North Pacific Coast Beaches Fecal Coliform Bacteria Source Investigation Study

Data Summary

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Cover photo: Connor Creek at Benner Road. Photo taken by Paul D. Anderson.

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Data Summary

by

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Water Resource Inventory Area (WRIA) and 8-digit Hydrologic Unit Code (HUC) numbers for the study area:

WRIAs
- 21 – Queets/Quinault
- 22 – Lower Chehalis

HUC numbers
- 17100102 – Queets-Quinault
- 17100105 – Grays Harbor

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Abstract

The Washington State Department of Health (DOH) classifies recreational and commercial shellfish growing areas around the state for the protection of public health. In 2011, DOH downgraded classifications of shellfish growing areas along the Pacific Coast due to fecal coliform bacteria (FC) contamination. To help increase protection and restore classifications of shellfish growing areas, Grays Harbor County created a Shellfish Protection District.

In July 2013, an additional shellfish growing area was downgraded to *Prohibited* for harvest. Concern over the lack of identification of sources prompted the Washington State Department of Ecology (Ecology) to conduct a FC source identification study from April 2014 to April 2015. The study sampled 32 locations between the mouth of the Moclips River and the city of Ocean Shores.

No specific sources of bacterial contamination were found. Highest FC concentrations in freshwater were found in the dry season. Marine water sampling locations had the highest FC concentrations during the wet season. *Klebsiella* data indicate that, on an annual basis, most FC at the sampling locations are from warm-blooded animals. Discrete optical brightener measurement data did not show a conclusive link to a greywater-linked source for human-based FC. More study is needed with continuous data to determine the true concentration of optical brightener in the watershed.

Twelve new locations were found to exceed (not meet) Washington State water quality criteria for FC and are recommended for placement on the 303(d) list of impaired waterbodies. One marine location is recommended for a change in listing designation from category 5 (*Impaired*) to category 1 (*Meets Measured Criteria*).

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Introduction

Background

In July 2013, Washington State Department of Health (DOH) reclassified the public shellfish digging beach (Station 9) near Oyehut/Illahee from *Approved* (open all year for shellfish harvesting) to *Prohibited* (closed to shellfish harvesting) because of high fecal coliform bacteria (FC) concentrations. The source of the FC contamination was unknown. Other areas of concern include beaches near the mouths of the Moclips River (21-NOB-01) and Joe Creek (21-NOB-04), which were downgraded to *Conditionally Approved* (closed to shellfish harvesting in the summer) by DOH in 2011.

Several study-area waterbodies are also included on Ecology's 303(d) list of impaired waters for FC contamination, including three marine grid cells (Table 1); two near the mouth of the Moclips River (47124C2D2 and 47124C2E1) and one near the mouth of Joe Creek (47124B2I0).

Table 1. Category 5 listings for FC located in the north coast study area.

Waterbody Name	WRIA	Waterbody ID	Marine Grid Cell	2012 Assessment ID	Latitude/ Longitude
Pacific Ocean	21	1239693482477	47124C2D2	15926	47.235 -124.225
Pacific Ocean	21	1239693482477	47124C2E1	15927	47.245 -124.215
Pacific Ocean	21	1239693482477	47124B2I0	15931	47.185 -124.205

WRIA: Water Resource Inventory Area

Historical Data

A detailed review of historical data from other studies and jurisdictions is presented in the Quality Assurance (QA) Project Plan (Swanson and Anderson, 2014).

North Beach Shellfish Protection District

In August 2011, DOH notified Grays Harbor County (GHC) that the classification for portions of the Pacific Coast shellfish growing area were downgraded from *Approved* (open all year for harvesting) to *Conditionally Approved* (closed during the summer months). In response to this classification downgrade, GHC created a Shellfish Protection District per RCW 90.72.045. Among other things, a Shellfish Protection District gives the GHC:

- Authority to establish and fund programs to protect and restore water quality in shellfish growing areas.

- Ability to address local water quality needs, including stormwater runoff, onsite septic systems, farm animal wastes, boater wastes, water quality monitoring, and public education.

Much of this work and other activities are funded by an Ecology grant (G1400465). In addition to the activities listed above, the grant from Ecology requires on-site septic system (OSS) surveys as well as public education and outreach efforts.

Goals and Objectives

Goals

The goal of this study was to locate and identify sources of bacterial contamination in the North Pacific Ocean Beaches from the city of Ocean Shores north to the town of Moclips. This information will help inform strategies for the implementation of best management practices (BMP) to protect and improve shellfish harvesting and recreational opportunities. In addition, study data will help GHC refine the Shellfish Protection District response efforts.

Objectives

Objectives of the study were to:

- Maintain a fixed network of sampling sites for data comparison purposes, while also allowing for sampling flexibility when further investigation was necessary.
- Sample the four DOH marine water stations in *Prohibited* and *Conditionally Approved* areas at the same time freshwater sites are sampled.
- Sample under all seasonal and hydrological conditions, including during storm events.
- Identify sources of FC contamination by allocating more sampling resources to areas thought to contribute to nearshore FC contamination and shellfish growing area classification downgrades.
- Locate possible sources of human-derived FC through the strategic use of optical brightener sensors.
- Collect high quality data to support the development of an implementation strategy for BMPs that reduce bacteria pollution.

Study Area

The study area consisted of approximately 22 miles of continuous open ocean beach shoreline extending north from the mouth of Grays Harbor to the mouth of the Moclips River. The area north of the Moclips River to Point Grenville, is owned by the Quinault Indian Nation and was not studied due to historically low FC concentrations and low human population in the area.

Significant drainages include Copalis River, Moclips River, Joe Creek, Connor Creek, Boone Creek, and Elk Creek (Figure 1). Many smaller drainages flow across the beaches as well. Ecology sampled many of the smaller freshwater drainages to track sources of FC affecting beaches and nearshore ocean waters.

The study area lies within two Water Resource Inventory Areas (WRIAs): 21 (Queets) and 22 (Lower Chehalis). The focus of this study is geared towards finding sources of FC along the Pacific Ocean nearshore zone and from freshwater rivers and streams. As such, Ecology focused its sampling efforts near the mouths of streams and drainages. Figure 1 shows fixed stations Ecology sampled throughout the study period. Over the course of the study several other sites were investigated to aid in source identification. In addition, a number of sites were sampled to determine the upstream extent of human influence.

The following paragraphs describe the study area in greater detail and were taken from DOH's Shoreline Survey of the Pacific Coast (DOH, 2005):

The study area is characterized by sand beaches that are exposed to an open ocean surf line. The beaches are shallow and a large intertidal area is exposed at low tide. Freshwater streams from minor drainages and larger watersheds run across the surface of the beach and into the surf zone at numerous locations along the length of the area (Figure 1).

Land use in the area is a mix of urban, rural residential, recreational, and forest land. Seven beachfront communities are located along the length of the North Pacific Coast shellfish area. These communities, from north to south are: Moclips, Sunset Beach, Pacific Beach, Copalis Beach, Ocean City, Oyehut, and Ocean Shores. Three ocean beach state parks−Pacific Beach State Park, Griffiths-Priday State Park, and Ocean City State Park−are located within the boundaries of the shellfish area.

Sewage treatment and disposal in the area is accomplished with on-site systems and three community wastewater treatment plants (WWTPs). A WWTP that serves the Qui-nai-elt Village development, located on the Quinault Reservation, discharges treated effluent to the Moclips River. A WWTP closure zone (for harvesting shellfish) extends 300 yards north and 300 yards south of the mouth of the Moclips River. A WWTP that serves the towns of Moclips and Pacific Beach discharges its treated effluent to Joe Creek at Ocean Beach Road. A WWTP closure zone extends 100 yards north and 100 yards south of the mouth of Joe Creek. A third WWTP serving the town of Ocean Shores discharges treated effluent outside of the Pacific Coast shellfish area near the mouth of Grays Harbor. The residences and businesses that are not connected to one of these three WWTPs use on-site systems for the treatment and disposal of sewage.

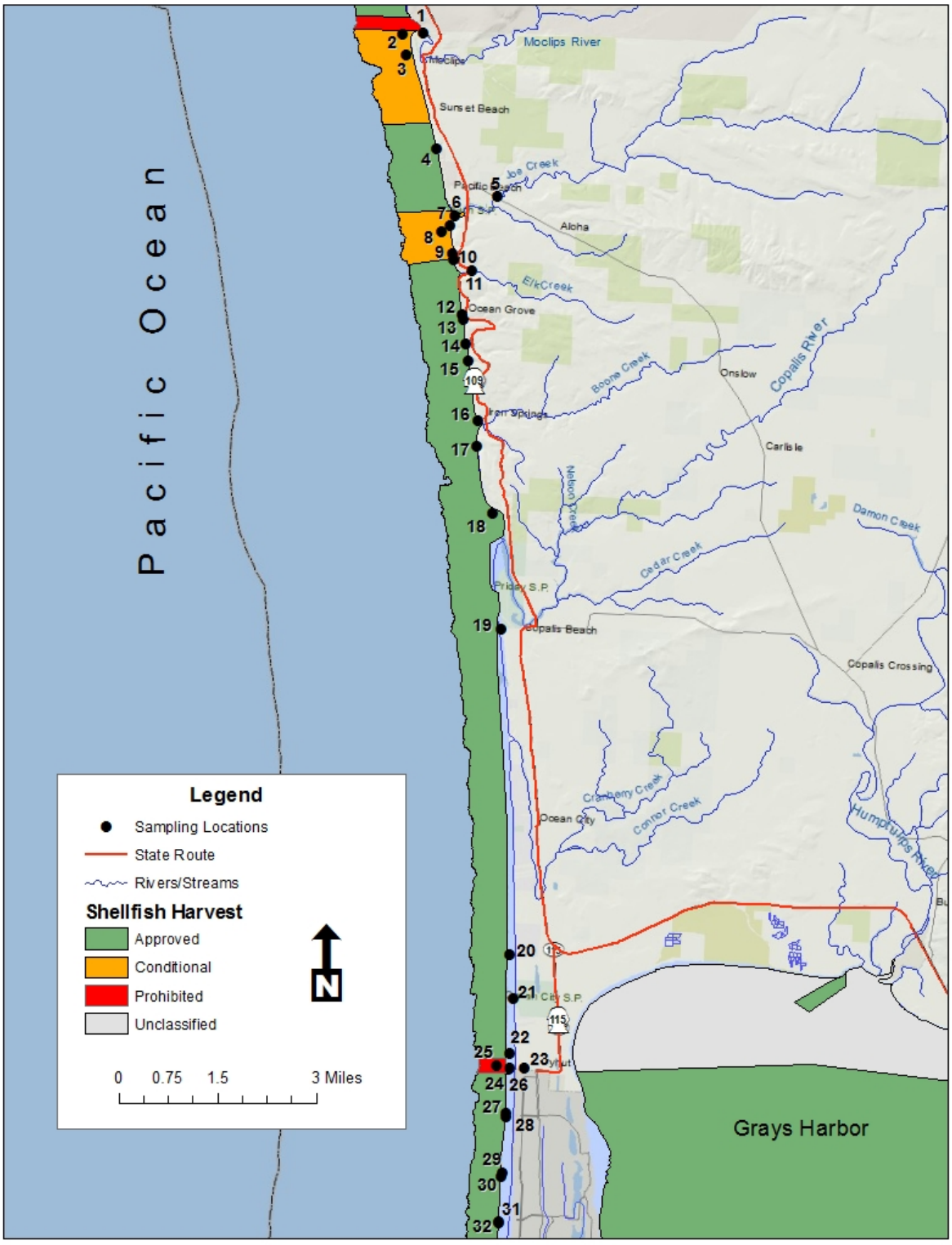

Figure 1. North coast study area with sampling sites and 2015 Washington Department of Health (DOH) shellfish classifications.

Numbers reference sampling locations in Table 2.

The Pacific Coast shellfish area supports a large population of Pacific Razor Clams that are harvested commercially and recreationally. The Quinault Indian Nation also has treaty rights to harvest razor clams in this area. The beaches from the mouth of Grays Harbor north to the mouth of the Moclips River are open periodically to public recreational harvest. Commercial harvest occurs along the entire length of the area.

Horseback riding is a popular activity on beaches throughout the shellfish area. Several horse rental businesses operate in the area on a seasonal basis. Other beach activities include wading, swimming, flying kites, biking, bird watching, and fishing.

The beach environment provides habitat for several species of waterfowl and shorebirds that are often present in large flocks around freshwater streams or feeding on the intertidal expanses that are exposed during low tides.

The Pacific Coast is subject to mixed tides, predominantly semi-diurnal, characterized by a large inequality in the high water heights, low water heights, or both. There are usually two high and two low tides each day but occasionally the tidal pattern will result in only one high or one low tide in a single day.

Tide heights for the north ocean beaches, using the Point Grenville reference point, range from an extreme high of 10.2 feet above the zero foot mark to an extreme low of -2.7 feet below the zero foot mark.

Annual Average Precipitation recorded at the Hoquiam Airport weather station for the period 1953 to 2005 is 69.68 inches.

Potential Sources of Contamination

Point Sources

Stormwater

Stormwater runoff from roads and other impervious surfaces has potential to impact surface water quality in the study area. Ecology sampled FC in ditches along beach access roads near Ocean Shores and Illahee/Oyehut during times of surface runoff (Table 2).

Urban areas that collect stormwater runoff in municipal separate storm sewers (MS4s) and discharge it to surface waters are required to have a permit under the federal Clean Water Act. U.S. Environmental Protection Agency (EPA) stormwater regulations established two phases – Phase I and Phase II – for the municipal stormwater permit program.

Ecology develops and issues National Pollutant Discharge Elimination System (NPDES) municipal stormwater permits in Washington. No municipalities within the study area meet the population size thresholds set for permit coverage, therefore Ecology's municipal stormwater permit requirements do not apply. However, municipalities can do much to prevent stormwater from polluting waters of the State by following Ecology's 2012 Stormwater Management Manual for Western Washington. Municipalities should note that if Ecology determines an MS4

substantially contributes to the pollutant loading of waters of the State, municipal stormwater permit coverage may be triggered, notwithstanding population size.

The Washington State Department of Transportation maintains state roads and highways that have potential to impact waters in the study area, and they should follow guidelines in their Western Highway Runoff Manual for runoff entering rivers and streams where SR 109 and SR 115 drain storm runoff into them.

Wastewater Treatment Plants

NPDES permitted facility information was taken from the Ecology Permit and Reporting Information System database and EPA's website. There are currently three WWTPs operating in the study area. Two of the WWTPs are operated by local jurisdictions and are permitted by Ecology. The third, Moclips River Estates WWTP, is operated by the Quinault Indian Nation and is permitted by EPA.

One of the Ecology-permitted facilities is operated by the City of Ocean Shores under NPDES permit number WA0023817. The Ocean Shores sewer system consists of a combination of gravity and vacuum sewer collection lines with pump stations. Wastewater is delivered to the WWTP, which uses secondary treatment with ultraviolet (UV) disinfection. Effluent from the WWTP discharges to the entrance of Grays Harbor Estuary near the seaward edge of the North Jetty. Although this WWTP is within the study area, it does not discharge to any waters that are in direct contact with harvest areas.

The second Ecology-permitted facility is operated by the City of Pacific Beach under NPDES permit number WA0037095. Pacific Beach's sewer system consists of force mains connected to four pump stations that carry wastewater from the town of Pacific Beach, Pacific Beach State Park, and parts of the town of Moclips. Wastewater is delivered to the WWTP, which uses secondary treatment with UV disinfection. Treated and disinfected effluent from the WWTP discharges directly to Joe Creek (at about river mile 1.0) downstream of the Ocean Beach Road bridge. Joe Creek flows to the Pacific Ocean. The area at the mouth of Joe Creek is *Conditionally Approved* for shellfish harvesting due to degraded seasonal water quality conditions.

The third WWTP (Moclips River Estates) is operated by the Quinault Indian Nation and is permitted by EPA under NPDES permit number WA0026603. Domestic sewage from the Qui-nai-elt Village is collected by a gravity system. At the time of permit application in 2009, a total of 15 homes were being serviced with an additional 32 homes to be serviced in the future. Wastewater is delivered to the WWTP, which uses secondary treatment with UV disinfection. Effluent is discharged to the Moclips River, (approximately river mile 2.7) within the Quinault Indian Nation Reservation boundary. The Moclips River flows into the Pacific Ocean at the town of Moclips.

Nonpoint Sources

Nonpoint pollution sources are dispersed across the landscape, typically from land use activities near surface waterbodies, and not controlled through NPDES permits. Potential nonpoint sources within the Pacific Coast shellfish area include:

- Residential properties adjacent to the creeks and beaches
- Pet waste (including horses)
- Human waste
- Failing OSSs
- Excessive wildlife waste
- Recreation

Nonpoint pollution sources are important to understand because they affect stream and beach water quality and are a major component of stormwater runoff. Some of the different categories of nonpoint sources will be discussed in more detail in the following sections.

Septic Systems

The Grays Harbor County Environmental Health Division (GHCEHD) is the regulating authority for OSSs for properties that are not connected to municipal sewage treatment systems. Over time, the cities of Ocean Shores and Pacific Beach have expanded their service area and connected properties with failing septic systems to the municipal wastewater collection and treatment facilities that they operate. However, there are still many aging residential septic systems in unincorporated areas along the coast.

Of particular note is the area immediately north of Damon Road in Ocean Shores, known as Illahee and Oyehut. Many of these properties were developed prior to any regulatory oversight of septic design and installation. As a result, most of the septic systems in the area are not functioning properly, due to a high water table that inundates septic drain fields and, at times, septic tanks (GHCEHD, 2011). These failing or non-functioning septic systems likely have potential to impact the Pacific Coast shellfish area in the vicinity of Ocean Shores.

Through an Ecology grant, GHCEHD has been surveying septic system throughout the North Beach area as part of an effort to begin to identify failing systems that could be contributing FC to surface waters draining to shellfish harvest areas. Working with landowners to take corrective actions is the responsibility of the GHCEHD. Financial assistance opportunities may be available through the Craft3 program which has recently been expanded to the Grays Harbor County area. Craft3 is a nonprofit community development financial institution with a mission to strengthen economic, ecological and family resilience in Pacific Northwest communities.

Wildlife

There is a variety of wildlife within the Pacific Coast shellfish area. Warm-blooded mammals and birds present a potential source of FC. On and around the ocean beaches, birds are especially likely to be a potential source of FC because of the area's plentiful feeding and roosting grounds.

Usually, these sources are dispersed and do not elevate FC levels enough to violate state criteria. However, animal populations can occasionally become concentrated and impair water quality. Any areas with concentrated wildlife were noted during sampling surveys.

Recreation and Pet Waste

Recreational activities in the watershed are extensive and include clamming, fishing, beach combing, birding, flying kites, horseback riding, walking dogs, and many other activities associated with the ocean beach. Most relevant to this study is razor clam digging, associated with the Pacific Coast shellfish area.

Every year thousands of people recreate on the ocean beaches. Unfortunately, this can also result in the inappropriate disposal of human waste and pet waste (including horses). Dog and horse waste can accumulate on the beaches, especially during the summer months, and contribute bacteria to nearshore zones. Any inappropriate disposal of human waste, pet, and horse waste was noted during sampling surveys.

Methods

Overview

The study objectives were met through characterizing annual and seasonal FC concentrations. FC concentrations were monitored at multiple locations in major streams and outflows and at other key locations within the study area from April 2014 through April 2015.

The freshwater component of the study included (1) a fixed network of sites sampled twice monthly throughout the sampling period, and (2) investigation sampling when high FC concentrations were found. Investigation sampling used a targeted or bracketed sampling approach. This method of sampling was used to help find sources of FC in areas with higher FC contamination.

Where appropriate, Ecology used optical brightener sensors to help detect or confirm the presence of human-derived FC pollution. Optical brighteners are commonly used in laundry detergents, and their presence or absence is an indication of human wastewater sources of FC.

Ecology attempted to conduct several storm event surveys during times of heavy rainfall. These surveys are useful in further characterizing seasonal and rain event FC contributions to the beaches.

Sampling Sites

Fixed Network

Data from the fixed network provide an estimate of the annual and seasonal geometric mean and estimated 90th percentile statistics for FC. The sampling schedule was designed to provide at least 24 samples per fixed site to develop the annual statistics, including 8 samples per site during the dry season (June – September) and 16 samples per site during the wet season (October – May). Due to unusually dry spring and summer conditions, many of the smaller fixed network sampling sites did not have any flowing water to sample for a large portion of the study period.

The locations of the fixed network sites are listed in Table 2 and shown in Figure 1. Sites were selected based on historical site locations and data collection, areas where high FC was a concern, and ease of access.

Ecology did not directly sample the WWTPs on the Moclips River and Joe Creek.

Table 2. Fixed network sampling sites.

