek. Therefore, conditions that elevate TSS could also be elevating FC concentrations in these reaches during the irrigation season.
- Non-irrigation season chloride loading percentages were also high for NF Cowiche Creek, the reach between RM 6.3 and RM 0.7, and SF Cowiche Creek. This suggests that conditions and nonpoint sources that elevate chloride could also be elevating FC concentrations.
- Irrigation season chloride loading percentages were also high for SF Cowiche Creek and the irrigation return at Weikel Road. Conditions and sources that elevate chloride concentrations may also be elevating FC concentrations in these reaches during the irrigation season.

2010 analysis

- Both sites sampled met the water quality criteria during the non-irrigation season.
- Both sites did not meet either part of the criteria during the irrigation season.
- The non-irrigation season FC load to Cowiche Creek was nearly split evenly between the two reaches: the reach between RM 2.7 and 0.7 (56%) and above RM 2.7 (44%).
- The entire irrigation season FC loading percentage to Cowiche Creek appears to be from above RM 2.7 (100%).
- FC concentrations from the two studies, 2004-06 and 2010, were not statistically different at 38-FC-1 according to the Wilcoxon Rank Sum test.
- TSS loading percentages were also high above RM 2.7 for both seasons. This suggests that conditions that elevate TSS, such as high flows or runoff processes (causing soil erosion), could also be elevating FC concentrations above RM 2.7 during both seasons.
- There was a weak but positive relationship between irrigation season TSS concentrations and FC concentrations. This illustrates that conditions that elevate TSS could also be elevating FC concentration in this portion of Cowiche Creek during the irrigation season.

Wide Hollow Creek

Wide Hollow Creek

2004-06 analysis

- Ten out of the 19 sites sampled during the non-irrigation season did not meet the water quality criteria.

- FC concentrations during the non-irrigation season appear to increase downstream of 80th Avenue (Yakima city limits) to the mouth. Mainstem Wide Hollow Creek sites in this sub-reach that did not meet water quality criteria were 37-FW-5, 37-FW-1, and 37-FW-0. Tributary sites in this sub-reach that did not meet water quality criteria were 37-SS-38, 37-SS-11, 37-IS-17.5 / 37-SS-9, and 37-SS-6.
- FC concentrations during the irrigation season were elevated versus the non-irrigation season. A drain at 4th Avenue (37-IS-10) was the only site to meet the water quality criteria during the irrigation season.
- Most of the non-irrigation season FC load to Wide Hollow Creek was from Cottonwood Creek (30%), the reach between RM 0.7 and RM 0.6 (21%), the tributary at Stone Road near Cook Road (18%), and the reach between RM 6.7 and RM 5.3 (10%).
- The majority of the irrigation season FC load to Wide Hollow Creek was from the reach between RM 9.6 and RM 6.7 (32%), the reach between RM 4.4 and RM 0.7 (21%), and Congdon Canal (17%).
- Eighteen sites in the non-irrigation season and 16 sites in the irrigation season did not have concentration or streamflow data available for the sample surveys where the mainstem fixed-network sites were also sampled. Therefore, these sites were omitted from the loading analysis. More samples and streamflow need to be collected at these sites to characterize their percentages of FC loading to Wide Hollow Creek.
- Non-irrigation TSS loading percentages were also high in Cottonwood Creek and the tributary at Stone Road near Cook Road. This suggests that conditions that elevate TSS, such as high flows or runoff processes (causing soil erosion), could also be elevating FC concentrations in these tributaries.
- Irrigation TSS loading percentages were high in the reach between RM 9.6 and RM 6.7 and in Congdon Canal. Therefore, conditions or sources that elevate TSS could also be elevating FC concentrations in these reaches.
- Non-irrigation chloride loading percentages were high for the reach between RM 0.7 and RM 0.6, the reach between RM 6.7 and RM 5.3, and the tributary at Stone Road near Cook Road. This suggests that conditions and nonpoint sources that elevate chloride, such as failing septic tanks, could be elevating FC concentrations.
- There appears to be an irrigation season relationship between high chloride loading percentages and FC loading percentages for the reach between RM 9.6 and RM 6.7, and the reach between RM 0.7 and RM 0.6. Conditions and nonpoint sources that elevate chloride could also be elevating FC concentrations.