Site Name[1]	Map #	Latitude	Longitude	Description	Parameters
21-NOB-01[2]	1	47.24453	-124.21553	Moclips River near mouth, tidal influence	FCMF, FCMPN, ECMPN, % Klebsiella
22-DOH-195	2	47.24341	-124.22108	Department of Health marine sampling station 195	FCMPN
22-DOH-11	3	47.23891	-124.21966	Department of Health marine sampling station 11	FCMPN
21-NOB-02	4	47.21886	-124.20842	Mouth of creek at Analyde Gap Road	FCMF
21-NOB-03	5	47.20879	-124.18808	Joe Creek above Pacific Beach Sewage Treatment Plant	FCMF
21-NOB-04	6	47.20432	-124.20139	Joe Creek at Pacific Beach State Park	FCMF, % Klebsiella
21-NOB-05	7	47.20207	-124.20270	Creek that crosses Diamond Drive	FCMF
22-DOH-197	8	47.20059	-124.20546	Department of Health marine sampling station 197	FCMPN
21-NOB-06	9	47.19593	-124.20172	Below confluence of 2 creeks that drain North Seabrook	FCMF
21-NOB-07	10	47.19444	-124.20121	Creek that drains from South Seabrook at staircase	FCMF
21-NOB-08	11	47.19225	-124.19524	Elk Creek on the downstream side of Hwy 109	FCMF, % Klebsiella
21-NOB-09	12	47.18262	-124.19744	Creek on the North side of Hwy 109 curve	FCMF
21-NOB-10	13	47.18152	-124.19718	Creek on the South side of Hwy 109 curve	FCMF
21-NOB-11	14	47.17625	-124.19602	Creek approx. 60 meters North of Roosevelt Beach Road	FCMF
21-NOB-12	15	47.17237	-124.19497	Creek approx. 360 meters South of Roosevelt Beach Road	FCMF
21-NOB-13	16	47.15948	-124.19107	Boone Creek at Iron Springs Resort below bluff	FCMF
21-NOB-14	17	47.15378	-124.19072	Creek that drains neigborhood South of Boone Creek	FCMF
21-NOB-15	18	47.11665	-124.16958	Copalis River at Hwy 109 bridge	FCMF, % Kelbsiella
21-NOB-16	19	47.11407	-124.18045	Connor Creek at Benner Road	FCMF, % Klebsiella
21-NOB-17	20	47.04255	-124.17285	Creek at Quinault Casino	FCMF
21-NOB-18	21	47.03287	-124.17074	Mouth of creek at Ocean City State Park	FCMF
21-NOB-19	22	47.02089	-124.17135	Wet area between Illahee/Oyehut and the beach	FCMF, % Klebsiella
21-NOB-20	23	47.01793	-124.16628	Ditch on Chickamin Ave South of RV park septic tank	FCMF
22-NOB-21	24	47.01751	-124.17155	North ditch on Damon Road	FCMF
22-DOH-9	25	47.01809	-124.17552	Department of Health marine sampling station 9	FCMPN
22-NOB-22	26	47.01739	-124.17157	South ditch on Damon Road	FCMF
22-NOB-23	27	47.00777	-124.17154	North ditch on W Chance A La Mer NW	FCMF
22-NOB-24	28	47.00706	-124.17154	South ditch on W Chance A La Mer NW	FCMF
22-NOB-25	29	46.99466	-124.17192	North ditch on Pacific Blvd NW	FCMF
22-NOB-26	30	46.99386	-124.17193	South ditch on Pacific Blvd NW	FCMF
22-NOB-27	31	46.98393	-124.17220	North ditch on Ocean Lake Way SW	FCMF
22-NOB-28	32	46.98348	-124.17221	South ditch on Ocean Lake Way SW	FCMF

[1] Sites are listed from north (top) to south (bottom)
[2] This site just upstream of DOH station 12

Bacteria Sampling

For FC sampling and analysis Ecology typically uses the membrane filter (MF) method because of its practicality and precision. However, in turbid and saline waters, samples are typically analyzed using the most probable number (MPN) method. The MPN method is used because it has better enumeration than the MF method for organisms that are injured or stressed. All samples collected from marine locations and the mouth of the Moclips River were analyzed using the MPN method.

In addition, *Escherichia coli* (*E. coli*) and percent *Klebsiella* were collected from selected sites during the study 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 (Udeh, 2004). A higher

percentage of *Klebsiella* would indicate bacteria from wood waste (Geldreich, 1996). *E. coli* was sampled weekly at the mouth of the Moclips River and percent *Klebsiella* was sampled once per month at six sites (Table 2). Future decisions about the types of best management practices (BMPs) and specific source identification procedures could be influenced by this information.

Investigation, Source Tracking, and Optical Brightener Surveys

Due to the lack of water in many of the targeted creeks during the study period, there were few opportunities to investigate high FC concentrations. Any investigative effort was also hindered by slow returns of laboratory data. With no current laboratory data to work with, making a decision to investigate a site was difficult.

Targeted and Bracketed Sampling

Regular sampling rarely confirmed consistently high FC concentrations at a site. Any high FC concentrations found at a site were usually a single occurrence or occurred at irregular intervals. Some targeted sampling was conducted on creeks with more than one high FC concentrations. Targeted sampling involves multiple sampling over ever-decreasing distances to identify sources of FC pollution. Unfortunately, due to unusually dry conditions and slow laboratory returns not enough samples were collected to be of use and those data are not presented in this report.

A similar approach to targeted sampling is bracketed sampling. Bracketed sampling is simply targeting an area thought to have high FC concentrations by sampling upstream and downstream of the area in ever-decreasing distances until the source of the FC is found or further bracketing is deemed unnecessary. No area was found to need bracketed sampling.

Optical Brightener Sampling

Where appropriate, Ecology used fluorometry as an inexpensive and practical bacterial source tracking (BST) method to identify human sources of fecal contamination associated with greywater. Fluorometry is a chemical BST method which identifies human fecal contamination by detecting optical brighteners, also known as fluorescent whitening agents. Optical brighteners are added to most laundry detergents and represent about 0.15% of the total detergent weight (Hartel et al., 2008). Because household plumbing systems typically mix effluent from washing machines and toilets together, optical brighteners are associated with human sewage in septic systems and WWTPs (Hartel et al., 2008).

Ecology used a Turner Designs Cyclops 7 optical brightener sensor to take discrete measurements for concentrations of optical brighteners. While positive concentrations were measured, it was unclear whether the two potential interferences were the cause. Optical brightener data collected during the study are presented in Table 13. In addition to discrete samples, the plan was for the optical brightener sensors to be deployed in a continuous data collection system. Unfortunately, no suitable location was identified to deploy the two continuous optical brightener loggers so that loss from theft or environmental conditions was minimized.

There are two potential interferences with optical brightener detection that are related to its light emission wavelength. Optical brighteners emit light in overlapping wavelengths with organic matter and heavier weight oils. If one or all of these compounds were in the water it would be impossible to tell the difference between them without chemical analysis. To minimize the potential for interference Turner Designs optical brightener sensors use a narrow emission spectrum of 445 ± 7.5 nm. This allows for more confidence that only optical brighteners are detected and not organic matter or oil (crude). While the optical brightener sensor has been designed to minimize potential interferences at high enough concentrations, organic matter and heavier oils could cause readings that are false positives, especially in areas that drain wetlands and that receive road runoff during storm events.

It should also be noted that optical brighteners degrade quickly (minutes to hours) in UV light (Hartel et al., 2007), although some studies conflict on their photo-decay rates (Tavares et al., 2008). Confirmation of optical brighteners in waters likely means that a source of optical brighteners is nearby. The Cyclops 7 optical brightener sensor instantaneously detects optical brighteners in the field, so UV degradation during sample collection and transport will not be an issue.

Optical brighteners can persist in sediment (Hartel et al., 2007), so Ecology may find that optical brightener concentrations increase during storm events from sediment re-suspension. Storms may inundate any OSS installed below the high water mark. This could cause optical brighteners to move more quickly from malfunctioning OSS to waterways. Also, storms can carry optical brighteners more quickly downstream without as much time for UV attenuation, and more turbid waters may also decrease UV degradation.

These factors may complicate analyses, but Ecology planned multiple sampling events during wet and dry seasons to allow for a clear and complete analysis of the data. Unfortunately, unusually dry weather conditions only allowed for one storm event. During the one storm that was sampled, conditions were not safe enough to spend the time at each site needed to collect optical brightener concentrations. The lack of data did not allow for a complete analysis of optical brightener contamination during storm events.

To ensure proper optical brightener sampling techniques are followed, Ecology has recently developed a standard operating procedure (SOP) for optical brightener sampling (Anderson and Swanson, 2014).

Storm Monitoring

The purpose of storm monitoring is to better characterize potential sources of FC to the study area. Historical data from other studies in Washington show that higher FC concentrations and loading can occur during rain events. A storm event was defined as a minimum of 0.2 inches of rainfall in a 24-hour period preceded by no more than trace rainfall in the previous 24-hour period. This amount of rain should be sufficient to cause runoff from impervious surface areas and raise creek levels (based on previous sampling in similar watersheds) (Swanson and Anderson, 2014). Due to the dry weather conditions seen during the study period only one wet-season and no dry-season storm events were captured. These results are presented in Table 10.

Field Procedures and Laboratory Analyses

Field

A full description of field procedures and laboratory analysis is included in the QA Project Plan (Swanson and Anderson, 2014).

Grab samples for bacteria (freshwater and marine water) were collected directly into pre-cleaned containers following Ecology standard operating procedures (SOPs) EAP015 (Joy, 2013) and EAP030 (Ward and Mathieu, 2014).

Laboratory

Ecology's Manchester Environmental Laboratory (MEL) analyzed all of the bacteria samples. Several different methods were utilized for this study depending on the source of the water, and the sampling objective. These methods are presented in Table 3.

Table 3. Summary of laboratory bacteria methods.

Parameter	Sample Matrix	Method
Fecal coliform – membrane filter (MF)	Fresh surface water	SM 9222D
Fecal coliform – most probable number (MPN)	Marine or fresh surface water	SM 9221E2
E. coli – most probable number (MPN)	Fresh surface water	EPA 1104
% *Klebsiella*	Fresh surface water	MEL SOP

EPA: U.S. Environmental Protection Agency
MEL: Manchester Environmental Laboratory
SM: Standard Method
SOP: Standard Operating Procedure

Data Quality

Performance of laboratory analyses is governed by quality assurance/quality control (QA/QC) protocols. The QA/QC protocols employ application of blanks and laboratory duplicates as well as tracking of holding times. Field replicates integrated field and laboratory components of QA/QC. A summary of laboratory and field data quality are presented below. A detailed discussion of data quality is presented in Appendix A.

Over the study period a number of samples were analyzed outside of the 24-hour holding time. Any samples analyzed outside of the holding time were qualified as estimates by the laboratory. All laboratory duplicates, except one, met laboratory measurement quality objectives (MQOs) of 40% relative percent difference (RPD). The associated sample was qualified as an estimate.

Several bacteria analysis methods were employed during this study. The FC by MF method results met all study MQO criteria. The majority of FC by MPN method results met study MQO criteria. Those samples that did not meet the study MQOs were qualified as estimates. Several

E. coli by MPN method results were outside study MQOs. Several samples were rejected and some others were qualified as estimates. The majority of percent *Klebsiella* sample results met study MQOs. Those samples that did not meet the MQOs were qualified as estimates.

Water Quality Standards

The Washington State Water Quality Standards, set forth in Chapter 173-201A of the Washington Administrative Code (WAC), include designated uses and numeric and narrative water quality criteria for surface waters of the state.

Freshwater and marine waterbodies are required to meet water quality standards based on the designated uses of the waterbody. Numeric criteria for specific water quality parameters are intended to protect designated uses. Pacific Ocean coastal waters and all tributaries to the Pacific Ocean in the study area are designated as *Extraordinary Primary Contact Recreation* waters to protect shellfish harvest. All other waters in the study area are designated as *Primary Contact Recreation*.

Fecal Coliform Bacteria

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

Bacteria targets in the water quality standards are set to protect people who work and play in the water from waterborne illnesses, shellfish harvest, and to protect tributaries flowing to shellfish harvesting areas. In Washington State, surface water quality standards use FC as an "indicator bacteria" for the state's freshwaters (e.g., lakes and streams). FC in water indicate the presence of waste from humans and other warm-blooded animals, which is more likely to contain pathogens that will cause illness. Ecology's selection of FC as the indicator for pathogens in surface waters is explained in Setting Standards for the Bacteriological Quality of Washington's Surface Water Draft Discussion Paper and Literature Summary (Hicks, 2002).

Freshwater Criteria

The designated use of *Extraordinary Primary Contact Recreation* is intended for waters capable of "providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas." (WAC 173-201A-200). This designated use applies to all freshwater sampling locations except one (21-NOB-20). To protect this use, "Fecal coliform organism levels must not exceed a geometric mean value of 50 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 100 colonies/100 mL." [WAC 173-201A-200] (Table 3). The upper limit criterion (i.e., the level that not more than 10 percent of the samples shall exceed) has been interpreted in this study as the estimated 90th percentile of sample values.

Any other waters that do not fit in the *Extraordinary Primary Contact Recreation* use designation fall under the *Primary Contact Recreation* use designation. Only one of the sampling locations for this study fall under the use designation (21-NON-20). The criteria is less

stringent and to meet this standard, "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] (Table 4).

Table 4. Freshwater FC criteria for the north coast study area.

Freshwater Criteria	Geometric Mean	Not more than 10% (90th Percentile)
Freshwater tributaries to Pacific Ocean	50 cfu/100 mL	100 cfu/100 mL
Other waters	100 cfu/100 mL	200 cfu/100 mL

cfu: colony forming units

Marine Water Criteria

In marine waters, water quality standards for bacteria are set to protect shellfish consumption and people who work and play in and on the water. Marine water criteria apply when the salinity is ten parts per thousand (approximately 17,700 umhos/cm) or greater. Ecology uses two separate bacterial indicators in the state's marine waters:

- In waters protected for both *Primary Contact Recreation* and *Shellfish Harvesting*, the state uses FC as indicator bacteria to gauge the risk of waterborne diseases.

To protect either *Shellfish Harvesting* or *Primary Contact Recreation* in the study area: "Fecal coliform organism levels must not exceed a geometric mean value of 14 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 43 colonies/100 mL." [WAC 173-201A-210] (Table 5). The upper limit criterion (i.e., the level that not more than 10 percent of the samples shall exceed) has been interpreted in this study as the estimated 90th percentile of sample values.

Table 5. Marine water FC criteria for the study area.

Marine Criteria	Geometric Mean	Not more than 10% (90th Percentile)
North Ocean Beaches – Pacific Ocean (Shellfish Harvesting & Primary Contact Recreation)	14 cfu/100 mL	43 cfu/100 mL

Cfu: colony forming units

The criteria levels set to protect *Shellfish Harvesting* and *Primary Contact Recreation* on Pacific Ocean beaches are consistent with federal shellfish sanitation rules. FC concentrations in Washington's marine waters that meet shellfish protection requirements are also protective of primary contact recreation standards. Thus, Ecology uses the same criteria to protect both *Shellfish Harvesting* and *Primary Contact Recreation* uses in the state standards.

Compliance with Criteria

Results of water samples collected randomly from one site and analyzed for bacteria typically follow a lognormal distribution, which is why the geometric mean is used for central tendency of the data set. The geometric mean is a mathematical expression of central tendency (average) of multiple sample values in a group of lognormal sample values. This average dampens the effect of extreme values that could bias an arithmetic average.

Compliance with bacteria water quality standards is based on meeting both the geometric mean criterion and the "10 percent of samples" criterion. If ten or fewer total samples exist, then no single sample may exceed the estimated 90^{th} percentile. These two measures used in combination ensure that bacterial pollution in a waterbody will be maintained at a set level of risk to human health. While some discretion exists for selecting sample averaging periods, compliance will be evaluated for both annual (if five or more samples exist) and seasonal data sets.

If FC concentrations in the water exceed the numeric criteria, human activities that would increase concentrations above the criteria need to be managed in order to allow waters to meet standards. The state, in collaboration with local governments, tribes, and watershed stakeholders, will work to ensure that human activities are conducted in a manner that will bring FC concentrations back into compliance with water quality standards.

If natural levels of FC (from wildlife, for example) cause criteria to be exceeded, no allowance exists for human sources to measurably increase bacterial pollution beyond natural levels. Though the presence of bacterial contamination from wildlife is typical in most environments, there still may be a risk of human illness. For example, EPA recently published summary reports on the risk of human illnesses associated with the presence of waterborne pathogens from animals and birds (EPA, 2009, and EPA, 2011).

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Results and Discussion

Sampling locations are described in Table 2 and shown in Figure 1. An assessment of the FC data against water quality criteria is described in the subsequent sections and the results are highlighted in Tables 6 - 8 and Figures 2 - 6. As a comparison, data from DOH and the Quinault Indian Nation (QIN) are presented below. An explanation and summary of data for optical brighteners is included at the end of this section

Data for this project are available in Appendix B and at Ecology's (EIM) website at www.ecy.wa.gov/eim/index.htm. Search Study ID "TSWA0005".

Bacteria

Table 6 shows summary statistics as well as the geometric mean and estimated 90th percentile for data collected at each of the regularly sampled locations. The October 22, 2014 storm event results were not included in the data used to calculate any of the statistics shown in Table 6. For the data set presented in Table 6, FC concentrations ranged from 1 to 22,000 cfu/100 mL. The highest geometric means and estimated 90th percentiles were seen in the southern portion of the study area (Figure 2). There were, however, three sampling locations in the northern part of the study area (21-NOB-01, 21-NOB-10, and 21-NOB-16) that had geometric means and estimated 90th percentiles that were similar to those in the southern portion of the study area.

The Moclips River geometric mean and estimated 90th percentile values were similar to the locations in the southern portion of the study area (Figure 2 and Table 6). *E. coli* data collected at the Moclips River (21-NOB-01) had a similar range as the FC data from the other sampling locations. Elevated FC concentrations measured at the Moclips River are of particular concern because of the WWTP outfall located approximately three miles upstream of the mouth of the Moclips River (refer to page 48 for further detail). While the concentration of FC are elevated at the mouth of the Moclips River, there is insufficient data from this study to make a determination about the impact of the WWTP.

The source of FC causing elevated concentrations at 21-NOB-10 and 21-NOB-16 (Connor Creek) are not readily identifiable. Field samplers noted that the majority of the area upstream of the sampling location on 21-NOB-10 was forested, which suggests wildlife inputs. However, a portion of this creek runs near and under Highway 109 which may convey FC to the creek in stormwater runoff. Connor Creek is a much larger system that originates in a large wetland. The creek flows south from the wetland for several miles and drains many residential properties. Sources could include pet waste, wildlife, and failing or malfunctioning on-site septic systems.

Table 6. Summary statistics for FC (cfu/100 mL) at regularly sampled locations in the north coast watershed during the 2014-2015 sampling period.

Storm event data were not included in the analysis.
Shaded cells indicate sites where water quality criteria for bacteria were not met.

Site Name	Map #	Site Location	n	Min	Max	Geometric Mean	Estimated 90th Percentile
Fecal Coliform - Membrane Filter (Freshwater Criteria)							
21-NOB-01[1]	1	Moclips River near mouth, tidal influence	26	9	335	52	201
21-NOB-02	4	Mouth of creek at Analyde Gap Road	26	1	150	12	73
21-NOB-03	5	Joe Creek above Pacific Beach WWTP	26	1	130	11	79
21-NOB-04	6	Joe Creek at Pacific Beach State Park	26	1	160	13	89
21-NOB-05	7	Creek that crosses Diamond Drive	16	1	84	6	60
21-NOB-06	9	Below confluence of two creeks that drain North Seabrook	26	1	180	9	88
21-NOB-07	10	Creek that drains from South Seabrook at staircase	9	1	120	4	54
21-NOB-08	11	Elk Creek near the mouth	26	1	80	9	43
21-NOB-09	12	Creek on the North side of Highway 109 curve	26	1	660	7	87
21-NOB-10	13	Creek on the South side of Highway 109 curve	26	1	620	7	139
21-NOB-11	14	Creek approx. 60 meters North of Roosevelt Beach Road	26	1	61	2	10
21-NOB-12	15	Creek approx. 360 meters South of Roosevelt Beach Road	26	1	140	6	46
21-NOB-13	16	Boone Creek at Iron Springs Resort below bluff	26	1	96	9	62
21-NOB-14	17	Creek that drains neighborhood South of Boone Creek	20	1	80	8	35
21-NOB-15	18	Copalis River near the mouth	25	1	200	14	104*
21-NOB-16	19	Connor Creek at Benner Road	26	4	1600	27	168
21-NOB-17	20	Creek at Quinault Casino	17	1	790	10	95
21-NOB-18	21	Mouth of creek at Ocean City State Park	21	1	1100	19	116*
21-NOB-19	22	Wet area between Illahee/Oyehut and the beach	15	1	1500	3	37
21-NOB-20[2]	23	Ditch on Chickamin Ave South of RV park septic tank	14	6	22000	81	1607
22-NOB-21	24	North ditch on Damon Road	11	10	230	53	203
22-NOB-22	26	South ditch on Damon Road	10	16	800	88	602
22-NOB-23	27	North ditch on W Chance A La Mer Northwest	10	6	1500	49	423
22-NOB-24	28	South ditch on W Chance A La Mer Northwest	7	1	1200	34	771
22-NOB-25	29	North ditch on Pacific Blvd Northwest	11	3	920	30	632
22-NOB-26	30	South ditch on Pacific Blvd Northwest	10	8	1000	67	637
22-NOB-27	31	North ditch on Ocean Lake Way Southwest	12	1	460	33	290
22-NOB-28	32	South ditch on Ocean Lake Way Southwest	11	35	890	112	452
Fecal Coliform - Most Probable Number (Marine Criteria)							
21-DOH-195	2	Department of Health marine sampling station 195	24	1.8	79	7	42
21-DOH-11	3	Department of Health marine sampling station 11	25	1.8	230	6	35
21-DOH-197	8	Department of Health marine sampling station 197	25	1.8	230	11	86
22-DOH-9	25	Department of Health marine sampling station 9	24	1.8	33	5	23
E. Coli - Most Probable Number							
21-NOB-01[3]	1	Moclips River near mouth, tidal influence	22	7	230	35	143

*Sites numerically exceed the criteria but do not have enough samples above (10%) the criteria for an exceedance.
[1]The membrane filter (MF) and most probable number (MPN) results are averaged for this site.
[2]Site assessed for compliance with the primary contact criteria.
[3]There are not state water quality criteria for *E. coli*.

All of the sampling locations in the southern portion of the study area have elevated FC concentrations. These sampling locations are ditches that run into the Pacific Ocean and drain the beach access roads and the wetlands that they intersect. It was noted by field samplers on many occasions that birds, other wildlife, dogs, and humans come into contact with these ditches. Sources in these locations likely are diverse and could include wildlife, humans, road runoff, and pet waste.

Figure 2 shows the geometric mean and estimated 90^{th} percentile values for the marine stations relative to all of the other sampled locations. Overall, the marine water sampling locations had similar FC concentrations. The exception to this was the sampling location 21-DOH-197 which had the highest estimated 90^{th} percentile value of the marine locations. It is unclear why 21-DOH-197 had a higher estimated 90^{th} percentile value than the other marine locations. Many factors could have caused this difference and may include proximity and dispersion direction of freshwater inputs, birds, marine animals, and beach runoff during rain events.

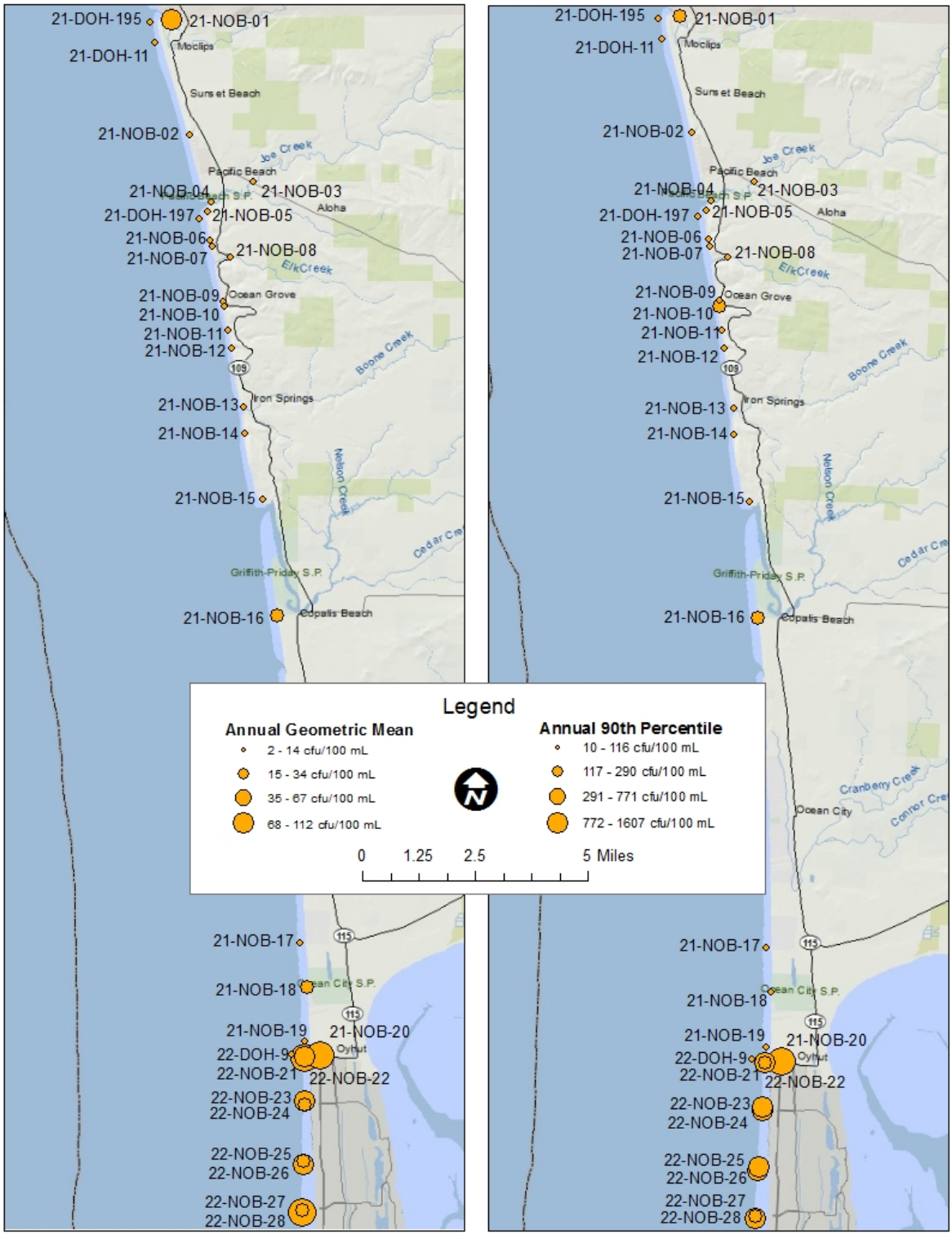

Figure 2. Annual geometric mean and estimated 90th percentile values for FC shown by location (cfu/100mL).

Location points are sized based on the value of the geometric mean or estimated 90th percentile. Larger dots equal larger values and smaller dots equal smaller values.

Compliance with Water Quality Criteria

Freshwater

Data in Table 6 under the FCMF (freshwater criteria) section were assessed for compliance with Washington State freshwater water quality criteria. Shaded boxes show those locations that exceeded freshwater water quality criteria for FC. All freshwater sampling locations, except one, were assessed against the *Extraordinary Primary Contact Recreation* criteria shown in Table 4. The exception (21-NOB-20) does not meet the definition for *Extraordinary Primary Contact Recreation* protection as described in the Water Quality Standards and Numeric Targets section above. Instead it was compared to the *Primary Contact Recreation* criteria described in Table 4. Moclips River (21-NOB-01) FCMF and FCMPN data were averaged for use in Table 6.

Twelve sampling locations exceeded one or both parts of the freshwater water quality criteria (Table 6). Two freshwater sampling locations numerically exceeded the estimated 90th percentile part of the criteria but less than 10% of the samples exceeded the 100 cfu/100 mL part of the criteria. All 12 sampling locations with shaded boxes (Table 6) will be recommended for placement in category 5 (impairment by a pollutant) of Washington State's 303(d) list of impaired waterbodies.

Marine

Four marine water sampling locations under the FCMPN (marine criteria) section of Table 6 were assessed against Washington State marine water quality criteria for *Shellfish Harvesting and Primary Contact Recreation* shown in Table 5. Data from Table 6 show that all marine sampling locations, except one, meet the marine water quality standards for *Shellfish Harvesting and Primary Contact Recreation* (Table 5). The exception was a marine sampling location (21-DOH-197) that is already on the 303(d) list for FC impairment.

In addition to the recommendations for the freshwater category 5 listings, one marine site (21-DOH-11) will be recommended for a category shift. The data from this study show that 21-DOH-11 meets water quality criteria on an annual, wet-season, and dry-season basis (Tables 6, 7, and 8). This marine sampling location is currently listed as a category 5 and will be recommended for a shift to category 1 (segment meets tested criteria).

Seasonality

To assess differences between seasons, data were divided into the dry season (June-September) and wet season (October-May). Summary statistics for the dry and wet season were calculated and are presented in Tables 7 and 8. Exceedances of the FC water quality criteria are shown by shaded boxes. To further assess differences, comparable data from annual, wet, and dry seasons were graphed with the associated water quality criteria. Figures 3 and 4 show freshwater data and Figures 5 and 6 show marine data.

Table 7. Dry-season summary statistics for FC (cfu/100 mL) at regularly sampled locations in the north coast watershed during the 2014-2015 sampling period.

Storm event data were not included in the analysis.
Shaded cells indicate sites where water quality criteria for bacteria were not met.

Site Name	Map #	Site Location	n	Min	Max	Geometric Mean	Estimated 90th Percentile
Fecal Coliform - Membrane Filter (Freshwater Criteria)							
21-NOB-01	1	Moclips River near mouth, tidal influence	9	16	335	72	252
21-NOB-02	4	Mouth of creek at Analyde Gap Road	9	1	45	8	33
21-NOB-03	5	Joe Creek above Pacific Beach WWTP	9	11	130	35	95
21-NOB-04	6	Joe Creek at Pacific Beach State Park	9	10	98	41	99
21-NOB-05	7	Creek that crosses Diamond Drive	2	1	1	NC	NC
21-NOB-06	9	Below confluence of two creeks that drain North Seabrook	9	4	120	33	129*
21-NOB-07	10	Creek that drains from South Seabrook at staircase	0			NC	NC
21-NOB-08	11	Elk Creek near the mouth	9	5	80	16	43
21-NOB-09	12	Creek on the North side of Highway 109 curve	9	1	660	28	377
21-NOB-10	13	Creek on the South side of Highway 109 curve	9	1	500	39	622
21-NOB-11	14	Creek approx. 60 meters North of Roosevelt Beach Road	9	1	29	3	11
21-NOB-12	15	Creek approx. 360 meters South of Roosevelt Beach Road	9	1	37	6	22
21-NOB-13	16	Boone Creek at Iron Springs Resort below bluff	9	1	96	22	146*
21-NOB-14	17	Creek that drains neighborhood South of Boone Creek	4	3	80	NC	NC
21-NOB-15	18	Copalis River near the mouth	8	14	200	38	122*
21-NOB-16	19	Connor Creek at Benner Road	9	4	300	48	241
21-NOB-17	20	Creek at Quinault Casino	1	1	1	NC	NC
21-NOB-18	21	Mouth of creek at Ocean City State Park	4	14	1100	NC	NC
21-NOB-19	22	Wet area between Illahee/Oyehut and the beach	0			NC	NC
21-NOB-20	23	Ditch on Chickamin Ave South of RV park septic tank	0			NC	NC
22-NOB-21	24	North ditch on Damon Road	0			NC	NC
22-NOB-22	26	South ditch on Damon Road	0			NC	NC
22-NOB-23	27	North ditch on W Chance A La Mer Northwest	0			NC	NC
22-NOB-24	28	South ditch on W Chance A La Mer Northwest	0			NC	NC
22-NOB-25	29	North ditch on Pacific Blvd Northwest	0			NC	NC
22-NOB-26	30	South ditch on Pacific Blvd Northwest	0			NC	NC
22-NOB-27	31	North ditch on Ocean Lake Way Southwest	0			NC	NC
22-NOB-28	32	South ditch on Ocean Lake Way Southwest	0			NC	NC
Fecal Coliform - Most Probable Number (Marine Criteria)							
21-DOH-195	2	Department of Health marine sampling station 195	9	1.8	46	5	30
21-DOH-11	3	Department of Health marine sampling station 11	9	1.8	23	4	16
21-DOH-197	8	Department of Health marine sampling station 197	9	1.8	79	10	86
22-DOH-9	25	Department of Health marine sampling station 9	8	1.8	23	6	28
E. Coli - Most Probable Number							
21-NOB-01[2]	1	Moclips River near mouth, tidal influence	8	23	230	52	155

*Sites numerically exceed the criteria but do not have enough samples above (10%) the criteria for an exceedance.
[1]The membrane filter (MF) and most probable number (MPN) results are averaged for this site.
[2]There are no state water quality criteria for *E. coli*.
NC: Not calculated, due to insufficient data.

Table 8. Wet-season summary statistics for FC (cfu/100 mL) at regularly sampled locations in the north coast watershed during the 2014-2015 sampling period.

Storm event data were not included in the analysis.
Shaded cells indicate sites where water quality criteria for bacteria were not met.

Site Name	Map #	Site Location	n	Min	Max	Geometric Mean	Estimated 90th Percentile
Fecal Coliform - Membrane Filter (Freshwater Criteria)							
21-NOB-01	1	Moclips River near mouth, tidal influence	17	9	261	43	175
21-NOB-02	4	Mouth of creek at Analyde Gap Road	17	1	150	15	105*
21-NOB-03	5	Joe Creek above Pacific Beach WWTP	17	1	110	6	39
21-NOB-04	6	Joe Creek at Pacific Beach State Park	17	1	160	7	47
21-NOB-05	7	Creek that crosses Diamond Drive	14	1	95	8	75
21-NOB-06	9	Below confluence of two creeks that drain North Seabrook	17	1	180	4	39
21-NOB-07	10	Creek that drains from South Seabrook at staircase	9	1	120	4	54
21-NOB-08	11	Elk Creek near the mouth	17	1	79	6	34
21-NOB-09	12	Creek on the North side of Highway 109 curve	17	1	84	4	24
21-NOB-10	13	Creek on the South side of Highway 109 curve	17	1	620	3	34
21-NOB-11	14	Creek approx. 60 meters North of Roosevelt Beach Road	17	1	61	2	9
21-NOB-12	15	Creek approx. 360 meters South of Roosevelt Beach Road	17	1	140	7	65
21-NOB-13	16	Boone Creek at Iron Springs Resort below bluff	17	1	83	6	32
21-NOB-14	17	Creek that drains neighborhood South of Boone Creek	16	1	56	6	27
21-NOB-15	18	Copalis River near the mouth	17	1	150	9	69
21-NOB-16	19	Connor Creek at Benner Road	17	5	1600	20	128*
21-NOB-17	20	Creek at Quinault Casino	16	2	790	12	102*
21-NOB-18	21	Mouth of creek at Ocean City State Park	17	1	92	15	71
21-NOB-19	22	Wet area between Illahee/Oyehut and the beach	15	1	1500	3	37
21-NOB-20[1]	23	Ditch on Chickamin Ave South of RV park septic tank	14	6	22000	81	1607
22-NOB-21	24	North ditch on Damon Road	11	10	260	53	203
22-NOB-22	26	South ditch on Damon Road	10	16	800	88	602
22-NOB-23	27	North ditch on W Chance A La Mer Northwest	10	6	1500	49	423
22-NOB-24	28	South ditch on W Chance A La Mer Northwest	7	1	1200	34	771
22-NOB-25	29	North ditch on Pacific Blvd Northwest	11	3	920	30	362
22-NOB-26	30	South ditch on Pacific Blvd Northwest	10	8	1000	67	637
22-NOB-27	31	North ditch on Ocean Lake Way Southwest	12	1	460	33	290
22-NOB-28	32	South ditch on Ocean Lake Way Southwest	11	35	890	112	452
Fecal Coliform - Most Probable Number (Marine Criteria)							
21-DOH-195	2	Department of Health marine sampling station 195	15	1.8	79	8	54
21-DOH-11	3	Department of Health marine sampling station 11	16	1.8	230	7	52
21-DOH-197	8	Department of Health marine sampling station 197	16	1.8	230	12	91
22-DOH-9	25	Department of Health marine sampling station 9	16	1.8	33	4	22
E. Coli - Most Probable Number							
21-NOB-01[3]	1	Moclips River near mouth, tidal influence	14	7	230	28	128

*Sites numerically exceed the criteria but do not have enough samples above (10%) the criteria for an exceedance.
[1]The membrane filter (MF) and most probable number (MPN) results are averaged for this site.
[2]Site assessed for compliance with the primary contact criteria.
[3]There are no state water quality criteria for *E. coli*.

Freshwater Locations

During the dry season most of the freshwater sampling locations in the southern portion (Ocean City south to Ocean Shores) and several sampling locations in the northern portion (Ocean City north to Moclips River) were either dry or did not have enough water to collect a sample. Summary statistics were not calculated for locations that did not have at least 5 sample results.

In general, for those locations with enough data, the geometric mean and estimated 90th percentile values were higher during the dry season than the wet season (Figures 3 and 4). This shows that in those locations where both wet-season and dry-season data are available, that the dry season had the highest freshwater FC concentrations. In addition, there were more exceedances of criteria, for those locations with enough data, during the dry season than the wet season (Figures 3 and 4). In both the dry and wet seasons, several sampling locations numerically exceeded the estimated 90th percentile part of the criteria but not enough samples exceeded the 100 cfu/100 mL criteria to be placed on the 303(d) list (Tables 7 and 8).

Figures 3 and 4 also show the elevated FC concentrations at 21-NOB-01 (Moclips River) and 21-NOB-16 that were discussed at the beginning of this section. What is not well shown, except in Figure 4, is the elevated FC concentrations from 21-NOB-10. All three of these locations are shown as elevated on an annual basis in Figure 2. Additionally, Figures 3 and 4 show that the Moclips River exceeds one or both parts of the water quality criteria for FC on an annual basis and during the wet and dry season.

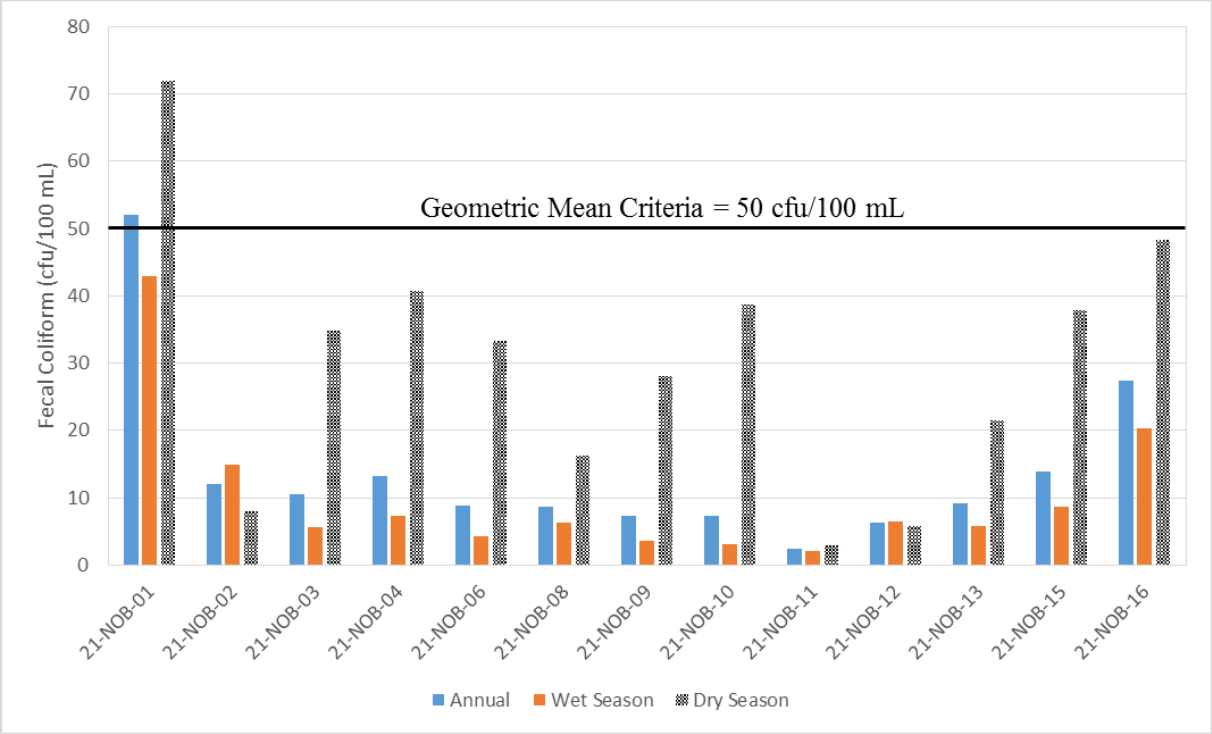

Figure 3. Annual, wet-season, and dry-season geometric mean values for freshwater sampling locations (cfu/100 mL).

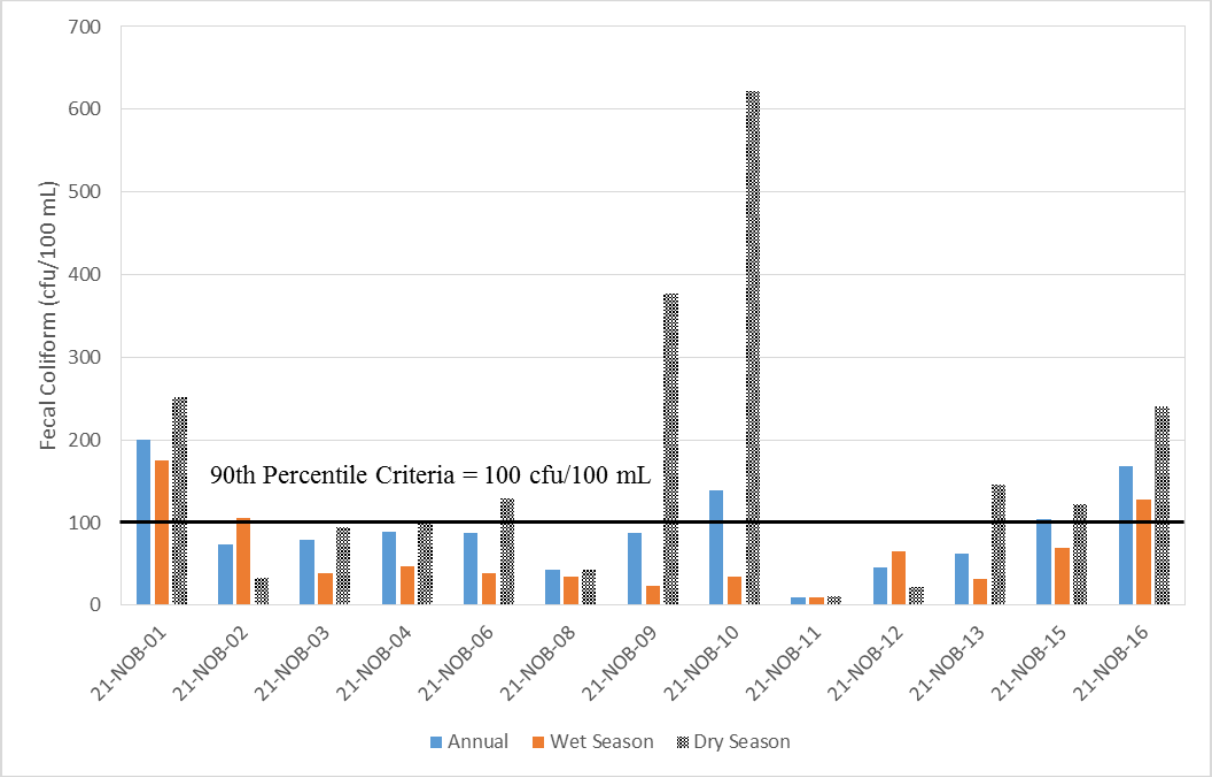

Figure 4. Annual, wet-season, and dry-season estimated 90th percentile values for freshwater sampling locations (cfu/100 mL).

Marine Locations

For the marine sampling locations, except 22-DOH-9, the wet-season geometric mean and estimated 90th percentile values were higher than the dry season (Figures 5 and 6). At 22-DOH-9, the dry-season geometric mean and estimated 90th percentile values are higher than the wet season (Figures 5 and 6). This data shows that higher FC concentrations occur during the wet season at all the marine sampling locations, except 22-DOH-9.

The three marine sampling locations with higher FC during the wet season are in areas where a number of freshwater creeks and rivers enter the ocean. During storm events and wet weather conditions, these creeks and rivers deliver more FC to marine waters than during the dry season. In addition, during the wet-season rain, water washes off the beach via overland flow into the marine water. This delivery of FC via creeks and rivers as well as surface runoff is then reflected in the sample results.

Highest FC concentrations for 22-DOH-9 occur during the dry season which corresponds to the summer vacation season. One explanation for this difference in seasonal patterns could be the proximity of the 22-DOH-9 to the city of Ocean Shores. During the summer vacation season many people come to recreate on the beach in and around the city of Ocean Shores. This area is popular because of ease of access to the ocean beach, nearby amenities such as hotels and restaurants, and horseback riding on the beach.