2010 analysis

- Non-irrigation FC concentrations in Wide Hollow Creek upstream of 40th Avenue met the water quality criteria. Downstream of 40th Avenue the concentrations became elevated. The mainstem Wide Hollow Creek sites that did not meet either part of the criteria in the non-irrigation season were 37-FW-3 and 37-FW-0. The tributary sites that did not meet either part of the criteria in the non-irrigation season were 37-IS-17.5 / 37-SS-9, 37-IS-17, and 37-IS-15.

- FC concentrations during the irrigation season were elevated versus the non-irrigation season. 37-SS-48, 37-IS-13, and 37-IS-12B were the only sites to meet the water quality criteria for the irrigation season.
- It does not appear that efforts to improve stormwater conveyances, after the 2004-06 sampling, in the Yakima urban areas have resulted in reducing bacteria concentrations or loads to Wide Hollow Creek. The Wilcoxon Rank Sum test was conducted on each site that was sampled at least twice during each study. FC concentrations at most of the sites were not statistically different between the 2004-06 and 2010 studies. Only the FC concentrations at 37-SS-12 during the irrigation season were statistically different between the 2004-06 and 2010 studies.
- Over 80% of the non-irrigation FC loads in Wide Hollow Creek were from the reach between RM 4.4 and RM 0.6 (82%). The next largest FC loading percentage during the non-irrigation season was from Randall Park Pond (10%).
- Over half of the irrigation season FC loads in Wide Hollow Creek were from the reach between RM 8.3 and RM 6.7 (51%). The majority of the other half of the FC loads was from Congdon Canal (14%) and the reach between RM 4.4 and RM 0.6 (13%).
- TSS loading percentage was also the highest from the reach between RM 4.4 and RM 0.6 for the non-irrigation season. This suggests that conditions that elevate TSS, such as high flows or runoff processes (causing soil erosion), could also be elevating FC concentrations in this reach during the non-irrigation season.
- Irrigation season FC loading percentages and TSS loading percentages were both high for Congdon Canal, above RM 9.6, and the reach between 9.6 and 6.7. This suggests that conditions that elevate TSS could also be elevating FC concentrations in these reaches during the irrigation season.

Cottonwood Creek

2004-06 analysis

- During the non-irrigation season, both sites met the water quality criteria. However, at both sites the percentage of samples greater than 200 cfu / 100 mL was over 10%.
- During the irrigation season, both sites did not meet either part of the criteria.
- Based on seasonal averages, it appears that 100% of the FC loading to Cottonwood Creek was from above the site at Moore Road (37-FW-14). Therefore, the reach downstream of Moore Road to the mouth does not appear to be contributing any additional FC loads to Cottonwood Creek.
- Cottonwood Creek went dry during the irrigation season at Moore Road after May, and high FC concentrations were still present at Dazet Road in June and July. Therefore, it is not appropriate to eliminate the existence of a possible source of FC bacteria between Moore Road and Dazet Road.

- There is an apparent relationship between non-irrigation season and irrigation season TSS loads and FC loads above Moore Road. This suggests that conditions or sources that elevate TSS appear to be elevating FC concentrations in Cottonwood Creek.
- There is a weak but positive relationship between irrigation season TSS concentrations and FC concentrations for both sites in Cottonwood Creek. This illustrates that conditions that elevate TSS could also be elevating FC concentrations in Cottonwood Creek during the irrigation season.