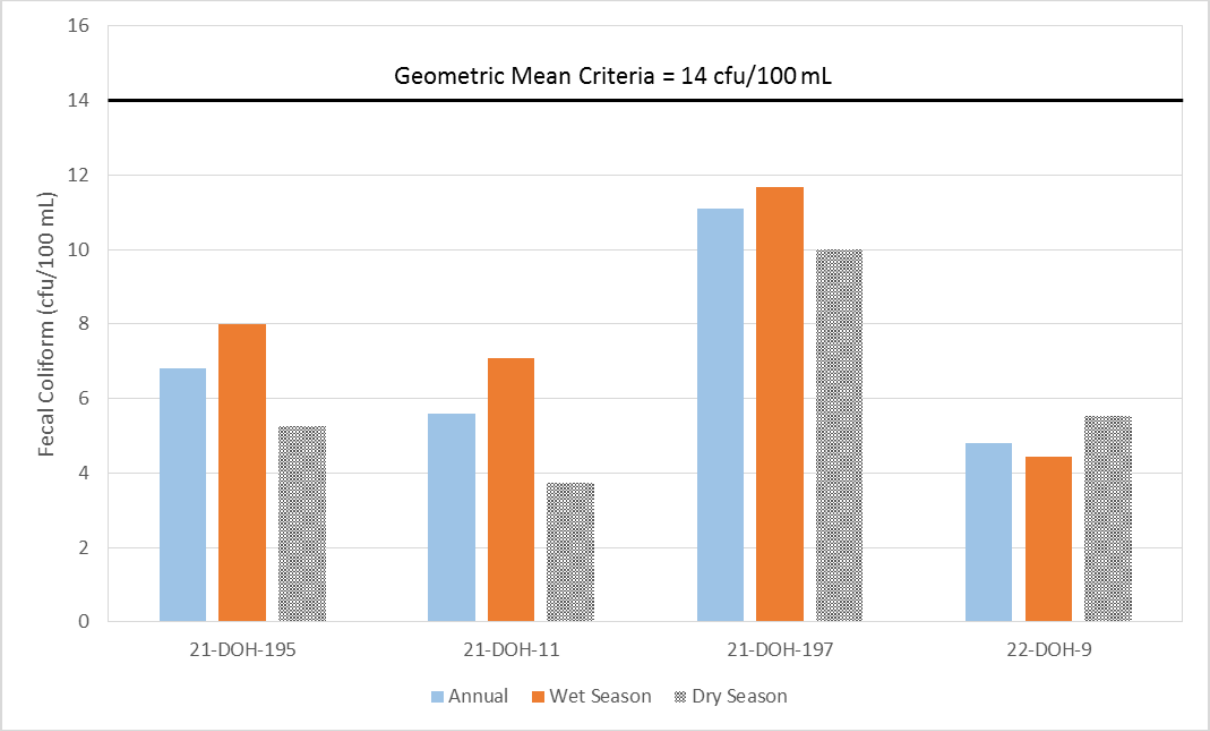

Figure 5. Annual, wet-season, and dry-season geometric mean values for marine sampling locations (cfu/100 mL).

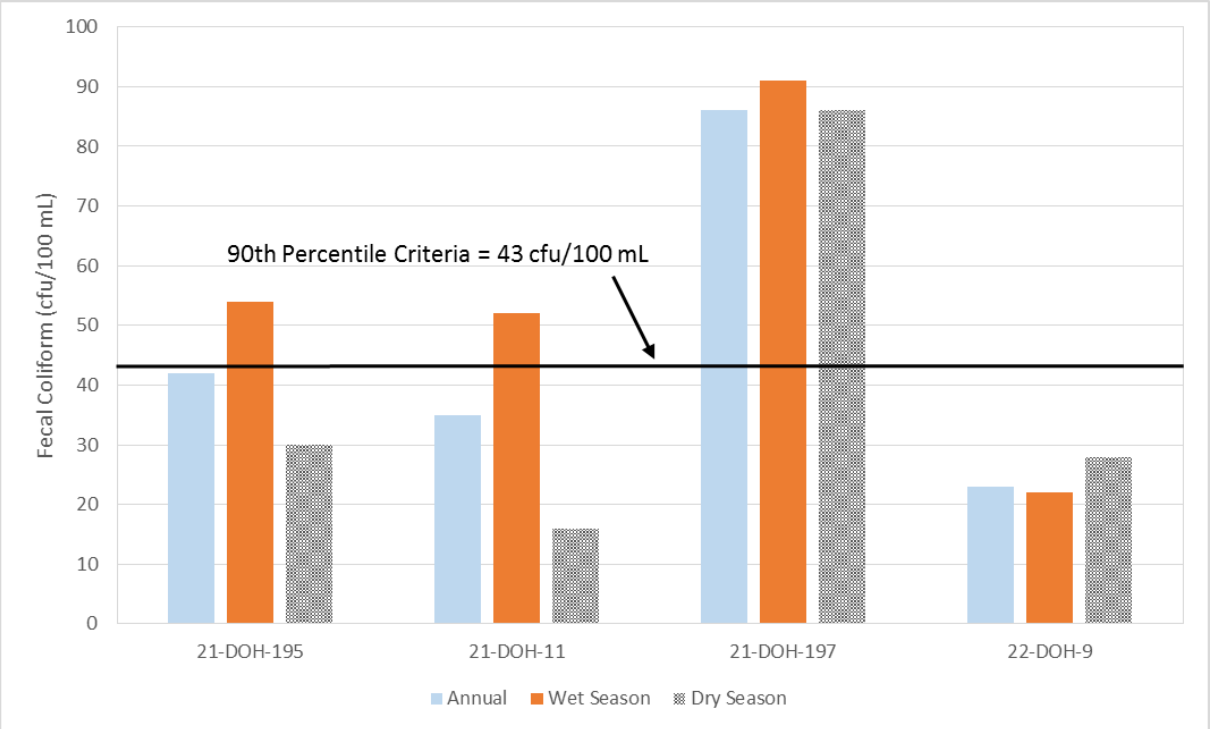

Figure 6. Annual, wet-season, and dry-season estimated 90th percentile values for marine sampling locations (cfu/100 mL).

On warm summer days field samplers observed much higher densities of people on the beach in the area around the city of Ocean Shores compared to northern sampling locations. Also noted during warm summer days were two businesses offering guided horse rides on the beach. These businesses operated in the heavy use areas of the beach around the city of Ocean Shores. Each business likely had 15-20 horses. The number could be higher. It was not possible to count the total number horses because there was always a group out on a ride. In addition to the horse concessionaire businesses, privately owned horses were being ridden on the beach. In the areas where the horses were ridden, field samplers noted horse feces on the beach and in the surf.

E. Coli and Other Bacteria Species

E. coli is the species of the FC group most commonly associated with wastes from warm-blooded animals and *Klebsiella sp.* are associated more with wood waste and decaying vegetation. State and federal FC criteria do not make allowances for the type of bacteria reported as FC. Identifying specific types of bacteria within the FC group is helpful for identifying probable sources and planning methods for their control.

The only location that was sampled for *E. coli* was the Moclips River. Over the sampling period, 54% of analyzed samples had *E. coli* representing 50% or greater of the total FC group. This shows that *E. coli* is the predominant type of FC in most of the Moclips River samples, and wastes from warm-blooded animals likely make up the major portion of the sources of contamination. *Klebsiella* data shown in Table 9 agree with the *E. coli* results except during the dry season, where sources are equally split between FC from warm-blooded animals and decaying vegetation.

Table 9. Summary statistics for percent *Klebsiella* data collected during the study period (%).

Site Name	Map #	Site Location	n	Minimum	Maximum	Mean
21-NOB-01	1	Moclips River near Mouth, tidal influence	12	0	93	30
21-NOB-04	6	Joe Creek at Pacific Beach State Park	12	0	100	44
21-NOB-08	11	Elk Creek near the mouth	11	0	100	34
21-NOB-15	18	Copalis River near the mouth	12	0	100	48
21-NOB-16	19	Connor Creek at Benner Road	12	6	90	48
21-NOB-19	22	Wet area between Illahee/Oyehut and the beach	6	0	100	25

In addition to the Moclips River, *Klebsiella* was sampled at five other sampling locations. One of the locations (21-NOB-19) was dry much of the sampling period so not enough data were collected to assess the influence of *Klebsiella*. *Klebsiella* data from the other sampled locations show that on an annual and wet-season basis, except at one location (21-NOB-04), the largest source of FC is from warm-blooded animals (Figures 7 and 8). During the dry season the major source of FC varies from location to location (Figure 9). Some of the variability seen between the seasons could be the result of the source of the river or creek and characteristics of the watershed it flows through.

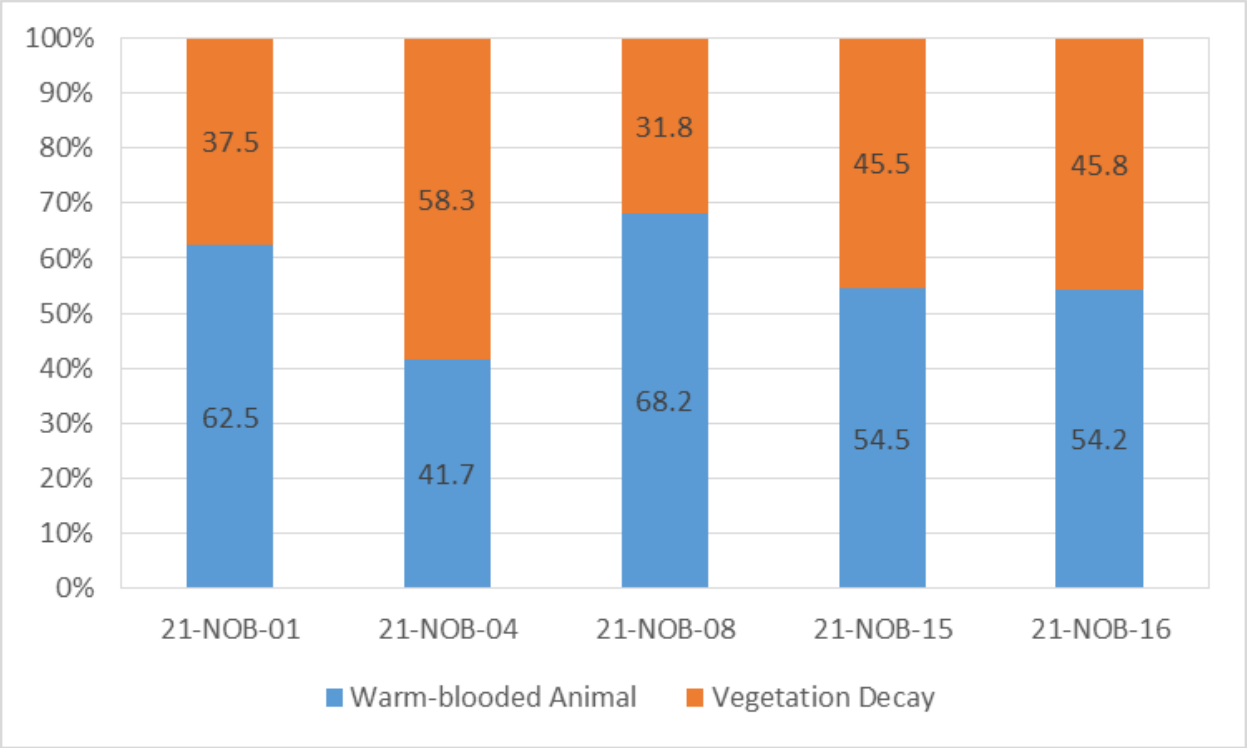

Figure 7. Annual percent contributions of major FC sources.

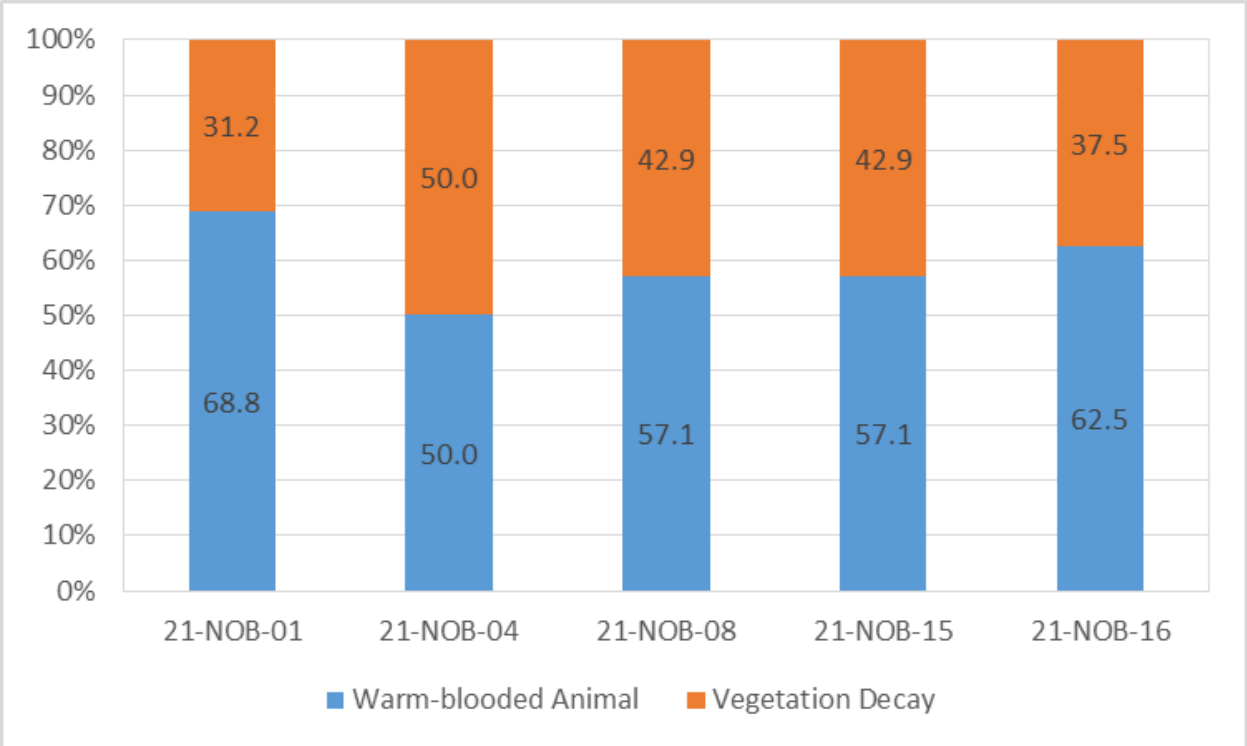

Figure 8. Wet-season (October – May) percent contributions of major FC sources.

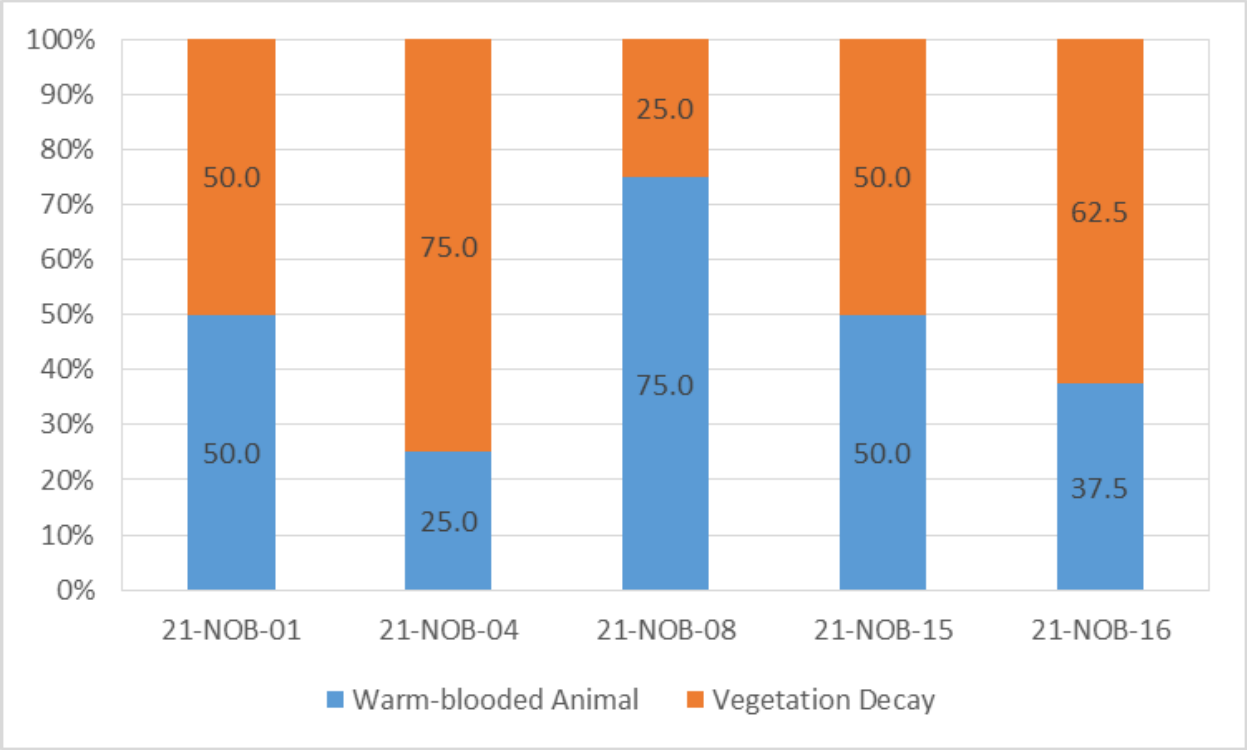

Figure 9. Dry-season (June – September) percent contributions of major FC sources.

Storm Event

The study design called for sampling of at least two wet-season (October-May) storm events and one dry-season (June-September) storm event. Due to the extremely dry weather conditions during the study period, only one storm event was captured. This storm event occurred during the wet season (10/22/14). While the storm occurred during the wet season it was the first large rain event that brought flow back to dry creeks and ditches as well as increased the flows in the creeks being sampled.

This storm event also did not meet the criteria described in the QA Project Plan (Swanson and Anderson, 2014). Data from Grays Harbor County (GHC) Community Collaborative Rain, Hail, and Snow Network showed that sampling occurred on the third day of greater than a trace of rainfall accumulation. Three days prior to the storm sample approximately 0.06 inches of rain fell over the study area. Forty-eight hours prior to the storm sampling approximately 1.29 inches of rain fell over the study area. On the day of storm sampling (10/22/14) approximately 0.89 inches of rain fell over the study area.

The two days previous to the storm sampling were regularly scheduled days of sample collection. During the regularly scheduled sampling, field staff did not observe increases in flows until the afternoon of the second day of the regularly scheduled sampling. The decision to sample this storm event, despite being outside of the criteria, was made by the project manager based on this observation.

Results from the storm event show that FC concentrations were much higher than the geometric mean of the wet season (Table 10). In some instances the results are greater than an order of magnitude higher. The majority of the storm event sample values are higher than the wet-season maximum concentrations. These higher concentrations found during storm events are similar to those seen in historical data from other studies (Swanson and Anderson, 2014). One notable exception to this is 21-NOB-20 where the maximum wet-season concentration was more than 27 times greater than the storm event concentrations. This suggests the wet-season maximum value was the result of something other than stormwater runoff, perhaps related to the land use of the property adjacent to the sampling location.

Table 10. FC data (cfu/100 mL) from regularly sampled locations for a storm event that occurred on 10/22/14 with wet-season geometric means for comparison.

Site Name	Map #	Site Location	Storm Event	Wet Season Maximum	Wet Season Geometric Mean
Fecal Coliform - Membrane Filter (Freshwater Criteria)					
21-NOB-01[1]	1	Moclips River near mouth, tidal influence	590 J	261	43
21-NOB-02	4	Mouth of creek at Analyde Gap Road	72	150	15
21-NOB-03	5	Joe Creek above Pacific Beach WWTP	290	110	6
21-NOB-04	6	Joe Creek at Pacific Beach State Park	250	160	7
21-NOB-05	7	Creek that crosses Diamond Drive	37	95	8
21-NOB-06	9	Below confluence of two creeks that drain North Seabrook	250	180	4
21-NOB-07	10	Creek that drains from South Seabrook at staircase	44	120	4
21-NOB-08	11	Elk Creek near the mouth	440	79	6
21-NOB-09	12	Creek on the North side of Highway 109 curve	89 J	84	4
21-NOB-10	13	Creek on the South side of Highway 109 curve	120	620	3
21-NOB-11	14	Creek approx. 60 meters North of Roosevelt Beach Road	190	61	2
21-NOB-12	15	Creek approx. 360 meters South of Roosevelt Beach Road	140	140	7
21-NOB-13	16	Boone Creek at Iron Springs Resort below bluff	110	83	6
21-NOB-14	17	Creek that drains neighborhood South of Boone Creek	87 J	56	6
21-NOB-15	18	Copalis River near the mouth	230	150	9
21-NOB-16	19	Connor Creek at Benner Road	260	1600	20
21-NOB-17	20	Creek at Quinault Casino	1300 J	790	12
21-NOB-18	21	Mouth of creek at Ocean City State Park	52	92	15
21-NOB-19	22	Wet area between Illahee/Oyehut and the beach	Dry	1500	3
21-NOB-20	23	Ditch on Chickamin Ave South of RV park septic tank	800 G	22000	81
22-NOB-21	24	North ditch on Damon Road	800 G	260	53
22-NOB-22	26	South ditch on Damon Road	800 G	800	88
22-NOB-23	27	North ditch on W Chance A La Mer Northwest	Dry	1500	49
22-NOB-24	28	South ditch on W Chance A La Mer Northwest	Dry	1200	34
22-NOB-25	29	North ditch on Pacific Blvd Northwest	Dry	920	30
22-NOB-26	30	South ditch on Pacific Blvd Northwest	Dry	1000	67
22-NOB-27	31	North ditch on Ocean Lake Way Southwest	Dry	460	33
22-NOB-28	32	South ditch on Ocean Lake Way Southwest	Dry	890	112
Fecal Coliform - Most Probable Number (Marine Criteria)					
21-DOH-195	2	Department of Health marine sampling station 195	230 J	79	8
21-DOH-11	3	Department of Health marine sampling station 11	490	230	7
21-DOH-197	8	Department of Health marine sampling station 197	490	230	12
22-DOH-9	25	Department of Health marine sampling station 9	790	33	4
E. Coli - Most Probable Number					
21-NOB-01	1	Moclips River near mouth, tidal influence	ND	230	28

[1]The membrane filter (MF) and most probable number (MPN) results are averaged for this site.
Dry: Site did not have water or was not flowing.
G: Greater than.
J: The organism was positively identified. The associated numerical result is an estimate.
ND: No data available or no sample collected.

Other Data

Washington State Department of Health (DOH)

DOH has a large network of marine bacteria monitoring locations. These sampling locations are placed where shellfish harvest (recreational and commercial) occurs on beaches. The purpose is to determine if the shellfish in the area of sample collection are safe for harvest. In most locations, DOH samples every other month unless there is a need for monthly data.

Table 11 summarizes data collected by the QIN for DOH near areas that were sampled during this study. Figure 10 shows the locations of the DOH sampling locations described in Table 11. In some cases the sampling locations are the same (Stations 9, 11, 195, and 197). At the bottom of Table 11 there are four locations that were added as special locations. All but one of these locations correspond to the same or nearby sampling location for this study. While many of these locations are the same or close to sites sampled for this study they are not completely equivalent. Samples collected by DOH are analyzed for FC by the MPN method. This is the same type of analysis performed at the Ecology locations but DOH uses a slightly different method.

Table 11. Summary statistics for Washington Department of Health (DOH) marine water FC data for selected locations in the north coast study area (cfu/100 mL).

Site	Site Description	n	Min	Max	Geometric Mean	Estimated 90th Percentile	DOH Classification
4	Ocean Crest Stairway	5	1.7	4.5	3	5	Approved
5	Copalis Beach Access	5	1.7	31	4	19	Approved
6	Iron Springs	5	1.7	11	4	10	Approved
9	Ocean Shores - Oyehut Access	5	2.0	130	10	75	Prohibited
11	Moclips access	9	1.7	240	4	32	Conditionally Approved
12	Molcips River-5th Ave Access	5	7.8	33	16	37	Prohibited
195	120 yd south of Moclips River line	9	1.7	350	6	50	Conditionally Approved
196	120 yd north of Joe Creek line	5	1.7	4.5	2	4	Approved
197	120 yd south of Joe Creek line	9	1.7	350	8	79	Conditionally Approved
SP1	Ditch across from Best Western	4	2	>2400	38	1775	n/a
SP2	Joe Creek bridge, Ocean Beach Rd	6	1.7	79	6	47	n/a
SP3	Joe Creek bridge, SR 109	6	1.7	>2400	17	480	n/a
SP4	Stream from OC State Park	6	1.7	920	20	566	n/a

n/a: not applicable
SP: special

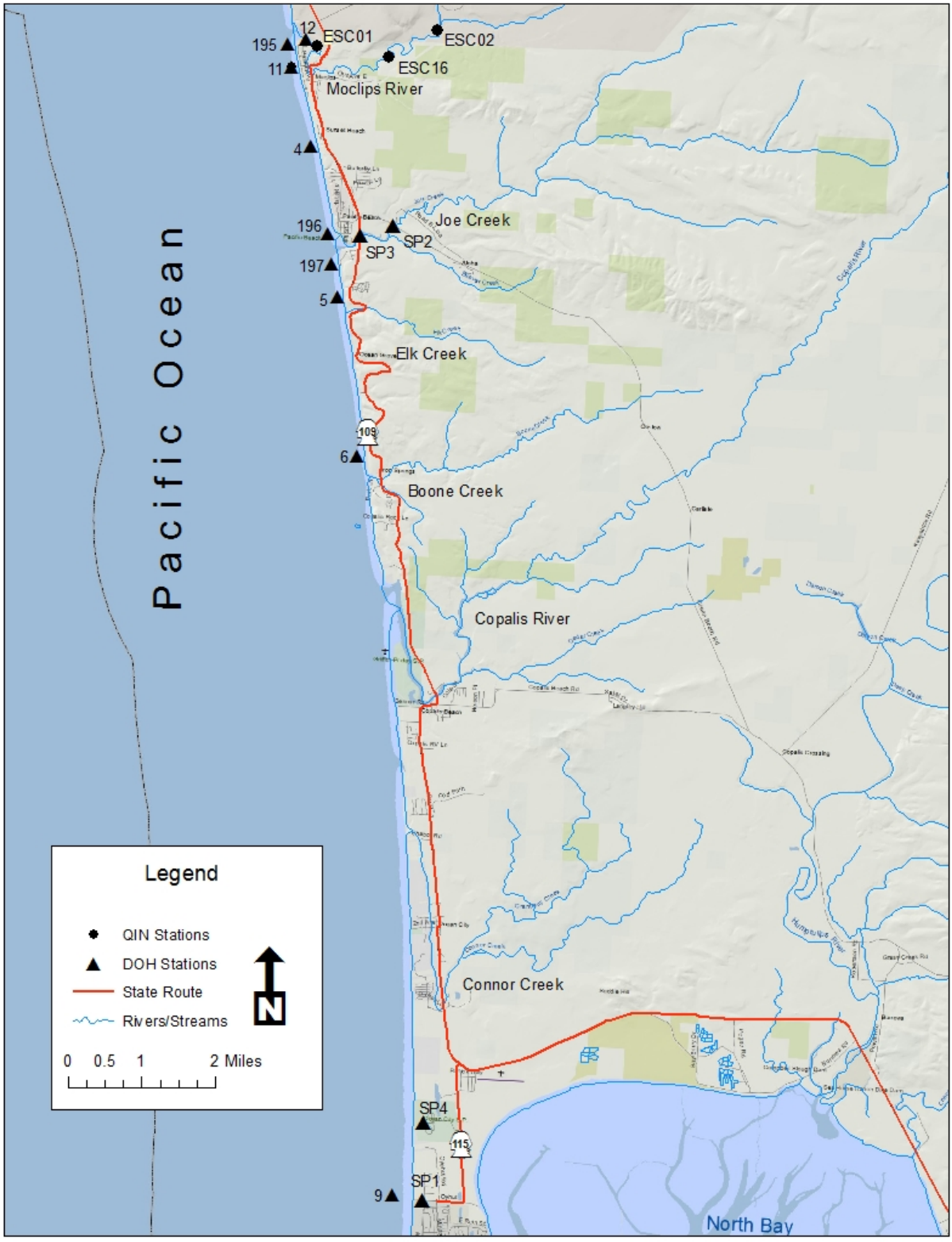

Figure 10. Map of north coast study area with locations of Washington Department of Health (DOH) and Quinault Indian Nation (QIN) sampling locations.

With the exception of two sites (Stations 9 and 12) Ecology and DOH geometric mean and estimated 90th percentile results were similar. Ecology data for geometric mean and estimated 90th percentile at Station 9 were lower and at Station 12 were higher than DOH data. The differences between the data likely are the result of differing sample collection date and time. Additionally, slightly different sampling locations, analysis method, and numbers of samples collected could have added to the difference from sample collection date and time. For similar located special sampling sites, DOH data were higher than Ecology data except for Joe Creek at Ocean Beach Road where Ecology data were higher. The reasons for the difference could be the same as the marine locations but could also include the positive bias seen between MF and MPN methods of enumeration.

Quinault Indian Nation

Quinault Indian Nation has a network of bacteria monitoring locations around the Quinault Reservation. Three of the sampling locations are on the Moclips River. These bacteria samples are collected for a routine monitoring program funded by EPA. All of the samples collected by the QIN are analyzed by the GHC Water Testing Laboratory. This laboratory is accredited by Ecology's Environmental Laboratory Accreditation Programs.

Data shown in Table 12 represent summary statistics for *E. coli* samples collected by the QIN. Sampling locations are shown in Figure 10. All the data were collected between June and December 2014. The summary statistics calculated for this data set are similar to what was found in the *E. coli* data from this study except at ESC02. This sampling location is above the Moclips River Estates WWTP outfall. The data show that the geometric mean and estimated 90th percentile more than double between ESC02 and ESC16 (below WWTP outfall).

The only known anthropogenic source between the two locations is the Moclips River Estates WWTP located in the Qui-nai-elt Village. However, this does not mean that the Moclips River Estates WWTP is the source of the *E. coli* bacteria. Discharge monitoring reports from the facility do not indicate the effluent contains levels of bacteria that would, by itself, cause the increase of bacteria concentrations measured in the samples downstream of the facility. There could be one or more unidentified sources between the two sampling locations.

Table 12. Summary statistics for Quinault Indian Nation *E. coli* bacteria sampling locations that are within the north coast study area (cfu/100 mL).

Site	Site Description	n	Min	Max	Geometric Mean	Estimated 90th Percentile
ESC02	Moclips River Aloha Mainline	5	4	127	12	66
ESC16	Moclips River downstream of WWTP	5	7	205	27	152
ESC01	Moclips River near mouth	5	9	194	27	137

It is important to note that despite showing an increase in *E. coli* bacteria, the geometric mean and the estimated 90th percentile are not exceeding the most conservative 2012 Recreational Water Quality Criteria recommended by EPA; *E. coli* water quality criteria (geometric mean criteria = 100 cfu/100 mL/estimated 90th percentile criteria = 320 cfu/100 mL). Also noteworthy, is that Washington State does not use *E. coli* as the basis for water quality criteria. Instead Washington State uses FC.

As is described in a previous section, data collected from this study show that the Moclips River is exceeding water quality criteria for FC at station 21-NOB-01 (near the mouth). This exceedance of water quality criteria may be the result of the effluent from the Moclips River Estates WWTP or unidentified source(s). It is not possible to determine the source of the bacteria contamination without more data and study of the area between ESC02 and ESC16. This extra study would need to include FC sampling above and below the WWTP outfall, WWTP effluent, and near the mouth of the Moclips River. Quinault Indian Nation staff have been collecting more bacteria data to determine the extent to which the WWTP is affecting downstream water quality. The best approach for finding other anthropogenic sources will be for Ecology to work closely with the QIN tribal council, the Quinault Division of Natural Resources, and EPA (tribal NPDES permit manager) to more thoroughly investigate this reach.

Optical Brighteners

Overall, average concentrations of optical brightener are low and do not indicate a greywater source of FC contamination in any of the sampled locations (Table 13). Most of the sampled locations do not have any upstream sources of optical brightener. This indicates that there likely is interference from dissolved organic matter. The other interfering compound (heavier oils) is unlikely because there is not a source in the area.

When optical brighteners and FC were sampled together most of the pairs had low bacteria and low optical brightener concentrations. This indicates that there may not be a source of human-caused FC contamination during the times of these paired samples. This, however, does not mean that there is no source of human-caused FC. It simply means that at the point in time of the sample collection, the FC concentration was not high and that there was not a source of greywater from a leaking or failing septic system.

Those locations that had a high FC concentration (>200) and low optical brightener concentration (21-NOB-09, 21-NOB-10, 21-NOB-20, 22-NOB-22, and 22-NOB-25) could indicate that when the sample was collected the likely source of FC contamination was from a human FC source (outhouse) that does not mix greywater with toilet water or from some other warm-blooded animal.

As with other parameters like temperature and dissolved oxygen, a discrete measurement only represents a snapshot in time and may not represent the true condition of the water. Discrete measurements also miss spikes and other significant changes that occur outside of the single sample that is collected. Due to the nature of how optical brighteners enter the environment (through mixing of laundry water with toilet water), it is unlikely that a discrete sample will accurately characterize or capture true concentrations in surface water.

Table 13. Summary statistics for discrete optical brightener measurements (ppb).

Site	Map #	Site Location	n	Minimum	Maximum	Mean
21-NOB-01	1	Moclips River near Mouth, tidal influence	11	16	46	33
21-NOB-02	4	Mouth of creek at Analyde Gap Road	12	7	44	26
21-NOB-03	5	Joe Creek above Pacific Beach WWTP	10	12	44	26
21-NOB-04	6	Joe Creek at Pacific Beach State Park	11	14	41	26
21-NOB-05	7	Creek that crosses Diamond Drive	8	36	46	42
21-NOB-06	9	Below confluence of two creeks that drain North Seabrook	10	20	51	36
21-NOB-07	10	Creek that drains from South Seabrook at staircase	6	16	59	42
21-NOB-08	11	Elk Creek near the mouth	12	11	46	23
21-NOB-09	12	Creek on the North side of Highway 109 curve	11	17	38	24
21-NOB-10	13	Creek on the South side of Highway 109 curve	10	17	36	24
21-NOB-11	14	Creek approx. 60 meters North of Roosevelt Beach Road	9	6	24	13
21-NOB-12	15	Creek approx. 360 meters South of Roosevelt Beach Road	11	13	34	20
21-NOB-13	16	Boone Creek at Iron Springs Resort below bluff	11	9	46	22
21-NOB-14	17	Creek that drains neighborhood South of Boone Creek	9	5	28	16
21-NOB-15	18	Copalis River near the mouth	8	5	35	22
21-NOB-16	19	Connor Creek at Benner Road	12	19	36	28
21-NOB-17	20	Creek at Quinault Casino	9	36	61	49
21-NOB-18	21	Mouth of creek at Ocean City State Park	8	35	54	44
21-NOB-19	22	Wet area between Illahee/Oyehut and the beach	9	22	50	34
21-NOB-20	23	Ditch on Chickamin Ave South of RV park septic tank	9	17	30	22
22-NOB-21	24	North ditch on Damon Road	7	26	37	33
22-NOB-22	26	South ditch on Damon Road	6	20	30	25
22-NOB-23	27	North ditch on W Chance A La Mer Northwest	6	21	41	30
22-NOB-24	28	South ditch on W Chance A La Mer Northwest	3	1	6	3
22-NOB-25	29	North ditch on Pacific Blvd Northwest	7	15	39	24
22-NOB-26	30	South ditch on Pacific Blvd Northwest	5	10	38	26
22-NOB-27	31	North ditch on Ocean Lake Way Southwest	7	34	53	46
22-NOB-28	32	South ditch on Ocean Lake Way Southwest	5	27	48	39

The best way to do this would be to put out optical brightener sensors, in logging configurations, in locations where FC concentrations have been found to be consistently high or in areas where it is suspected that septic systems are failing. As was stated earlier in this document, no acceptable location was found to deploy the optical brightener sensors in a logging configuration. If future work is deemed necessary, it is recommended that optical brighteners be used in a logging configuration.

Conclusions

Results of this 2014-2015 study support the following conclusions:

- Over the study period the majority of the highest freshwater fecal coliform bacteria (FC) concentrations were seen in the southern portion of the study area.
- Where data were available for both seasons (wet and dry), the dry season (June – September) had the highest freshwater FC concentrations.
- Highest marine water FC concentrations mostly occurred during the wet season (October – May). The exception was marine location 22-DOH-9 where the highest marine water FC concentrations were seen during the dry season (June – September).
- Storm events likely result in elevated FC concentrations, especially if they occur after a period of little to no precipitation.
- Upstream sampling of the Moclips River on Quinault Indian Nation land is needed to determine any source of bacterial contamination causing exceedances of water quality criteria at the mouth of the river.
- Data from this study show that 12 new locations should be recommended for placement on Washington State's 303(d) list of impaired waterbodies for FC.
- Data from this study show that marine grid cell 47124C2D2 represented by 21-DOH-11 meets Washington State water quality criteria.
- *Klebsiella* data indicate that most of the bacteria contamination during the study period came from warm-blooded animals.
- Optical brightener concentrations do not indicate a greywater source of human-based FC. However, more study is needed with continuous data to determine the true concentration of optical brighteners in the study area.

Recommendations

Results of this 2014-2015 study support the following recommendations:

- Refer the next water quality assessment to evaluate the segments of the waterbodies associated with the sampling locations in the following table as candidates for category 5 on the 303(d) list.

Sampling Location	Name
21-NOB-04	Moclips River near mouth
21-NOB-10	Creek on south side of Hwy 109
21-NOB-16	Connor Creek at Benner Road
21-NOB-20	Ditch on Chickamin Ave South
22-NOB-21	North ditch on Damon Rd
22-NOB-22	South ditch on Damon Rd
22-NOB-23	North ditch on W Chance A La Mer NW
22-NOB-24	South ditch on W Chance A La Mer NW
22-NOB-25	North ditch on Pacific Blvd NW
22-NOB-26	South ditch on Pacific Blvd NW
22-NOB-27	North ditch on Ocean Lake Way SW
22-NOB-28	South ditch on Ocean Lake Way SW

- Pending further review of data, DOH is considering upgrading the shellfish classification at 21-DOH-11. If this upgrade occurs, the listing status of marine grid cell 47124C2D2 (represented by 21-DOH-11) in listing ID 15926 should be considered for a change in listing status from a category 5 (impaired) to a category 1 (meets measured criteria).

- Discrete sampling using optical brighteners did not yield much useful information for this study. Because of how optical brighteners enter surface water, future use of optical brightener sensors should be done in a continuous logging configuration.

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Appendices

Appendix A. Data Quality

Bacteria Method Comparison

Analysis of the data showed high variability between the FCMF and FCMPN samples collected at the Moclips River. This high variability is shown by the 75.1 pooled percent relative standard deviation (RSD). In a paper examining bacteria replicate precision, Mathieu (2006) shows that the percent RSD for FCMF (19 to 24%) is lower than FCMPN (37 to 41%). While the Mathieu (2006) study does not compare methods it does give a point of reference.

Some of the variability could be associated with the ability of the MPN analysis to better enumerate stressed organisms which would produce a higher fecal coliform bacteria (FC) value (positive bias) for the MPN than the MF method for the same actual concentration. In general, the majority of the MPN method samples from the Moclips River were higher than those for the MF method. Past studies (Joy, 2000; Swanson, 2008) have shown that MPN and MF results are comparable but not highly correlated. Taking into account the variability in replicate precision for the different methods and the lack of highly correlated data from comparison of methods from other studies, the data are considered usable without qualification.

Laboratory Data Quality

Several samples were analyzed outside the 24-hour holding time. For the FCMF method, 22 samples were analyzed outside the holding time and were qualified as estimates by the laboratory. Six FCMPN method samples were analyzed outside the holding time and were qualified as estimates by the laboratory. Only one *E. coli* most probable number (ECMPN) sample was analyzed outside the holding time and was qualified as an estimate by the laboratory.

Sometimes there are non-fecal colonies that may interfere with the enumeration of bacteria colonies during the analysis. This occurred in five samples. These samples were qualified as estimates by the laboratory. In addition, if there are too many colonies that grow during analysis, the colonies may overlap and the reported number may not be accurate. Twenty-two samples had this issue and were appropriately qualified by the laboratory.

On 12/16/14 there was a malfunction of the walk-in refrigerator at the location where the samples are stored before being transported to Ecology's Manchester Environmental Laboratory (MEL). The walk-in refrigerator froze 16 samples. Frozen FC samples are not considered viable because FC can be killed by cold temperatures. Despite their being frozen, the samples were run by MEL, at the request of the project manager. The results of the samples were rejected for use in this study.

Laboratory Duplicates

All laboratory duplicates met laboratory data quality objectives of 40% relative percent difference (RPD). One MPN sample that was not assessed by MEL was flagged and assessed by the project manager. The sample in question had a detection of 130 cfu/100 mL and the laboratory duplicate had a non-detect at the reporting limit of 1.8 cfu/100 mL. After looking at rainfall and other possible mitigating factors, the sample value was qualified as an estimate.

Over two and half inches of rain fell the day of sampling and may have caused the discrepancy between the laboratory duplicate and field sample. Based on the QA data provided by the laboratory all other MPN data for the sampling day are usable as delivered by MEL.

Field Replicates

Field replicate samples are two samples collected from the same location at the same time and submitted to MEL as blind pairs (no identification provided). Collecting field replicates is a method of looking at the precision of the entire process of sampling and analysis. Differences between the results of replicate samples can arise from variations in the sampling location, collection process, sample containers, and/or analytical procedures (MEL, 2008).

The QA Project Plan describes the replicate precision measurement quality objectives (MQOs) in detail (Swanson and Anderson, 2014). Table A-3 summarizes the laboratory replicate precision MQOs and field replicate statistics by parameter from the QA Project Plan. The MQOs listed below only apply to those parameters with 10 or more replicate pairs. Only FCMF and FCMPN analysis methods achieved more than 10 replicate pairs. *E. coli* and percent *Klebsiella* replicate pairs were assessed for usability on a case-by-case basis along with the samples with a mean concentration less than or equal to 20 cfu/100 mL.

Table A-1. Summarized laboratory replicate precision measurement quality objectives (MQOs) and field replicate statistics by parameter.

Parameter	Measurement Quality Objective[1]	Number of Replicates	Number of Samples	Total Samples	Samples Replicated
Fecal Coliform – MF	50% of replicate pairs < 20% RSD 90% of replicate pairs < 50% RSD	167	531	699	31%
Fecal Coliform – MPN	50% of replicate pairs < 50% RSD 90% of replicate pairs < 100% RSD	26	123	148	21%
E. coli – MPN	50% of replicate pairs < 50% RSD 90% of replicate pairs < 100% RSD	6	25	31	24%
% Klebsiella	50% of replicate pairs < 50% RSD 90% of replicate pairs < 100% RSD	9	65	74	14%

[1]Replicate results with a mean of less than or equal to 20 cfu/100 mL will be evaluated separately.
MF: membrane filter method MPN: most probable number method RSD: relative standard deviation

Ecology collected 167 membrane filtered fecal coliform (FCMF) replicates at all freshwater sites in 2014 and 2015. Twenty-four replicate pairs had at least one non-detect. For the QA analysis, the value for the reporting limit was substituted for the reported value. Out of the 167 replicate pairs, 64 had a mean concentration > 20 cfu/100 mL. Out of these 64 replicate pairs 58% (37) were below 20% RSD and 98% (63) were below 50% RSD. All FCMF results with a mean concentration > 20 met Ecology's MQO QA precision criteria and are considered usable without qualification. Data for replicate pairs with means ≤ 20 were assessed individually and were found to be useable without qualification.

Over the study period (April 2014 – April 2015), Ecology collected 26 most probable number fecal coliform (FCMPN) replicates at marine sampling locations. Twelve of the 26 replicate pairs had at least one non-detect. Non-detect values were replaced with the reporting limit for

the analysis. Thirteen of the replicate pairs did not have a mean concentration > 20 cfu/100 mL. For the 13 samples with a mean concentration > 20 cfu/100 mL, 77% (10) of the replicate pairs were below 50% RSD and 92% (12) were below 100% RSD. All of the FCMPN samples with a mean concentration > 20 met the MQO QA precision criteria.

Assessment of the 13 replicate pairs with means ≤ 20 found three sampling dates that require qualification of data due to high percent RSD (126%, 127%, and 127%). All FCMPN data collected on 8/11/2014, 12/1/2014, and 1/12/2015 were J qualified as estimates. After qualification of the samples associated with the replicate pairs, all data are considered usable.

At the Moclips River (21-NOB-01), Ecology collected six replicates for MPN *E. coli* samples over the sampling period. With less than ten sample pairs, statistics on replicate precision were not calculated. Instead the replicate pairs were assessed individually. The assessment identified one set of replicates that were rejected and two sets of replicates that were censored. When a data point is censored that quality code of the data point is downgraded. For example, a data point could go from unqualified (good quality) to estimated (less certain about the reported value).

Data for the sample and replicate collected on 4/24/2014 are rejected due to the large discrepancy between the two samples (2300 cfu/100 mL vs 230 cfu/100 mL). The project manager confirmed the sample value with MEL (personal communication, 2014). Despite the confirmation, it is possible that there was an addition of a trailing zero at the laboratory. Two other replicate pairs were collected on 8/11/14 and 10/6/14, respectively, and had an elevated percent RSD. Data from 8/11/14 were already qualified at the laboratory as estimated, due to analysis beyond holding time. No additional qualification is needed. Sample data from 10/6/14 needed J qualification as an estimate. Other than the data from the 4/24/14 and the data discussed below, sample data are considered usable as qualified.