Randall Park Pond

2004-06 analysis

- One sample was collected at 37-IS-17.5 / 37-SS-9 during the non-irrigation season. This sample had a concentration of 200 cfu / 100 mL, so it did not meet the water quality criteria.
- The irrigation season FC concentrations in Randall Park Pond did not meet either part of the criteria for both sites. FC concentrations appear to be elevated at the outlet of the pond in comparison to above the pond in DID #48.
- There was not enough data available for average non-irrigation season FC loads to be calculated for Randall Park Pond.
- 80% of the irrigation season FC loading to Randall Park Pond was from the reach between 48th Avenue and 44th Avenue including the pond. The pond and park have a large duck and goose colony. 20% of the irrigation season FC loading was from above 48th Avenue in DID #48.
- Based on the data from the two sampling surveys, there appears to be a relationship between estimated FC loading percentages and estimated TSS loading percentages during the irrigation season in Randall Park Pond. There was also a strong positive relationship between irrigation season TSS concentrations and FC concentrations in Randall Park Pond. This suggests that conditions that elevate TSS could also be elevating FC concentrations in the pond during the irrigation season.

2010 analysis

- Both sites did not meet water quality criteria during both seasons.
- One sample was collected at 37-IS-18B during each season. The concentrations in these samples were both over 200 cfu / 100 mL.
- Two samples were collected at the outlet of the pond (37-IS-17.5 / 37-SS-9) during the non-irrigation season. Both samples were greater than 100 cfu / 100 mL. Ten samples were collected at this site during the irrigation season, and 100% of the samples were greater than 200 cfu / 100 mL.
- The Wilcoxon Rank Sum test was conducted for 37-IS-17.5/37-SS-9, and there was no statistical difference between the 2004-06 and 2010 FC concentrations at this site.

- Average FC and TSS loading percentages to Randall Park Pond for 2010 could not be calculated due to the limited data available at the upstream site (37-IS-18B).
- There is a weak but positive relationship between irrigation season TSS concentrations and FC concentrations in Randall Park Pond. Conditions that elevate TSS may also be elevating FC concentrations in Randall Park Pond in the irrigation season.

East Spring Creek

2004-06 analysis

- One sample was collected at the city stormwater outfall at the east end of Ahtanum Road (37-SS-2) during the non-irrigation season, and two were collected during the irrigation season. These samples had a wide range of FC concentration of 31 - 400 cfu / 100 mL indicating a potential source of FC bacteria to the creek.
- FC concentrations at the mouth of East Spring Creek (37-FW-2) were consistently elevated only during the irrigation season. Counts stayed fairly constant from May through August at around 180 – 300 cfu/100 mL. The site failed both parts of the FC criteria during the irrigation season.
- Average FC, TSS, and chloride loading percentages to East Spring Creek could not be calculated due to the limited data available at the city stormwater outfall site (37-SS-2).

Moxee Drain

Moxee Drain

2004-06 analysis

- During the non-irrigation season, 5 out of the 7 sampled sites did not meet the water quality criteria. Moxee Drain near the mouth (37-FM-1) met both parts of the criteria, but 1 of 8 (13%) of the sample concentrations were greater than 200 cfu / 100 mL.
- Moxee Drain at Walters Road (37-FM-9) and at Beaudry Road (37-FM-8) were the only 2 sites to meet water quality criteria during the non-irrigation season.
- FC concentrations appear to be elevated during the irrigation season. Twelve out of the 14 sampled sites during the irrigation season did not meet the water quality criteria. Two of these sites, the irrigation outfall at Beaudry Road (37-IS-4.5) and the irrigation ditch at Beaudry Road (37-FM-7 / 37-IS-3), met 1 of the 2 parts of the criteria.
- The outfall from Roza Canal (37-IS-5) and an outfall at Walters Road (37-FM-9.5) met water quality criteria during the irrigation season.
- Nearly three-quarters of the non-irrigation FC loading percentages to Moxee Drain was from the reach between RM 4 and RM 2.1 (72%). The majority of the remaining non-irrigation FC loading percentage was from DID #11 (18%).