In addition to the replicate discrepancy, there were two *E. coli* samples collected on 9/8/14 and 12/15/14 that were several hundred cfu/100 mL above the fecal coliform (MF and MPN) results. This large of a discrepancy between the FC and the *E. coli* likely is not real because the concentration of *E. coli* is a subset of the FC group and should be a lower concentration than the FC result. These two values were rejected.

Percent *Klebsiella* was collected once per month at five sites over the sampling period. Nine replicate pairs were collected to assess precision. With less than ten sample pairs, statistics on replicate precision were not calculated. Instead the replicate pairs were assessed individually. The assessment showed that two pairs of replicates collected on 2/24/15 and 3/23/15, respectively, required qualification as estimates. Qualification of the data was required because of the high percent RSD (both 141%). All of the percent *Klebsiella* samples were not qualified on these dates because the samples were collected from different waterbodies and are not representative of conditions at the rest of the sampling locations.

Field Data Quality

The optical brightener discrete measurement instrument was calibrated following manufacturer instructions and Ecology SOP EAP091 (Anderson and Swanson, 2014).

Appendix B. Bacteria Data

This appendix presents fecal coliform bacteria (FC), *E. coli*, and *Klebsiella* data for the study.

Table B-1 presents the color code used to identify qualified results presented in Table B-2.

Table B-1. Color codes for the data qualifiers used to identify qualified results.

Qualifier	Color Code	Qualifier Description
U or UJ		Analyte was not detected at or above the reported result; or for 'UJ' at or above the reported estimated result.
J or JG		Analyte was positively identified. The associated numerical result is an estimate; or for 'JG' value may be greater than the reported estimate.
REJ		Data are unusable for all purposes.
G		Value is likely greater than the reported result. Reported result may be biased low.

Table B-2. FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-DOH-11	21-DOH-11	4/21/2014	13:20	1404044-06	230		
21-DOH-11	21-DOH-11	5/5/2014	12:45	1405032-04	7.8		
21-DOH-11	21-DOH-11	5/19/2014	16:00	1405033-03	1.8		
21-DOH-11	21-DOH-11	5/19/2014	16:00	1405033-04	1.8		
21-DOH-11	21-DOH-11	6/2/2014	15:00	1406021-04	1.8		
21-DOH-11	21-DOH-11	6/16/2014	13:30	1406022-04	23		
21-DOH-11	21-DOH-11	6/30/2014	12:15	1406023-04	23		
21-DOH-11	21-DOH-11	7/14/2014	10:30	1407024-05	1.8		
21-DOH-11	21-DOH-11	7/28/2014	13:15	1407025-03	1.8		
21-DOH-11	21-DOH-11	7/28/2014	13:15	1407025-04	1.8		
21-DOH-11	21-DOH-11	8/11/2014	14:55	1408024-04	1.8		
21-DOH-11	21-DOH-11	8/25/2014	16:30	1408025-04	1.8		
21-DOH-11	21-DOH-11	9/8/2014	16:30	1409022-04	7.8		
21-DOH-11	21-DOH-11	9/22/2014	17:00	1409023-04	1.8		
21-DOH-11	21-DOH-11	10/6/2014	11:10	1410011-06	1.8		
21-DOH-11	21-DOH-11	10/6/2014	11:10	1410011-07	1.8		
21-DOH-11	21-DOH-11	10/20/2014	17:40	1410012-03	1.8		
21-DOH-11	21-DOH-11	10/22/2014	11:30	1410064-04	490		
21-DOH-11	21-DOH-11	11/3/2014	16:40	1411012-04	23		
21-DOH-11	21-DOH-11	11/17/2014	15:20	1411013-05	1.8		
21-DOH-11	21-DOH-11	12/1/2014	15:45	1412007-05	31		
21-DOH-11	21-DOH-11	12/15/2014	14:30	1412037-03	23		
21-DOH-11	21-DOH-11	12/15/2014	14:30	1412037-04	33		
21-DOH-11	21-DOH-11	1/12/2015	13:40	1501021-03	1.8		
21-DOH-11	21-DOH-11	1/26/2015	13:30	1501022-05	23		
21-DOH-11	21-DOH-11	2/9/2015	11:10	1502017-06	23		
21-DOH-11	21-DOH-11	2/23/2015	13:20	1502018-05	23		
21-DOH-11	21-DOH-11	3/9/2015	11:00	1503014-04	1.8		
21-DOH-11	21-DOH-11	3/23/2015	11:15	1503015-04	1.8		
21-DOH-11	21-DOH-11	4/6/2015	15:20	1504052-04	1.8		
21-DOH-195	21-DOH-195	4/21/2014	13:00	1404044-04	49		
21-DOH-195	21-DOH-195	4/21/2014	13:00	1404044-05	23		
21-DOH-195	21-DOH-195	5/5/2014	12:25	1405032-02	23		
21-DOH-195	21-DOH-195	5/5/2014	12:25	1405032-03	7.8		
21-DOH-195	21-DOH-195	5/19/2014	15:30	1405033-02	1.8		
21-DOH-195	21-DOH-195	6/2/2014	14:45	1406021-03	1.8		
21-DOH-195	21-DOH-195	6/16/2014	13:00	1406022-03	23		
21-DOH-195	21-DOH-195	6/30/2014	12:00	1406023-03	23		
21-DOH-195	21-DOH-195	7/14/2014	10:15	1407024-03	1.8		
21-DOH-195	21-DOH-195	7/14/2014	10:15	1407024-04	1.8		
21-DOH-195	21-DOH-195	7/28/2014	12:30	1407025-02	6.8		
21-DOH-195	21-DOH-195	8/11/2014	15:05	1408024-03	1.8		
21-DOH-195	21-DOH-195	8/25/2014	16:10	1408025-03	1.8		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-DOH-195	21-DOH-195	9/8/2014	16:40	1409022-03	46		
21-DOH-195	21-DOH-195	9/22/2014	16:30	1409023-02	1.8		
21-DOH-195	21-DOH-195	9/22/2014	16:30	1409023-03	1.8		
21-DOH-195	21-DOH-195	10/6/2014	11:00	1410011-05	1.8		
21-DOH-195	21-DOH-195	10/20/2014	17:30	1410012-02	79		
21-DOH-195	21-DOH-195	10/22/2014	9:30	1410064-03	230		
21-DOH-195	21-DOH-195	11/3/2014	16:30	1411012-03	23		
21-DOH-195	21-DOH-195	11/17/2014	15:15	1411013-04	1.8		
21-DOH-195	21-DOH-195	12/1/2014	15:30	1412007-03	1.8		
21-DOH-195	21-DOH-195	12/1/2014	15:30	1412007-04	33		
21-DOH-195	21-DOH-195	1/12/2015	13:30	1501021-02	23		
21-DOH-195	21-DOH-195	1/26/2015	13:20	1501022-04	23		
21-DOH-195	21-DOH-195	2/9/2015	10:55	1502017-04	23		
21-DOH-195	21-DOH-195	2/9/2015	10:55	1502017-05	46		
21-DOH-195	21-DOH-195	2/23/2015	13:10	1502018-03	23		
21-DOH-195	21-DOH-195	2/23/2015	13:10	1502018-04	23		
21-DOH-195	21-DOH-195	3/9/2015	10:45	1503014-03	1.8		
21-DOH-195	21-DOH-195	3/23/2015	11:10	1503015-03	1.8		
21-DOH-195	21-DOH-195	4/6/2015	15:10	1504052-03	1.8		
21-DOH-197	21-DOH-197	4/21/2014	14:40	1404044-12	230		
21-DOH-197	21-DOH-197	5/5/2014	16:15	1405032-13	23		
21-DOH-197	21-DOH-197	5/19/2014	16:50	1405033-09	1.8		
21-DOH-197	21-DOH-197	6/2/2014	16:00	1406021-10	1.8		
21-DOH-197	21-DOH-197	6/2/2014	16:00	1406021-11	1.8		
21-DOH-197	21-DOH-197	6/16/2014	14:30	1406022-12	33		
21-DOH-197	21-DOH-197	6/30/2014	13:30	1406023-10	23		
21-DOH-197	21-DOH-197	7/14/2014	11:30	1407024-11	1.8		
21-DOH-197	21-DOH-197	7/28/2014	13:40	1407025-11	79		
21-DOH-197	21-DOH-197	8/11/2014	14:30	1408024-09	1.8		
21-DOH-197	21-DOH-197	8/11/2014	14:30	1408024-10	31		
21-DOH-197	21-DOH-197	8/25/2014	15:30	1408025-09	70		
21-DOH-197	21-DOH-197	9/8/2014	14:45	1409022-10	23		
21-DOH-197	21-DOH-197	9/22/2014	14:30	1409023-08	1.8		
21-DOH-197	21-DOH-197	10/6/2014	12:00	1410011-13	1.8		
21-DOH-197	21-DOH-197	10/20/2014	15:00	1410012-11	64		
21-DOH-197	21-DOH-197	10/20/2014	15:00	1410012-12	33		
21-DOH-197	21-DOH-197	10/22/2014	11:50	1410064-11	490		
21-DOH-197	21-DOH-197	11/3/2014	15:15	1411012-10	49		
21-DOH-197	21-DOH-197	11/17/2014	13:45	1411013-11	1.8		
21-DOH-197	21-DOH-197	12/1/2014	14:00	1412007-13	23		
21-DOH-197	21-DOH-197	12/15/2014	12:30	1412037-09	23		
21-DOH-197	21-DOH-197	1/12/2015	12:00	1501021-11	1.8		
21-DOH-197	21-DOH-197	1/26/2015	14:48	1501022-10	23		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-DOH-197	21-DOH-197	2/9/2015	14:00	1502017-12	23		
21-DOH-197	21-DOH-197	2/23/2015	14:20	1502018-13	23		
21-DOH-197	21-DOH-197	3/9/2015	14:50	1503014-09	1.8		
21-DOH-197	21-DOH-197	3/9/2015	14:50	1503014-10	1.8		
21-DOH-197	21-DOH-197	3/23/2015	14:15	1503015-10	33		
21-DOH-197	21-DOH-197	4/6/2015	11:45	1504052-12	1.8		
21-NOB-01	21-NOB-01	4/21/2014	12:45	1404044-01	2	2300	0
21-NOB-01	21-NOB-01	4/21/2014	12:45	1404044-02	1		0
21-NOB-01	21-NOB-01	4/21/2014	12:45	1404044-03		230	
21-NOB-01	21-NOB-01	5/5/2014	12:00	1405032-01	40	33	0
21-NOB-01	21-NOB-01	5/19/2014	15:00	1405033-01	13	13	
21-NOB-01	21-NOB-01	6/2/2014	14:00	1406021-01	23	23	0
21-NOB-01	21-NOB-01	6/2/2014	14:00	1406021-02	11		
21-NOB-01	21-NOB-01	6/16/2014	12:15	1406022-01	46	33	
21-NOB-01	21-NOB-01	6/16/2014	12:15	1406022-02		79	
21-NOB-01	21-NOB-01	6/30/2014	11:30	1406023-01	79	33	
21-NOB-01	21-NOB-01	6/30/2014	11:30	1406023-02	33		
21-NOB-01	21-NOB-01	7/14/2014	10:00	1407024-01	330	170	60
21-NOB-01	21-NOB-01	7/14/2014	10:00	1407024-02	67		
21-NOB-01	21-NOB-01	7/28/2014	12:20	1407025-01	23	49	
21-NOB-01	21-NOB-01	8/11/2014	10:30	1408024-01	460	230	73
21-NOB-01	21-NOB-01	8/11/2014	10:30	1408024-02		790	
21-NOB-01	21-NOB-01	8/25/2014	10:30	1408025-01	230	33	
21-NOB-01	21-NOB-01	8/25/2014	10:30	1408025-02	47		
21-NOB-01	21-NOB-01	9/8/2014	17:15	1409022-01	350	920	7
21-NOB-01	21-NOB-01	9/8/2014	17:15	1409022-02	350		
21-NOB-01	21-NOB-01	9/22/2014	16:15	1409023-01	49	33	
21-NOB-01	21-NOB-01	10/6/2014	10:45	1410011-01	70	70	23
21-NOB-01	21-NOB-01	10/6/2014	15:00	1410011-02	91		17
21-NOB-01	21-NOB-01	10/6/2014	15:00	1410011-03		230	
21-NOB-01	21-NOB-01	10/20/2014	17:00	1410012-01	220	220	
21-NOB-01	21-NOB-01	10/22/2014	9:15	1410064-01	790		
21-NOB-01	21-NOB-01	10/22/2014	9:15	1410064-02	490		
21-NOB-01	21-NOB-01	11/3/2014	17:00	1411012-01	33	33	93
21-NOB-01	21-NOB-01	11/17/2014	15:30	1411013-01	490	40	
21-NOB-01	21-NOB-01	11/17/2014	15:30	1411013-02	27		
21-NOB-01	21-NOB-01	11/17/2014	15:30	1411013-03	490		
21-NOB-01	21-NOB-01	12/1/2014	16:00	1412007-01	49	8	56
21-NOB-01	21-NOB-01	12/1/2014	16:00	1412007-02	6		
21-NOB-01	21-NOB-01	12/15/2014	14:00	1412037-01	220	490	
21-NOB-01	21-NOB-01	12/29/2014	14:20	1412038-01	9		
21-NOB-01	21-NOB-01	12/29/2014	14:20	1412038-02	4		
21-NOB-01	21-NOB-01	1/12/2015	12:30	1501021-01	49	84	

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-01	21-NOB-01	1/26/2015	12:25	1501022-01	33	7	50
21-NOB-01	21-NOB-01	1/26/2015	12:25	1501022-02	23	8	
21-NOB-01	21-NOB-01	2/9/2015	10:30	1502017-01	330	230	
21-NOB-01	21-NOB-01	2/9/2015	10:30	1502017-02	41		
21-NOB-01	21-NOB-01	2/23/2015	12:18	1502018-01	23	8	0
21-NOB-01	21-NOB-01	3/9/2015	10:15	1503014-01	49	17	
21-NOB-01	21-NOB-01	3/9/2015	10:15	1503014-02		23	
21-NOB-01	21-NOB-01	3/23/2015	10:40	1503015-01	23	13	0
21-NOB-01	21-NOB-01	3/23/2015	10:40	1503015-02	5		20
21-NOB-01	21-NOB-01	4/6/2015	14:50	1504052-01	33	11	
21-NOB-01	21-NOB-01	4/6/2015	14:50	1504052-02	330		
21-NOB-02	21-NOB-02	4/21/2014	13:40	1404044-07	17		
21-NOB-02	21-NOB-02	5/5/2014	15:15	1405032-05	35		
21-NOB-02	21-NOB-02	5/5/2014	15:15	1405032-06	65		
21-NOB-02	21-NOB-02	5/19/2014	16:10	1405033-05	64		
21-NOB-02	21-NOB-02	6/2/2014	15:15	1406021-05	4		
21-NOB-02	21-NOB-02	6/16/2014	13:50	1406022-05	1		
21-NOB-02	21-NOB-02	6/16/2014	13:50	1406022-06	1		
21-NOB-02	21-NOB-02	6/30/2014	13:00	1406023-05	11		
21-NOB-02	21-NOB-02	6/30/2014	13:00	1406023-06	15		
21-NOB-02	21-NOB-02	7/14/2014	10:45	1407024-06	14		
21-NOB-02	21-NOB-02	7/28/2014	13:00	1407025-05	45		
21-NOB-02	21-NOB-02	7/28/2014	13:00	1407025-06	43		
21-NOB-02	21-NOB-02	8/11/2014	14:45	1408024-05	26		
21-NOB-02	21-NOB-02	8/25/2014	15:45	1408025-05	5		
21-NOB-02	21-NOB-02	9/8/2014	16:00	1409022-05	5		
21-NOB-02	21-NOB-02	9/8/2014	16:00	1409022-06	12		
21-NOB-02	21-NOB-02	9/22/2014	15:45	1409023-05	7		
21-NOB-02	21-NOB-02	10/6/2014	11:30	1410011-08	53		
21-NOB-02	21-NOB-02	10/20/2014	16:45	1410012-04	22		
21-NOB-02	21-NOB-02	10/20/2014	16:45	1410012-05	47		
21-NOB-02	21-NOB-02	10/22/2014	11:40	1410064-05	72		
21-NOB-02	21-NOB-02	11/3/2014	16:00	1411012-05	53		
21-NOB-02	21-NOB-02	11/17/2014	15:00	1411013-06	8		
21-NOB-02	21-NOB-02	12/1/2014	15:15	1412007-06	36		
21-NOB-02	21-NOB-02	12/1/2014	15:15	1412007-07	19		
21-NOB-02	21-NOB-02	12/15/2014	14:40	1412037-05	7		
21-NOB-02	21-NOB-02	12/29/2014	14:10	1412038-03	1		
21-NOB-02	21-NOB-02	1/12/2015	14:10	1501021-04	1		
21-NOB-02	21-NOB-02	1/12/2015	14:10	1501021-05	8		
21-NOB-02	21-NOB-02	1/26/2015	13:50	1501022-06	29		
21-NOB-02	21-NOB-02	2/9/2015	11:30	1502017-07	150		
21-NOB-02	21-NOB-02	2/23/2015	13:37	1502018-06	1		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-02	21-NOB-02	2/23/2015	13:37	1502018-07	1		
21-NOB-02	21-NOB-02	3/9/2015	11:05	1503014-05	19		
21-NOB-02	21-NOB-02	3/23/2015	11:25	1503015-05	35		
21-NOB-02	21-NOB-02	4/6/2015	15:30	1504052-05	6		
21-NOB-02	21-NOB-02	4/6/2015	15:30	1504052-06	3		
21-NOB-03	21-NOB-03	4/21/2014	14:00	1404044-08	4		
21-NOB-03	21-NOB-03	5/5/2014	15:40	1405032-07	44		
21-NOB-03	21-NOB-03	5/5/2014	15:40	1405032-08	44		
21-NOB-03	21-NOB-03	5/19/2014	14:00	1405033-06	4		
21-NOB-03	21-NOB-03	6/2/2014	13:45	1406021-06	11		
21-NOB-03	21-NOB-03	6/16/2014	11:30	1406022-07	20		
21-NOB-03	21-NOB-03	6/16/2014	11:30	1406022-08	28		
21-NOB-03	21-NOB-03	6/30/2014	10:00	1406023-07	79		
21-NOB-03	21-NOB-03	7/14/2014	11:10	1407024-07	33		
21-NOB-03	21-NOB-03	7/28/2014	11:20	1407025-07	37		
21-NOB-03	21-NOB-03	7/28/2014	11:20	1407025-08	25		
21-NOB-03	21-NOB-03	8/11/2014	11:00	1408024-06	130		
21-NOB-03	21-NOB-03	8/25/2014	10:45	1408025-06	35		
21-NOB-03	21-NOB-03	9/8/2014	15:45	1409022-07	15		
21-NOB-03	21-NOB-03	9/8/2014	15:45	1409022-08	9		
21-NOB-03	21-NOB-03	9/22/2014	14:45	1409023-06	52		
21-NOB-03	21-NOB-03	10/6/2014	10:30	1410011-09	27		
21-NOB-03	21-NOB-03	10/20/2014	16:15	1410012-06	110		
21-NOB-03	21-NOB-03	10/20/2014	16:15	1410012-07	140		
21-NOB-03	21-NOB-03	10/22/2014	11:05	1410064-07	300		
21-NOB-03	21-NOB-03	10/22/2014	11:15	1410064-06	290		
21-NOB-03	21-NOB-03	11/3/2014	11:00	1411012-06	18		
21-NOB-03	21-NOB-03	11/17/2014	14:00	1411013-07	2		
21-NOB-03	21-NOB-03	12/1/2014	14:30	1412007-08	6		
21-NOB-03	21-NOB-03	12/1/2014	14:30	1412007-09	5		
21-NOB-03	21-NOB-03	12/15/2014	13:45	1412037-06	5		
21-NOB-03	21-NOB-03	12/29/2014	14:00	1412038-04	72		
21-NOB-03	21-NOB-03	1/12/2015	14:30	1501021-06	4		
21-NOB-03	21-NOB-03	1/12/2015	14:30	1501021-07	2		
21-NOB-03	21-NOB-03	1/26/2015	11:10	1501022-07	2		
21-NOB-03	21-NOB-03	2/9/2015	10:10	1502017-08	2		
21-NOB-03	21-NOB-03	2/23/2015	11:42	1502018-08	1		
21-NOB-03	21-NOB-03	2/23/2015	11:42	1502018-09	1		
21-NOB-03	21-NOB-03	3/9/2015	11:15	1503014-06	1		
21-NOB-03	21-NOB-03	3/23/2015	11:40	1503015-06	1		
21-NOB-03	21-NOB-03	4/6/2015	14:25	1504052-07	2		
21-NOB-03	21-NOB-03	4/6/2015	14:25	1504052-08	1		
21-NOB-04	21-NOB-04	4/21/2014	14:15	1404044-09	3		100

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-04	21-NOB-04	4/21/2014	14:15	1404044-10	9		
21-NOB-04	21-NOB-04	5/5/2014	11:00	1405032-09	55		2
21-NOB-04	21-NOB-04	5/5/2014	11:00	1405032-10			2
21-NOB-04	21-NOB-04	5/19/2014	14:30	1405033-07	9		
21-NOB-04	21-NOB-04	6/2/2014	13:15	1406021-07	10		50
21-NOB-04	21-NOB-04	6/2/2014	13:15	1406021-08	6		
21-NOB-04	21-NOB-04	6/16/2014	11:45	1406022-09	20		
21-NOB-04	21-NOB-04	6/30/2014	10:30	1406023-08	36		
21-NOB-04	21-NOB-04	7/14/2014	11:00	1407024-08	76		75
21-NOB-04	21-NOB-04	7/14/2014	11:00	1407024-09	69		
21-NOB-04	21-NOB-04	7/28/2014	11:55	1407025-09	44		
21-NOB-04	21-NOB-04	8/11/2014	11:15	1408024-07	98		72
21-NOB-04	21-NOB-04	8/25/2014	11:30	1408025-07	45		
21-NOB-04	21-NOB-04	8/25/2014	11:30	1408025-08	31		
21-NOB-04	21-NOB-04	9/8/2014	15:30	1409022-09	56		4
21-NOB-04	21-NOB-04	9/22/2014	15:00	1409023-07	52		
21-NOB-04	21-NOB-04	10/6/2014	16:00	1410011-10	45		9
21-NOB-04	21-NOB-04	10/6/2014	16:00	1410011-11	28		
21-NOB-04	21-NOB-04	10/20/2014	16:30	1410012-08	160		
21-NOB-04	21-NOB-04	10/22/2014	11:05	1410064-08	250		
21-NOB-04	21-NOB-04	10/22/2014	11:05	1410064-09	260		
21-NOB-04	21-NOB-04	11/3/2014	15:45	1411012-07	49		59
21-NOB-04	21-NOB-04	11/3/2014	15:45	1411012-08	47		
21-NOB-04	21-NOB-04	11/17/2014	14:30	1411013-08	10		
21-NOB-04	21-NOB-04	11/17/2014	14:30	1411013-09	7		
21-NOB-04	21-NOB-04	12/1/2014	15:00	1412007-10	10		60
21-NOB-04	21-NOB-04	12/15/2014	12:45	1412037-07	6		
21-NOB-04	21-NOB-04	12/29/2014	12:30	1412038-05	1		
21-NOB-04	21-NOB-04	12/29/2014	12:30	1412038-06	1		
21-NOB-04	21-NOB-04	1/12/2015	11:30	1501021-08	3		
21-NOB-04	21-NOB-04	1/26/2015	11:50	1501022-08	3		100
21-NOB-04	21-NOB-04	2/9/2015	10:00	1502017-09	5		
21-NOB-04	21-NOB-04	2/9/2015	10:00	1502017-10	9		
21-NOB-04	21-NOB-04	2/23/2015	11:25	1502018-10	2		0
21-NOB-04	21-NOB-04	3/9/2015	11:45	1503014-07	1		
21-NOB-04	21-NOB-04	3/23/2015	12:00	1503015-07	5		0
21-NOB-04	21-NOB-04	3/23/2015	12:00	1503015-08	5		
21-NOB-04	21-NOB-04	4/6/2015	11:20	1504052-09	3		
21-NOB-05	21-NOB-05	4/21/2014	14:30	1404044-11	1		
21-NOB-05	21-NOB-05	5/5/2014	16:00	1405032-11	1		
21-NOB-05	21-NOB-05	5/5/2014	16:00	1405032-12	1		
21-NOB-05	21-NOB-05	5/19/2014	16:40	1405033-08	1		
21-NOB-05	21-NOB-05	6/2/2014	15:45	1406021-09	1		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-05	21-NOB-05	6/16/2014	14:15	1406022-10	1		
21-NOB-05	21-NOB-05	6/16/2014	14:15	1406022-11	1		
21-NOB-05	21-NOB-05	10/20/2014	14:45	1410012-09	32		
21-NOB-05	21-NOB-05	10/20/2014	14:45	1410012-10	39		
21-NOB-05	21-NOB-05	10/22/2014	11:45	1410064-10	37		
21-NOB-05	21-NOB-05	11/3/2014	14:55	1411012-09	84		
21-NOB-05	21-NOB-05	11/17/2014	13:30	1411013-10	33		
21-NOB-05	21-NOB-05	12/1/2014	13:45	1412007-11	12		
21-NOB-05	21-NOB-05	12/1/2014	13:45	1412007-12	23		
21-NOB-05	21-NOB-05	12/15/2014	12:00	1412037-08	24		
21-NOB-05	21-NOB-05	12/29/2014	12:25	1412038-07	3		
21-NOB-05	21-NOB-05	1/12/2015	11:40	1501021-09	2		
21-NOB-05	21-NOB-05	1/12/2015	11:40	1501021-10	1		
21-NOB-05	21-NOB-05	1/26/2015	14:40	1501022-09	1		
21-NOB-05	21-NOB-05	2/9/2015	13:45	1502017-11	18		
21-NOB-05	21-NOB-05	3/23/2015	14:05	1503015-09	22		
21-NOB-05	21-NOB-05	4/6/2015	11:30	1504052-10	95		
21-NOB-05	21-NOB-05	4/6/2015	11:30	1504052-11	71		
21-NOB-06	21-NOB-06	4/21/2014	15:00	1404044-13	3		
21-NOB-06	21-NOB-06	5/5/2014	16:30	1405032-14	11		
21-NOB-06	21-NOB-06	5/5/2014	16:30	1405032-15	13		
21-NOB-06	21-NOB-06	5/19/2014	17:15	1405033-10	2		
21-NOB-06	21-NOB-06	6/2/2014	16:15	1406021-12	11		
21-NOB-06	21-NOB-06	6/16/2014	14:45	1406022-13	4		
21-NOB-06	21-NOB-06	6/16/2014	14:45	1406022-14	5		
21-NOB-06	21-NOB-06	6/30/2014	13:45	1406023-11	30		
21-NOB-06	21-NOB-06	7/14/2014	11:45	1407024-12	35		
21-NOB-06	21-NOB-06	7/28/2014	14:10	1407025-12	35		
21-NOB-06	21-NOB-06	7/28/2014	14:10	1407025-13	36		
21-NOB-06	21-NOB-06	8/11/2014	14:00	1408024-11	120		
21-NOB-06	21-NOB-06	8/25/2014	15:00	1408025-10	60		
21-NOB-06	21-NOB-06	9/8/2014	14:30	1409022-11	48		
21-NOB-06	21-NOB-06	9/8/2014	14:30	1409022-12	29		
21-NOB-06	21-NOB-06	9/22/2014	14:05	1409023-09	91		
21-NOB-06	21-NOB-06	10/6/2014	12:15	1410011-14	39		
21-NOB-06	21-NOB-06	10/20/2014	13:45	1410012-13	75		
21-NOB-06	21-NOB-06	10/20/2014	13:45	1410012-14	140		
21-NOB-06	21-NOB-06	10/22/2014	12:05	1410064-12	250		
21-NOB-06	21-NOB-06	11/3/2014	14:45	1411012-11	180		
21-NOB-06	21-NOB-06	11/17/2014	13:15	1411013-12	1		
21-NOB-06	21-NOB-06	12/1/2014	13:30	1412007-14	31		
21-NOB-06	21-NOB-06	12/1/2014	13:30	1412007-15	19		
21-NOB-06	21-NOB-06	12/15/2014	11:50	1412037-10	8		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-06	21-NOB-06	12/29/2014	12:40	1412038-08	1		
21-NOB-06	21-NOB-06	1/12/2015	14:50	1501021-12	1		
21-NOB-06	21-NOB-06	1/12/2015	14:50	1501021-13	3		
21-NOB-06	21-NOB-06	1/26/2015	15:00	1501022-11	2		
21-NOB-06	21-NOB-06	2/9/2015	14:05	1502017-13	2		
21-NOB-06	21-NOB-06	2/23/2015	14:30	1502018-14	1		
21-NOB-06	21-NOB-06	2/23/2015	14:30	1502018-15	1		
21-NOB-06	21-NOB-06	3/9/2015	14:35	1503014-11	1		
21-NOB-06	21-NOB-06	3/23/2015	14:20	1503015-11	1		
21-NOB-06	21-NOB-06	4/6/2015	11:50	1504052-13	2		
21-NOB-06	21-NOB-06	4/6/2015	11:50	1504052-14	1		
21-NOB-07	21-NOB-07	4/21/2014	15:15	1404044-14	1		
21-NOB-07	21-NOB-07	5/5/2014	16:45	1405032-16	1		
21-NOB-07	21-NOB-07	5/5/2014	16:45	1405032-17	1		
21-NOB-07	21-NOB-07	10/20/2014	13:30	1410012-32	36		
21-NOB-07	21-NOB-07	10/22/2014	12:10	1410064-13	44		
21-NOB-07	21-NOB-07	11/3/2014	14:30	1411012-12	120		
21-NOB-07	21-NOB-07	12/1/2014	13:15	1412007-16	110		
21-NOB-07	21-NOB-07	12/1/2014	13:15	1412007-17	190		
21-NOB-07	21-NOB-07	12/15/2014	11:45	1412037-11	5		
21-NOB-07	21-NOB-07	12/29/2014	12:45	1412038-09	1		
21-NOB-07	21-NOB-07	1/26/2015	15:20	1501022-12	1		
21-NOB-07	21-NOB-07	2/9/2015	14:15	1502017-14	5		
21-NOB-07	21-NOB-07	3/23/2015	14:30	1503015-12	1		
21-NOB-08	21-NOB-08	4/21/2014	15:25	1404044-15	1		0
21-NOB-08	21-NOB-08	4/21/2014	15:25	1404044-16	3		
21-NOB-08	21-NOB-08	5/5/2014	17:00	1405032-18	15		0
21-NOB-08	21-NOB-08	5/19/2014	13:30	1405033-12	15		
21-NOB-08	21-NOB-08	5/19/2014	14:30	1405033-21	6		
21-NOB-08	21-NOB-08	6/2/2014	12:45	1406021-14	5		40
21-NOB-08	21-NOB-08	6/2/2014	12:45	1406021-15	8		50
21-NOB-08	21-NOB-08	6/16/2014	11:00	1406022-17	20		
21-NOB-08	21-NOB-08	6/30/2014	11:00	1406023-12	21		
21-NOB-08	21-NOB-08	7/14/2014	12:00	1407024-13	80		50
21-NOB-08	21-NOB-08	7/14/2014	12:00	1407024-14	56		
21-NOB-08	21-NOB-08	7/28/2014	14:25	1407025-14	22		
21-NOB-08	21-NOB-08	8/11/2014	11:45	1408024-12	9		33
21-NOB-08	21-NOB-08	8/25/2014	12:15	1408025-11	15		
21-NOB-08	21-NOB-08	8/25/2014	12:15	1408025-12	18		
21-NOB-08	21-NOB-08	9/8/2014	14:15	1409022-13	13		0
21-NOB-08	21-NOB-08	9/22/2014	13:45	1409023-10	12		
21-NOB-08	21-NOB-08	10/6/2014	13:00	1410011-16	14		
21-NOB-08	21-NOB-08	10/6/2014	13:00	1410011-17	10		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-08	21-NOB-08	10/20/2014	14:00	1410012-15	79		
21-NOB-08	21-NOB-08	10/22/2014	12:25	1410064-14	440		
21-NOB-08	21-NOB-08	11/3/2014	14:00	1411012-13	73		72
21-NOB-08	21-NOB-08	11/17/2014	12:45	1411013-14	6		
21-NOB-08	21-NOB-08	11/17/2014	12:45	1411013-15	4		
21-NOB-08	21-NOB-08	12/1/2014	13:00	1412007-18	6		67
21-NOB-08	21-NOB-08	12/1/2014	13:00	1412007-19			60
21-NOB-08	21-NOB-08	12/15/2014	11:30	1412037-12	6		
21-NOB-08	21-NOB-08	12/29/2014	12:50	1412038-10	4		
21-NOB-08	21-NOB-08	12/29/2014	12:50	1412038-11	2		
21-NOB-08	21-NOB-08	1/12/2015	11:00	1501021-16	1		
21-NOB-08	21-NOB-08	1/26/2015	15:35	1501022-13	8		100
21-NOB-08	21-NOB-08	2/9/2015	13:30	1502017-15	6		
21-NOB-08	21-NOB-08	2/9/2015	13:30	1502017-16	6		
21-NOB-08	21-NOB-08	2/23/2015	15:00	1502018-18	1		0
21-NOB-08	21-NOB-08	3/9/2015	14:25	1503014-13	1		
21-NOB-08	21-NOB-08	3/23/2015	13:55	1503015-13	9		11
21-NOB-08	21-NOB-08	3/23/2015	13:55	1503015-14	9		
21-NOB-08	21-NOB-08	4/6/2015	12:30	1504052-17	5		
21-NOB-09	21-NOB-09	4/21/2014	15:35	1404044-17	74		
21-NOB-09	21-NOB-09	5/5/2014	17:45	1405032-19	12		
21-NOB-09	21-NOB-09	5/5/2014	17:45	1405032-20	6		
21-NOB-09	21-NOB-09	5/19/2014	18:00	1405033-14	1		
21-NOB-09	21-NOB-09	6/2/2014	16:45	1406021-16	1		
21-NOB-09	21-NOB-09	6/16/2014	15:30	1406022-18	3		
21-NOB-09	21-NOB-09	6/16/2014	15:30	1406022-19	1		
21-NOB-09	21-NOB-09	6/30/2014	14:15	1406023-13	32		
21-NOB-09	21-NOB-09	7/15/2014	11:25	1407024-15	44		
21-NOB-09	21-NOB-09	7/28/2014	14:50	1407025-15	28		
21-NOB-09	21-NOB-09	7/28/2014	14:50	1407025-16	28		
21-NOB-09	21-NOB-09	8/11/2014	13:30	1408024-13	9		
21-NOB-09	21-NOB-09	8/25/2014	14:30	1408025-13	660		
21-NOB-09	21-NOB-09	9/8/2014	13:15	1409022-14	230		
21-NOB-09	21-NOB-09	9/8/2014	13:15	1409022-15	190		
21-NOB-09	21-NOB-09	9/22/2014	13:15	1409023-11	68		
21-NOB-09	21-NOB-09	10/6/2014	13:15	1410011-18	23		
21-NOB-09	21-NOB-09	10/20/2014	12:30	1410012-16	84		
21-NOB-09	21-NOB-09	10/20/2014	12:30	1410012-17	76		
21-NOB-09	21-NOB-09	10/22/2014	10:15	1410064-15	89		
21-NOB-09	21-NOB-09	10/22/2014	10:15	1410064-16	140		
21-NOB-09	21-NOB-09	11/3/2014	13:15	1411012-14	4		
21-NOB-09	21-NOB-09	11/17/2014	12:00	1411013-16	1		
21-NOB-09	21-NOB-09	12/1/2014	12:00	1412007-20	2		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-09	21-NOB-09	12/1/2014	12:00	1412007-21	4		
21-NOB-09	21-NOB-09	12/15/2014	11:15	1412037-13	3		
21-NOB-09	21-NOB-09	12/29/2014	13:00	1412038-12	1		
21-NOB-09	21-NOB-09	1/12/2015	15:30	1501021-17	2		
21-NOB-09	21-NOB-09	1/12/2015	15:30	1501021-18	1		
21-NOB-09	21-NOB-09	1/26/2015	15:50	1501022-14	1		
21-NOB-09	21-NOB-09	2/9/2015	14:40	1502017-17	5		
21-NOB-09	21-NOB-09	2/23/2015	15:15	1502018-19	1		
21-NOB-09	21-NOB-09	2/23/2015	15:15	1502018-20	3		
21-NOB-09	21-NOB-09	3/9/2015	14:05	1503014-14	1		
21-NOB-09	21-NOB-09	3/23/2015	14:35	1503015-15	4		
21-NOB-09	21-NOB-09	4/6/2015	12:35	1504052-18	2		
21-NOB-09	21-NOB-09	4/6/2015	12:35	1504052-19	3		
21-NOB-10	21-NOB-10	4/21/2014	15:40	1404044-18	1		
21-NOB-10	21-NOB-10	5/5/2014	18:00	1405032-21	11		
21-NOB-10	21-NOB-10	5/5/2014	18:00	1405032-22	13		
21-NOB-10	21-NOB-10	5/19/2014	18:10	1405033-15	2		
21-NOB-10	21-NOB-10	6/2/2014	17:00	1406021-17	1		
21-NOB-10	21-NOB-10	6/16/2014	15:45	1406022-20	3		
21-NOB-10	21-NOB-10	6/16/2014	15:45	1406022-21	8		
21-NOB-10	21-NOB-10	6/30/2014	14:00	1406023-14	13		
21-NOB-10	21-NOB-10	7/15/2014	11:20	1407024-16	33		
21-NOB-10	21-NOB-10	7/15/2014	11:20	1407024-17	41		
21-NOB-10	21-NOB-10	7/28/2014	15:00	1407025-17	26		
21-NOB-10	21-NOB-10	7/28/2014	15:00	1407025-18	27		
21-NOB-10	21-NOB-10	8/11/2014	13:15	1408024-14	330		
21-NOB-10	21-NOB-10	8/25/2014	14:15	1408025-14	500		
21-NOB-10	21-NOB-10	9/8/2014	13:05	1409022-16	200		
21-NOB-10	21-NOB-10	9/8/2014	13:05	1409022-17	160		
21-NOB-10	21-NOB-10	9/22/2014	13:00	1409023-12	180		
21-NOB-10	21-NOB-10	10/6/2014	13:40	1410011-20	620		
21-NOB-10	21-NOB-10	10/20/2014	12:15	1410012-18	79		
21-NOB-10	21-NOB-10	10/20/2014	12:15	1410012-19	49		
21-NOB-10	21-NOB-10	10/22/2014	10:15	1410064-17	120		
21-NOB-10	21-NOB-10	10/22/2014	10:15	1410064-18	100		
21-NOB-10	21-NOB-10	11/3/2014	13:00	1411012-15	4		
21-NOB-10	21-NOB-10	11/17/2014	11:50	1411013-17	3		
21-NOB-10	21-NOB-10	12/1/2014	11:45	1412007-22	15		
21-NOB-10	21-NOB-10	12/15/2014	10:55	1412037-14	1		
21-NOB-10	21-NOB-10	12/29/2014	13:05	1412038-13	1		
21-NOB-10	21-NOB-10	1/12/2015	15:15	1501021-19	1		
21-NOB-10	21-NOB-10	1/12/2015	15:15	1501021-20	1		
21-NOB-10	21-NOB-10	1/26/2015	16:05	1501022-16	1		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-10	21-NOB-10	2/9/2015	15:00	1502017-19	1		
21-NOB-10	21-NOB-10	2/23/2015	15:30	1502018-22	1		
21-NOB-10	21-NOB-10	2/23/2015	15:30	1502018-23	1		
21-NOB-10	21-NOB-10	3/9/2015	13:55	1503014-15	1		
21-NOB-10	21-NOB-10	3/23/2015	14:55	1503015-16	1		
21-NOB-10	21-NOB-10	4/6/2015	12:50	1504052-20	1		
21-NOB-10	21-NOB-10	4/6/2015	12:50	1504052-21	1		
21-NOB-11	21-NOB-11	4/21/2014	16:10	1404044-19	1		
21-NOB-11	21-NOB-11	5/5/2014	18:06	1405032-23	10		
21-NOB-11	21-NOB-11	5/19/2014	18:25	1405033-16	4		
21-NOB-11	21-NOB-11	5/19/2014	18:25	1405033-17	1		
21-NOB-11	21-NOB-11	6/2/2014	17:15	1406021-18	1		
21-NOB-11	21-NOB-11	6/16/2014	16:00	1406022-22	1		
21-NOB-11	21-NOB-11	6/30/2014	14:30	1406023-15	3		
21-NOB-11	21-NOB-11	6/30/2014	14:30	1406023-16	4		
21-NOB-11	21-NOB-11	7/15/2014	11:15	1407024-18	29		
21-NOB-11	21-NOB-11	7/28/2014	15:20	1407025-19	4		
21-NOB-11	21-NOB-11	8/11/2014	13:00	1408024-15	4		
21-NOB-11	21-NOB-11	8/11/2014	13:00	1408024-16	6		
21-NOB-11	21-NOB-11	8/25/2014	14:00	1408025-15	1		
21-NOB-11	21-NOB-11	9/8/2014	12:45	1409022-18	3		
21-NOB-11	21-NOB-11	9/22/2014	12:45	1409023-13	4		
21-NOB-11	21-NOB-11	9/22/2014	12:45	1409023-14	4		
21-NOB-11	21-NOB-11	10/6/2014	13:45	1410011-22	4		
21-NOB-11	21-NOB-11	10/20/2014	12:00	1410012-20	61		
21-NOB-11	21-NOB-11	10/22/2014	10:20	1410064-19	190		
21-NOB-11	21-NOB-11	11/3/2014	12:30	1411012-16	8		
21-NOB-11	21-NOB-11	11/3/2014	12:30	1411012-17	4		
21-NOB-11	21-NOB-11	11/17/2014	11:30	1411013-18	2		
21-NOB-11	21-NOB-11	12/1/2014	11:15	1412007-23	1		
21-NOB-11	21-NOB-11	12/15/2014	10:30	1412037-15	1		
21-NOB-11	21-NOB-11	12/15/2014	10:30	1412037-16	1		
21-NOB-11	21-NOB-11	12/29/2014	13:10	1412038-14	1		
21-NOB-11	21-NOB-11	1/12/2015	15:45	1501021-21	1		
21-NOB-11	21-NOB-11	1/26/2015	16:30	1501022-18	1		
21-NOB-11	21-NOB-11	1/26/2015	16:30	1501022-19	1		
21-NOB-11	21-NOB-11	2/9/2015	15:05	1502017-21	1		
21-NOB-11	21-NOB-11	2/23/2015	15:45	1502018-25	2		
21-NOB-11	21-NOB-11	3/9/2015	13:20	1503014-16	1		
21-NOB-11	21-NOB-11	3/9/2015	13:20	1503014-17	1		
21-NOB-11	21-NOB-11	3/23/2015	15:25	1503015-17	1		
21-NOB-11	21-NOB-11	4/6/2015	13:15	1504052-22	1		
21-NOB-12	21-NOB-12	4/21/2014	16:16	1404044-20	5		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-12	21-NOB-12	5/5/2014	18:15	1405032-24	10		
21-NOB-12	21-NOB-12	5/19/2014	18:40	1405033-18	2		
21-NOB-12	21-NOB-12	5/19/2014	18:40	1405033-19	1		
21-NOB-12	21-NOB-12	6/2/2014	17:45	1406021-19	4		
21-NOB-12	21-NOB-12	6/16/2014	16:15	1406022-23	1		
21-NOB-12	21-NOB-12	6/30/2014	14:45	1406023-17	5		
21-NOB-12	21-NOB-12	6/30/2014	14:45	1406023-18	1		