- Most of the irrigation season FC loading to Moxee Drain was from DID #11 (72%). The majority of the remaining irrigation season loads was from the reach between RM 6.3 and RM 4 (9%) and the reach between RM 8.5 and RM 6.3 (8%).
- The reach between RM 4 and RM 2.1 and DID #11 had large FC loading percentages and chloride loading percentages during the non-irrigation season.
- DID #11, the reach between RM 8.5 and RM 6.3, and the reach between RM 6.3 and RM 4 had the highest FC concentrations during the irrigation season. These reaches also had 3 of the 4 highest chloride loads to Moxee Drain during the irrigation season. This suggests that conditions or sources that elevate chloride concentrations may be elevating FC concentrations in these reaches during the irrigation season.

2010 analysis

- All of the sites sampled did not meet either part of the water quality criteria during both seasons. The seasonal summary statistics clearly indicate the continued presence of high FC concentrations at these sites.
- Based on the 2 sample sets (2004-06 and 2010), there was no net increase, but instead a decrease, in FC loads in the reach between 37-FM-3 and 37-FM-1. During the non-irrigation season, there were no other mainstem sites monitored upstream of 37-FM-3. During the irrigation season, there appears to be minimal FC loading from above RM 8.5.
- The Wilcoxon Rank Sum test was conducted for all 3 Moxee Drain sites. 37-FM-1 was the only site to have a statistical difference (increase) between the 2004-06 and 2010 FC concentrations.
- The reach between RM 8.5 and RM 2.1 had the highest FC loading percentage and highest TSS loading percentage during the irrigation season. Therefore, conditions that elevate TSS may be also elevating FC concentrations during the irrigation season in that reach.

Drainage Improvement District (DID) #11

2004-06 analysis

- DID #11 at Bell Road (37-FM-5 / 37-IS-1) and at the mouth (37-FM-3.6) did not meet either part of the water quality criteria during the non-irrigation season.
- All the sites except at the POTW did not meet either part of the water quality criteria during the irrigation season.
- Nearly the entire non-irrigation season FC loading to DID #11 was from above Bell Road (99.8%). The load was mainly from the onsite septic system failure, although sources upstream of 37-FM-5.5 may have contributed. The only other reach to register a percentage was the Moxee POTW (0.2%).
- Most of the irrigation season FC loading to DID #11 was from the same sources (87%). The irrigation outfall at Bell Road and the Hubbard Canal at Bell Road each accounted for about 7% of the FC loading during the irrigation season.

- The TSS loading percentage in DID #11 above Bell Road was the highest during the non-irrigation season (97%) and the irrigation season (72%).
- There is a weak but positive relationship between TSS concentrations and FC concentrations in DID #11. This illustrates that conditions that elevate TSS could also be elevating FC concentrations in DID #11 during both seasons.
- The chloride loading percentage in DID #11 above Bell Road was the highest during the non-irrigation season (71%) and the irrigation season (68%). This further illustrates the presence of the leaky septic system above Bell Road.

Moxee Publicly Owned Treatment Works (POTW)

2004-06 analysis

- Both sites met the water quality permit criteria for all months except January 2006. There was one sample collected in January 2006 that had a concentration of 125 cfu / 100 mL.
- The FC concentrations were often elevated downstream at 37-FM-WWO, but the site still met the criteria.
- The majority of non-irrigation season and irrigation season FC loading at the Moxee POTW was from the reach between the UV chamber and the outfall to DID #11 (79% and 71%, respectively). Only about a quarter of the FC loads at the POTW are from after the UV chamber for both seasons.

Stormwater sampling

- The stormwater sample sites were visited on four dates during the 2004-06 surveys: May 9 and 10, 2005; February 28, 2006; and March 5, 2006. Stormwater samples were not collected during the 2010 surveys.
- The stormwater outfalls are expected to meet the FC concentration criteria of the water body they discharge to, Wide Hollow Creek.
- FC concentrations at 15 of the 18 stormwater sites did not meet either part of the Primary Contact Recreation criteria. The FC concentration at DID #38 outfall (37-SS-38) did not meet the geomean part of the criteria. The FC concentrations at DID #48 outfall (37-SS-48) and at the city storm outfall at the end of 34th Avenue (37-SS-8) met both parts of the water quality criteria.
- FC loading percentages were calculated for the May 9, 2005; February 28, 2006; and March 5, 2006 storm surveys. The total estimated stormwater loads were assigned to the three jurisdictions: Yakima County, City of Yakima, and City of Union Gap.
- Yakima County appears to have the lowest FC loading percentage for all 3 surveys. The City of Yakima appears to be the primary loading source during the winter/non-irrigation season storm events. Union Gap appears to be the primary loading source during the spring/irrigation season storm event.

E. coli and % Klebsiella, Enterobacter, and Serratia (KES)

Cowiche Creek

- Six of the 7 Cowiche Creek basin sites sampled had no % KES detects during the non-irrigation season. The only one to have a detection (14%) was Cowiche Creek near the mouth at Powerhouse Road (38-FC-1).
- During the irrigation season, 3 of the 6 sampled sites had no % KES detects and moderate to high *E. coli* concentrations. These 3 sites were in the upper part of the basin, similar to the non-irrigation season.
- Cowiche Creek at Zimmerman Road and Powerhouse Road (38-FC-1.5 and 38-FC-1, respectively) had a maximum % KES over 20%. However, both these sites also had elevated *E. coli* concentrations.

Wide Hollow Creek

- The 3 upper Wide Hollow Creek basin sites (37-FW-16, 37-FW-12 / 37-SS-16, and 37-FW-14) had no % KES detects and high *E. coli* concentrations in the non-irrigation season.
- The single sample taken at Cottonwood Creek at the mouth (37-FW-13) had a high % KES detection (66%). The single *E. coli* sample collected at 37-FW-13 did not have a detection, so it appears that bacteria at the mouth of Cottonwood Creek could be from decaying vegetation during the non-irrigation season.
- One of the 3 samples collected at Wide Hollow Creek at 44th Ave (37-FW-6) resulted in a detection for % KES (40%). All 3 of the *E. coli* samples for this site had low concentrations. It appears that some of the bacteria at this site may be from decaying vegetation.
- Wide Hollow Creek at Dazet Road (37-FW-12 / 37-SS-16) and Cottonwood Creek (37-FW-14 and 37-FW-13 / 37-SS-18) had low % KES and high *E. coli* concentrations during the irrigation season. It appears that bacteria may be from an animal source and not decaying vegetation at these sites during the irrigation season.
- Wide Hollow Creek sites between 80th Ave (37-FW-8 / 37-SS-14) and the Union Gap Public Works (37-FW-0 / 37-SS-1) had low to moderate % KES detections and moderate to high *E. coli* concentrations. It appears that decaying vegetation may only be a minor source of bacteria in this reach during the irrigation season.

Moxee Drain

- Moxee Drain at Beane Road (37-FM-10) had 1 out of 3 non-irrigation season samples result in a % KES detection (31%). However, moderate *E. coli* concentrations were also present at this site.
- Moxee Drain and its tributaries from Beaudry Road to Birchfield Road, including DID #11, had low % KES and high *E. coli* concentrations during the non-irrigation season.

- It does not appear that decaying vegetation is the main source of bacteria in Moxee Drain and DID #11 during the non-irrigation season.
- *E. coli* concentrations appear elevated at all sites during the irrigation season in the Moxee Drain basin.
- Two sites, the irrigation ditch to Moxee Drain at Beaudry (37-FM-7 / 37-IS-3) and the Hubbard canal at Bell Road (37-FM-4), had moderate to high % KES detections. These 2 sites also had moderate to high *E. coli* concentrations during the irrigation season.
- The Hubbard Canal had 92 % KES in the single sample collected at this site. Even though the *E. coli* concentration was also high at this site, decaying vegetation may be a significant source of bacteria in the canal during the irrigation season.

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Recommendations

As a result of this TMDL study, the following recommendations are made.

Implementation of TMDL targets

The goal of this TMDL study is to reduce fecal coliform (FC) bacteria at all sampling sites that are assigned target percent FC reductions so that all sites within the Cowiche Creek, Wide Hollow Creek, and Moxee Drain basins comply with Washington State water quality standards. Some sites did not require a reduction. In order to maintain water quality and the continuation of meeting water quality standards, these sites in compliance during the study cannot receive additional inputs of FC bacteria.

The following FC loads are prioritized (based on size of load and concentration) for implementation actions to reduce FC loads and concentrations during the non-irrigation season and irrigation season. Implementation may include further assessment, if necessary.

Cowiche Creek

Unexplained FC loads to Cowiche Creek during the non-irrigation season (November through March)

- From SF Cowiche Creek.
  - Above RM 7.7 of SF Cowiche Creek.
  - Between RM 4.8 and 0.1 of SF Cowiche Creek.
- Between RM 6.3 and 0.7 of Cowiche Creek.
- From NF Cowiche Creek.
  - Between RM 8.7 and 6.7 of NF Cowiche Creek.
  - Above RM 8.7 of NF Cowiche Creek.
  - Between RM 6.7 and 1.1 of NF Cowiche Creek.
  - From Cowiche Publicly Owned Treatment Works (POTW).

Unexplained FC loads to Cowiche Creek during the irrigation season (April through October)

- From SF Cowiche Creek.
  - Between RM 4.8 and 0.1 of SF Cowiche Creek.
  - Between RM 7.7 and 4.8 of SF Cowiche Creek.
  - Above RM 7.7 of SF Cowiche Creek.
- From the irrigation return at Weikel Road.
- From NF Cowiche Creek.
  - From Cowiche POTW.
  - Above RM 6.7 of NF Cowiche Creek.

Wide Hollow Creek

Unexplained FC loads to Wide Hollow Creek during the non-irrigation season (November through March)

- From Cottonwood Creek.
  - Above Moore Road.
- Between RM 0.7 and 0.6 of Wide Hollow Creek.
- From the tributary at Stone Road near Cook Road.
- Between RM 6.7 and 5.3 of Wide Hollow Creek.
- From the tributary at Stone Road near school.
- From East Spring Creek.
- From Randall Park Pond.

Unexplained FC loads to Wide Hollow Creek during the irrigation season (April through October)

- Between RM 9.6 and 6.7 of Wide Hollow Creek.
- Between RM 4.4 and 0.7 of Wide Hollow Creek.
- From Congdon Canal.
- Between RM 0.7 and 0.6 in Wide Hollow Creek.
- From East Spring Creek.

Moxee Drain

Unexplained FC loads to Moxee Drain during the non-irrigation season (November through March)

- Between RM 4 and 2.1 of Moxee Drain.
- From Drainage Improvement District (DID) #11.
  - Above Bell Road.
- Between RM 6.3 and 4 of Moxee Drain.
- Above RM 8.5 of Moxee Drain.

Unexplained FC loads to Moxee Drain during the irrigation season (April through October)

- From DID #11.
  - Above Bell Road.
  - From Hubbard Canal.
  - From the irrigation outfall at Bell Road.
- Between RM 6.3 and 4 of Moxee Drain.
- Between RM 8.5 and 6.3 of Moxee Drain.
- Above RM 8.5 of Moxee Drain.

Total suspended solids (TSS)

Correlations between TSS and FC loads and between TSS and FC concentrations suggest that conditions that elevate TSS, such as high streamflow and runoff processes (causing soil erosion), could also be elevating FC concentrations. Further investigation in Cowiche Creek, Wide Hollow Creek, and Moxee Drain is warranted to determine whether soil-erosion controls could also reduce FC levels, or if waste sources are elevating both TSS and FC levels.

Chloride

Correlations between chloride and FC loads suggest that conditions that elevate chloride, such as new water or waste inputs, could also be elevating FC concentrations. Further investigation in Cowiche Creek, Wide Hollow Creek, and Moxee Drain is warranted to determine what sources could be elevating both chloride and FC levels.

Stormwater management

In addition to the requirements outlined in the stormwater permits, jurisdictions should focus source-identification and management efforts in the areas and outfalls with FC reduction targets identified in this study.

Future monitoring for FC bacteria

Compliance with the FC bacteria water quality criteria and the target reduction goals should be monitored by sampling at the sites where data were used to generate those goals. Streamflow measurements should also be taken when samples are collected in order to estimate FC loads.

The following should be considered for further monitoring to isolate or better define possible FC sources to Cowiche Creek, Wide Hollow Creek, and Moxee Drain:

Cowiche Creek

- The consistent high FC concentrations and loading from SF Cowiche Creek should be investigated to reveal pollution sources. Investigation should include an assessment of:
    - Consistent FC sources between RM 4.8 and 0.1 of SF Cowiche Creek. Particular attention should be given to waste sources that elevate chloride in this reach.
    - Consistent FC sources above RM 7.7 of SF Cowiche Creek.
    - Irrigation season FC sources between RM 7.7 and 4.8 of SF Cowiche Creek.

- The consistent high FC concentrations and loading from NF Cowiche Creek should be investigated to reveal pollution sources. Investigation should include an assessment of:
    - Consistent FC sources above RM 6.7 of NF Cowiche Creek.

- Consistent FC sources at the Cowiche POTW. Particular attention should be given to the cooling channel during the irrigation season.
- Non-irrigation season FC sources above RM 8.7 and between RM 6.7 and 1.1.

- The consistent high FC concentrations and loading from the mainstem of Cowiche Creek should be investigated to reveal pollution sources. Investigation should include an assessment of:
  - Non-irrigation season FC sources between RM 6.3 and 0.7 of Cowiche Creek.
  - Irrigation season FC sources from the irrigation return at Weikel Road.

Wide Hollow Creek

- The high FC concentrations and non-irrigation season loading from Cottonwood Creek should be investigated to reveal pollution sources. Investigation should include an assessment of:
  - Consistent FC sources above Moore Road.

- The consistent high FC concentrations and loading from Wide Hollow Creek should be investigated to reveal pollution sources. Investigation should include an assessment of:
  - Irrigation season FC sources between RM 9.6 and 6.7 of Wide Hollow Creek.
  - Irrigation season FC sources between RM 4.4 and 0.7 of Wide Hollow Creek. Particular attention should be given to waste sources that elevate chloride in this reach.
  - Consistent FC sources between RM 0.7 and 0.6 of Wide Hollow Creek. Particular attention should be given to wastes sources that elevate chloride in this reach.
  - Non-irrigation season FC sources from the tributary at Stone Road near Cook Road.
  - Irrigation season FC sources from Congdon Canal. Particular attention should be given to run-off sources that elevate TSS in the canal.
  - Non-irrigation season FC sources between RM 6.7 and 5.3 of Wide Hollow Creek. Particular attention should be given to waste sources that elevate chloride in this reach.
  - Non-irrigation season FC sources from the tributary at Stone Road near the school.
  - Consistent FC sources from East Spring Creek.

- The high FC concentrations and non-irrigation season loading from Randall Park Pond should be investigated to reveal pollution sources. Investigation should include an assessment of:
  - FC sources between 48th Avenue and 44th Avenue.

Moxee Drain

- The consistent high FC concentrations and loading from DID #11 should be investigated to reveal pollution sources. Investigation should include an assessment of:
  - Consistent FC sources above Bell Road.

- Irrigation season FC sources from Hubbard Canal. Particular attention should be given to bacteria from decaying vegetation in the canal.
- Irrigation season FC sources in the irrigation return outfall at Bell Road.

- The consistent high FC concentrations and loading from Moxee Drain should be investigated to reveal pollution sources. Investigation should include an assessment of:
  - Non-irrigation season FC sources between RM 4 and 2.1 of Moxee Drain. Particular attention should be give to waste sources that elevate chloride in this reach.
  - Consistent FC sources between RM 6.3 and 4 of Moxee Drain. Particular attention should be given to sources that elevate TSS during the irrigation season in this reach.
  - Irrigation season FC sources between RM 8.5 and 6.3 of Moxee Drain. Particular attention should be given to waste sources that elevate chloride in this reach.
  - Consistent FC sources above RM 8.5 of Moxee Drain.

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Appendix. Glossary, acronyms, and abbreviations

Glossary

303(d) List: Section 303(d) of the federal Clean Water Act requires Washington State periodically to 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 water bodies (ocean waters, estuaries, lakes, and streams) that fall short of state surface water quality standards and are not expected to improve within the next two years.

Best management practices (BMPs): Physical, structural, or operational practices that, when used singularly or in combination, prevent or reduce pollutant discharges.

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.

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each water body or segment, regardless of whether or not the uses are currently attained.

Exceeded criteria: Did not meet criteria.

Existing uses: Those uses actually attained in fresh and marine waters on or after November 28, 1975, whether or not they are designated uses. Introduced species that are not native to Washington, and put-and-take fisheries comprised of non-self-replicating introduced native species, do not need to receive full support as an existing use.

Fecal coliform (FC): That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform bacteria are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

Geometric mean: A mathematical expression of the central tendency (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 nth root of a product of n factors, or

(2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

Irrigation season: In this study, April through October.

Load allocation: The portion of a receiving water's loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Loading capacity: The greatest amount of a substance that a water body can receive and still meet water quality standards.

Margin of safety: Required component of TMDLs that accounts for uncertainty about the relationship between pollutant loads and quality of the receiving water body.

Municipal separate storm sewer systems (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains): (1) owned or operated by a state, city, town, borough, county, parish, district, association, or other public body having jurisdiction over disposal of wastes, stormwater, or other wastes and (2) designed or used for collecting or conveying stormwater; (3) which is not a combined sewer; and (4) which is not part of a Publicly Owned Treatment Works (POTW) as defined in the Code of Federal Regulations at 40 CFR 122.2.

National Pollutant Discharge Elimination System (NPDES): National program for issuing and revising permits, as well as imposing and enforcing pretreatment requirements, under the Clean Water Act. The NPDES permit 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.

Non-irrigation season: In this study, November through March.

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 National Pollutant Discharge Elimination System 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.

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

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 to be 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.

Phase II stormwater permit: The second phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to smaller municipal separate storm sewer systems (MS4s) and construction sites over one acre.

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 that clear more than five acres of land.

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, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Primary contact recreation: Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

Reach: A specific portion or segment of a stream.

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.

Surrogate measures: To provide more meaningful and measurable pollutant loading targets, EPA regulations [40 CFR 130.2(i)] allow other appropriate measures, or surrogate measures in a TMDL. The Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program (EPA, 1998) includes the following guidance on the use of surrogate measures for TMDL development:

> *When the impairment is tied to a pollutant for which a numeric criterion is not possible, or where the impairment is identified but cannot be attributed to a single traditional "pollutant," the state should try to identify another (surrogate) environmental indicator that can be used to develop a quantified TMDL, using numeric analytical techniques where they are available, and best professional judgment (BPJ) where they are not.*

Total maximum daily load (TMDL): A distribution of a substance in a water body designed to protect it from exceeding 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.

Total suspended solids (TSS): The suspended particulate matter in a water sample as retained by a filter.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocations constitute one type of water quality-based effluent limitation.

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.

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

Acronyms and Abbreviations

BMP	Best management practice
DID	Drainage Improvement District
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FC	Fecal coliform
GIS	Geographic Information System software
KES	*Klebsiella*, Enterobacter, and *Serratia*
NF	North fork
NPDES	National Pollutant Discharge Elimination System
POTW	Publicly owned treatment works
RM	River mile
RSD	Relative standard deviation
SF	South fork
TMDL	Total maximum daily load (water cleanup plan)
TSS	Total suspended solids
USFS	United States Forest Service
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu/100 mL	colony forming units per 100 milliliters
ft	feet
mg/L	milligrams per liter (parts per million)
mL	milliliters
s.u.	standard units
uS/cm	microsiemens per centimeter, a unit of conductivity