21-NOB-12	21-NOB-12	7/15/2014	11:30	1407024-19	8		
21-NOB-12	21-NOB-12	7/28/2014	15:30	1407025-20	10		
21-NOB-12	21-NOB-12	8/11/2014	12:45	1408024-17	6		
21-NOB-12	21-NOB-12	8/11/2014	12:45	1408024-18	1		
21-NOB-12	21-NOB-12	8/25/2014	13:30	1408025-16	2		
21-NOB-12	21-NOB-12	9/8/2014	12:00	1409022-19	37		
21-NOB-12	21-NOB-12	9/22/2014	12:30	1409023-15	12		
21-NOB-12	21-NOB-12	9/22/2014	12:30	1409023-16	14		
21-NOB-12	21-NOB-12	10/6/2014	14:00	1410011-23	24		
21-NOB-12	21-NOB-12	10/20/2014	11:30	1410012-21	99		
21-NOB-12	21-NOB-12	10/22/2014	10:10	1410064-20	140		
21-NOB-12	21-NOB-12	11/3/2014	12:25	1411012-18	140		
21-NOB-12	21-NOB-12	11/3/2014	12:25	1411012-19	100		
21-NOB-12	21-NOB-12	11/17/2014	11:15	1411013-19	25		
21-NOB-12	21-NOB-12	12/1/2014	11:00	1412007-24	69		
21-NOB-12	21-NOB-12	12/15/2014	10:15	1412037-17	1		
21-NOB-12	21-NOB-12	12/15/2014	10:15	1412037-18	3		
21-NOB-12	21-NOB-12	12/29/2014	13:15	1412038-15	1		
21-NOB-12	21-NOB-12	1/12/2015	16:10	1501021-22	1		
21-NOB-12	21-NOB-12	1/26/2015	10:50	1501022-20	1		
21-NOB-12	21-NOB-12	1/26/2015	10:50	1501022-21	5		
21-NOB-12	21-NOB-12	2/9/2015	15:20	1502017-22	2		
21-NOB-12	21-NOB-12	2/23/2015	16:05	1502018-26	2		
21-NOB-12	21-NOB-12	3/9/2015	12:10	1503014-18	1		
21-NOB-12	21-NOB-12	3/9/2015	12:10	1503014-19	1		
21-NOB-12	21-NOB-12	3/23/2015	15:30	1503015-18	37		
21-NOB-12	21-NOB-12	4/6/2015	13:30	1504052-23	9		
21-NOB-13	21-NOB-13	4/21/2014	17:00	1404044-21	5		
21-NOB-13	21-NOB-13	5/5/2014	14:25	1405032-25	28		
21-NOB-13	21-NOB-13	5/19/2014	13:00	1405033-20	4		
21-NOB-13	21-NOB-13	6/2/2014	12:15	1406021-20	5		
21-NOB-13	21-NOB-13	6/16/2014	16:45	1406022-16	12		
21-NOB-13	21-NOB-13	6/16/2014	16:45	1406022-24	1		
21-NOB-13	21-NOB-13	6/30/2014	11:15	1406023-19	19		
21-NOB-13	21-NOB-13	6/30/2014	11:15	1406023-20	14		
21-NOB-13	21-NOB-13	7/15/2014	12:10	1407024-20	21		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-13	21-NOB-13	7/28/2014	15:35	1407025-21	88		
21-NOB-13	21-NOB-13	8/11/2014	12:15	1408024-19	96		
21-NOB-13	21-NOB-13	8/11/2014	12:15	1408024-20	92		
21-NOB-13	21-NOB-13	8/25/2014	12:45	1408025-17	36		
21-NOB-13	21-NOB-13	9/8/2014	11:45	1409022-20	20		
21-NOB-13	21-NOB-13	9/22/2014	11:45	1409023-17	83		
21-NOB-13	21-NOB-13	9/22/2014	11:45	1409023-18	44		
21-NOB-13	21-NOB-13	10/6/2014	14:15	1410011-24	28		
21-NOB-13	21-NOB-13	10/20/2014	16:00	1410012-22	83		
21-NOB-13	21-NOB-13	10/22/2014	10:05	1410064-21	110		
21-NOB-13	21-NOB-13	11/3/2014	12:00	1411012-20	35		
21-NOB-13	21-NOB-13	11/3/2014	12:00	1411012-21	49		
21-NOB-13	21-NOB-13	11/17/2014	10:45	1411013-20	10		
21-NOB-13	21-NOB-13	12/1/2014	10:30	1412007-25	4		
21-NOB-13	21-NOB-13	12/15/2014	13:00	1412037-19	4		
21-NOB-13	21-NOB-13	12/15/2014	13:00	1412037-20	5		
21-NOB-13	21-NOB-13	12/29/2014	13:20	1412038-16	9		
21-NOB-13	21-NOB-13	1/12/2015	10:15	1501021-23	1		
21-NOB-13	21-NOB-13	1/26/2015	10:31	1501022-22	6		
21-NOB-13	21-NOB-13	1/26/2015	10:31	1501022-23	3		
21-NOB-13	21-NOB-13	2/9/2015	12:20	1502017-23	7		
21-NOB-13	21-NOB-13	2/23/2015	10:35	1502018-27	1		
21-NOB-13	21-NOB-13	3/9/2015	12:35	1503014-20	1		
21-NOB-13	21-NOB-13	3/9/2015	12:35	1503014-21	1		
21-NOB-13	21-NOB-13	3/23/2015	12:50	1503015-19	2		
21-NOB-13	21-NOB-13	4/6/2015	11:00	1504052-24	2		
21-NOB-14	21-NOB-14	4/21/2014	17:30	1404044-22	5		
21-NOB-14	21-NOB-14	5/5/2014	14:40	1405032-26	8		
21-NOB-14	21-NOB-14	5/19/2014	19:15	1405033-22	3		
21-NOB-14	21-NOB-14	5/19/2014	19:15	1405033-23	1		
21-NOB-14	21-NOB-14	6/2/2014	18:00	1406021-21	3		
21-NOB-14	21-NOB-14	6/16/2014	17:00	1406022-25	8		
21-NOB-14	21-NOB-14	6/30/2014	15:00	1406023-21	80		
21-NOB-14	21-NOB-14	6/30/2014	15:00	1406023-22	140		
21-NOB-14	21-NOB-14	7/15/2014	12:00	1407024-21	27		
21-NOB-14	21-NOB-14	7/15/2014	12:00	1407024-22	11		
21-NOB-14	21-NOB-14	10/20/2014	15:15	1410012-23	40		
21-NOB-14	21-NOB-14	10/22/2014	10:00	1410064-22	87		
21-NOB-14	21-NOB-14	11/3/2014	11:30	1411012-22	11		
21-NOB-14	21-NOB-14	11/3/2014	11:30	1411012-23	8		
21-NOB-14	21-NOB-14	11/17/2014	10:15	1411013-21	7		
21-NOB-14	21-NOB-14	12/1/2014	10:15	1412007-26	6		
21-NOB-14	21-NOB-14	12/15/2014	9:45	1412037-21	4		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-14	21-NOB-14	12/15/2014	9:45	1412037-22	4		
21-NOB-14	21-NOB-14	12/29/2014	13:30	1412038-17	19		
21-NOB-14	21-NOB-14	1/12/2015	10:00	1501021-24	2		
21-NOB-14	21-NOB-14	1/26/2015	10:10	1501022-24	19		
21-NOB-14	21-NOB-14	1/26/2015	10:10	1501022-25	13		
21-NOB-14	21-NOB-14	2/9/2015	12:40	1502017-24	4		
21-NOB-14	21-NOB-14	2/23/2015	10:15	1502018-28	2		
21-NOB-14	21-NOB-14	3/9/2015	12:15	1503014-22	1		
21-NOB-14	21-NOB-14	3/9/2015	12:15	1503014-23	1		
21-NOB-14	21-NOB-14	3/23/2015	12:30	1503015-20	56		
21-NOB-14	21-NOB-14	4/6/2015	10:30	1504052-25	3		
21-NOB-15	21-NOB-15	4/21/2014	18:00	1404044-23	2		100
21-NOB-15	21-NOB-15	4/21/2014	18:00	1404044-24	8		
21-NOB-15	21-NOB-15	5/5/2014	13:15	1405032-27	72		0
21-NOB-15	21-NOB-15	5/19/2014	12:30	1405033-24	14		
21-NOB-15	21-NOB-15	6/2/2014	11:45	1406021-22	19		47
21-NOB-15	21-NOB-15	6/2/2014	11:45	1406021-23	18		
21-NOB-15	21-NOB-15	7/1/2014	10:45	1406023-23	14		
21-NOB-15	21-NOB-15	7/15/2014	12:20	1407024-23	81		74
21-NOB-15	21-NOB-15	7/15/2014	12:20	1407024-24	100		
21-NOB-15	21-NOB-15	7/29/2014	11:45	1407025-23	44		
21-NOB-15	21-NOB-15	8/12/2014	10:00	1408024-23	200		45
21-NOB-15	21-NOB-15	8/26/2014	10:30	1408025-18	44		
21-NOB-15	21-NOB-15	8/26/2014	10:30	1408025-19	63		
21-NOB-15	21-NOB-15	9/9/2014	16:30	1409022-21	36		81
21-NOB-15	21-NOB-15	9/9/2014	16:30	1409022-22	49		
21-NOB-15	21-NOB-15	9/22/2014	17:20	1409023-19	14		
21-NOB-15	21-NOB-15	10/7/2014	15:50	1410011-26	92		100
21-NOB-15	21-NOB-15	10/7/2014	15:50	1410011-27	160		
21-NOB-15	21-NOB-15	10/21/2014	15:45	1410012-24	80		
21-NOB-15	21-NOB-15	10/22/2014	10:45	1410064-23	230		
21-NOB-15	21-NOB-15	10/22/2014	10:45	1410064-24	210		
21-NOB-15	21-NOB-15	11/4/2014	14:00	1411012-24	150		0
21-NOB-15	21-NOB-15	11/18/2014	14:35	1411013-22	3		
21-NOB-15	21-NOB-15	11/18/2014	14:35	1411013-23	2		
21-NOB-15	21-NOB-15	12/2/2014	14:30	1412007-27	14		36
21-NOB-15	21-NOB-15	12/16/2014	14:45	1412037-23	12		
21-NOB-15	21-NOB-15	12/29/2014	13:35	1412038-18	3		
21-NOB-15	21-NOB-15	12/29/2014	13:35	1412038-19	2		
21-NOB-15	21-NOB-15	1/14/2015	13:30	1501021-27	6		
21-NOB-15	21-NOB-15	1/27/2015	12:18	1501022-26	9		89
21-NOB-15	21-NOB-15	2/10/2015	10:20	1502017-25	2		
21-NOB-15	21-NOB-15	2/10/2015	10:20	1502017-26	7		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-15	21-NOB-15	2/24/2015	10:30	1502018-29	1		0
21-NOB-15	21-NOB-15	3/10/2015	10:25	1503014-24	1		
21-NOB-15	21-NOB-15	3/24/2015	10:40	1503015-21	11		0
21-NOB-15	21-NOB-15	3/24/2015	10:40	1503015-22	10		
21-NOB-15	21-NOB-15	4/7/2015	10:25	1504052-26	2		
21-NOB-16	21-NOB-16	4/21/2014	18:15	1404044-25	7		71
21-NOB-16	21-NOB-16	4/21/2014	18:15	1404044-26	10		
21-NOB-16	21-NOB-16	5/5/2014	13:30	1405032-28	39		13
21-NOB-16	21-NOB-16	5/19/2014	12:05	1405033-25	15		
21-NOB-16	21-NOB-16	6/2/2014	11:00	1406021-24	23		65
21-NOB-16	21-NOB-16	6/2/2014	11:00	1406021-25	11		
21-NOB-16	21-NOB-16	6/16/2014	10:15	1406022-27	100		
21-NOB-16	21-NOB-16	7/1/2014	13:00	1406023-24	73		
21-NOB-16	21-NOB-16	7/1/2014	13:00	1406023-25	77		
21-NOB-16	21-NOB-16	7/15/2014	12:30	1407024-25	35		87
21-NOB-16	21-NOB-16	7/15/2014	12:30	1407024-26	49		
21-NOB-16	21-NOB-16	7/29/2014	12:15	1407025-24	27		
21-NOB-16	21-NOB-16	8/12/2014	10:30	1408024-24	300		36
21-NOB-16	21-NOB-16	8/12/2014	10:30	1408024-25			40
21-NOB-16	21-NOB-16	9/9/2014	15:14	1409022-24	140		59
21-NOB-16	21-NOB-16	9/9/2014	15:45	1409022-23	150		50
21-NOB-16	21-NOB-16	9/22/2014	17:45	1409023-20	4		
21-NOB-16	21-NOB-16	10/7/2014	15:30	1410011-29	1600		26
21-NOB-16	21-NOB-16	10/7/2014	15:30	1410011-30	1300		
21-NOB-16	21-NOB-16	10/21/2014	15:15	1410012-25	68		
21-NOB-16	21-NOB-16	10/22/2014	10:40	1410064-25	260		
21-NOB-16	21-NOB-16	11/4/2014	13:45	1411012-25	160		6
21-NOB-16	21-NOB-16	11/18/2014	14:05	1411013-24	9		
21-NOB-16	21-NOB-16	11/18/2014	14:05	1411013-25	6		
21-NOB-16	21-NOB-16	12/2/2014	14:20	1412007-28	6		33
21-NOB-16	21-NOB-16	12/16/2014	15:15	1412037-24	25		
21-NOB-16	21-NOB-16	12/29/2014	11:45	1412038-20	10		
21-NOB-16	21-NOB-16	12/29/2014	11:45	1412038-21	14		
21-NOB-16	21-NOB-16	1/14/2015	14:15	1501021-28	18		
21-NOB-16	21-NOB-16	1/27/2015	13:15	1501022-27	10		90
21-NOB-16	21-NOB-16	1/27/2015	13:15	1501022-28	7		71
21-NOB-16	21-NOB-16	2/10/2015	11:10	1502017-27	9		
21-NOB-16	21-NOB-16	2/10/2015	11:10	1502017-28	20		
21-NOB-16	21-NOB-16	2/24/2015	11:25	1502018-30	11		73
21-NOB-16	21-NOB-16	3/10/2015	10:50	1503014-25	5		
21-NOB-16	21-NOB-16	3/24/2015	11:35	1503015-23	15		20
21-NOB-16	21-NOB-16	3/24/2015	11:35	1503015-24	13		
21-NOB-16	21-NOB-16	4/7/2015	11:00	1504052-27	14		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-17	21-NOB-17	4/22/2014	10:30	1404044-27	2		
21-NOB-17	21-NOB-17	5/6/2014	14:10	1405032-29	3		
21-NOB-17	21-NOB-17	5/20/2014	14:15	1405033-26	6		
21-NOB-17	21-NOB-17	5/20/2014	14:15	1405033-27	4		
21-NOB-17	21-NOB-17	6/3/2014	10:45	1406021-26	1		
21-NOB-17	21-NOB-17	10/21/2014	13:00	1410012-29	790		
21-NOB-17	21-NOB-17	10/22/2014	14:05	1410064-26	1300		
21-NOB-17	21-NOB-17	11/4/2014	13:30	1411012-26	130		
21-NOB-17	21-NOB-17	11/4/2014	13:30	1411012-27	100		
21-NOB-17	21-NOB-17	11/18/2014	12:50	1411013-26	37		
21-NOB-17	21-NOB-17	12/2/2014	13:10	1412007-29	11		
21-NOB-17	21-NOB-17	12/16/2014	13:30	1412037-25	10		
21-NOB-17	21-NOB-17	12/16/2014	13:30	1412037-26	10		
21-NOB-17	21-NOB-17	12/29/2014	11:15	1412038-22	17		
21-NOB-17	21-NOB-17	1/14/2015	15:10	1501021-29	3		
21-NOB-17	21-NOB-17	1/27/2015	10:45	1501022-29	3		
21-NOB-17	21-NOB-17	1/27/2015	10:45	1501022-30	2		
21-NOB-17	21-NOB-17	2/10/2015	12:30	1502017-29	3		
21-NOB-17	21-NOB-17	2/24/2015	14:30	1502018-31	3		
21-NOB-17	21-NOB-17	3/10/2015	11:55	1503014-26	5		
21-NOB-17	21-NOB-17	3/10/2015	11:55	1503014-27	4		
21-NOB-17	21-NOB-17	3/24/2015	12:15	1503015-25	37		
21-NOB-17	21-NOB-17	4/7/2015	13:00	1504052-28	49		
21-NOB-18	21-NOB-18	4/22/2014	11:00	1404044-28	9		
21-NOB-18	21-NOB-18	5/6/2014	11:25	1405032-30	5		
21-NOB-18	21-NOB-18	5/20/2014	14:00	1405033-28	31		
21-NOB-18	21-NOB-18	5/20/2014	14:00	1405033-29	27		
21-NOB-18	21-NOB-18	6/3/2014	11:45	1406021-27	14		
21-NOB-18	21-NOB-18	6/3/2014	11:45	1406021-28	13		
21-NOB-18	21-NOB-18	6/17/2014	12:50	1406022-29	15		
21-NOB-18	21-NOB-18	7/1/2014	16:00	1406023-26	16		
21-NOB-18	21-NOB-18	7/1/2014	16:00	1406023-27	14		
21-NOB-18	21-NOB-18	7/29/2014	14:00	1407025-25	1100		
21-NOB-18	21-NOB-18	10/7/2014	14:45	1410011-33	41		
21-NOB-18	21-NOB-18	10/21/2014	12:13	1410012-30	63		
21-NOB-18	21-NOB-18	10/22/2014	14:15	1410064-27	52		
21-NOB-18	21-NOB-18	11/4/2014	13:25	1411012-28	77		
21-NOB-18	21-NOB-18	11/4/2014	13:25	1411012-29	100		
21-NOB-18	21-NOB-18	11/18/2014	12:30	1411013-27	14		
21-NOB-18	21-NOB-18	12/2/2014	13:00	1412007-30	20		
21-NOB-18	21-NOB-18	12/16/2014	13:15	1412037-27	30		
21-NOB-18	21-NOB-18	12/16/2014	13:15	1412037-28	24		
21-NOB-18	21-NOB-18	12/29/2014	11:05	1412038-23	7		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-18	21-NOB-18	1/14/2015	15:30	1501021-30	9		
21-NOB-18	21-NOB-18	1/27/2015	11:11	1501022-31	28		
21-NOB-18	21-NOB-18	1/27/2015	11:11	1501022-32	15		
21-NOB-18	21-NOB-18	2/10/2015	12:10	1502017-30	12		
21-NOB-18	21-NOB-18	2/24/2015	14:15	1502018-32	1		
21-NOB-18	21-NOB-18	3/10/2015	12:15	1503014-28	3		
21-NOB-18	21-NOB-18	3/10/2015	12:15	1503014-29	3		
21-NOB-18	21-NOB-18	3/24/2015	12:35	1503015-26	92		
21-NOB-18	21-NOB-18	4/7/2015	13:15	1504052-29	11		
21-NOB-19	21-NOB-19	4/22/2014	12:00	1404044-29	1		0
21-NOB-19	21-NOB-19	4/22/2014	12:00	1404044-30	2		
21-NOB-19	21-NOB-19	5/6/2014	12:10	1405032-31	45		15
21-NOB-19	21-NOB-19	5/20/2014	12:40	1405033-30	1		
21-NOB-19	21-NOB-19	8/26/2014	11:15	1408025-20	51		
21-NOB-19	21-NOB-19	8/26/2014	11:15	1408025-21	39		
21-NOB-19	21-NOB-19	11/4/2014	13:00	1411012-30	1500		0
21-NOB-19	21-NOB-19	11/18/2014	11:30	1411013-28	8		
21-NOB-19	21-NOB-19	11/18/2014	11:30	1411013-29	6		
21-NOB-19	21-NOB-19	12/2/2014	12:50	1412007-31	2		50
21-NOB-19	21-NOB-19	12/16/2014	13:05	1412037-29	1		
21-NOB-19	21-NOB-19	12/29/2014	11:00	1412038-24	2		
21-NOB-19	21-NOB-19	12/29/2014	11:00	1412038-25	3		
21-NOB-19	21-NOB-19	1/14/2015	15:50	1501021-31	1		
21-NOB-19	21-NOB-19	1/27/2015	11:33	1501022-33	1		100
21-NOB-19	21-NOB-19	2/10/2015	11:50	1502017-31	1		
21-NOB-19	21-NOB-19	2/10/2015	11:50	1502017-32	1		
21-NOB-19	21-NOB-19	2/24/2015	13:52	1502018-33	1		0
21-NOB-19	21-NOB-19	2/24/2015	13:52	1502018-34	2		50
21-NOB-19	21-NOB-19	3/10/2015	12:35	1503014-30	1		
21-NOB-19	21-NOB-19	3/24/2015	12:50	1503015-27	1		0
21-NOB-19	21-NOB-19	3/24/2015	12:50	1503015-28	1		
21-NOB-19	21-NOB-19	4/7/2015	13:45	1504052-30	1		
21-NOB-20	21-NOB-20	4/22/2014	11:15	1404044-31	40		
21-NOB-20	21-NOB-20	5/6/2014	12:40	1405032-32	9		
21-NOB-20	21-NOB-20	10/21/2014	12:00	1410012-34	800		
21-NOB-20	21-NOB-20	10/22/2014	13:30	1410064-29	800		
21-NOB-20	21-NOB-20	11/4/2014	12:50	1411012-31	22000		
21-NOB-20	21-NOB-20	11/4/2014	12:50	1411012-32	24000		
21-NOB-20	21-NOB-20	11/18/2014	11:05	1411013-30	150		
21-NOB-20	21-NOB-20	12/2/2014	11:50	1412007-32	32		
21-NOB-20	21-NOB-20	12/16/2014	12:55	1412037-30	400		
21-NOB-20	21-NOB-20	12/16/2014	12:55	1412037-31	400		
21-NOB-20	21-NOB-20	12/29/2014	11:25	1412038-26	8		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
21-NOB-20	21-NOB-20	1/14/2015	14:55	1501021-32	6		
21-NOB-20	21-NOB-20	1/27/2015	11:45	1501022-34	10		
21-NOB-20	21-NOB-20	1/27/2015	11:45	1501022-35	6		
21-NOB-20	21-NOB-20	2/10/2015	11:30	1502017-33	64		
21-NOB-20	21-NOB-20	2/24/2015	13:40	1502018-35	13		
21-NOB-20	21-NOB-20	3/24/2015	11:55	1503015-29	700		
21-NOB-20	21-NOB-20	4/7/2015	11:35	1504052-31	150		
22-DOH-9	22-DOH-9	4/22/2014	11:45	1404044-34	23		
22-DOH-9	22-DOH-9	5/6/2014	11:45	1405032-34	7.8		
22-DOH-9	22-DOH-9	5/20/2014	12:30	1405033-34	13		
22-DOH-9	22-DOH-9	6/3/2014	12:00	1406021-31	23		
22-DOH-9	22-DOH-9	6/17/2014	13:32	1406022-31	1.8		
22-DOH-9	22-DOH-9	6/17/2014	13:32	1406022-32	1.8		
22-DOH-9	22-DOH-9	7/15/2014	13:00	1407024-28	23		
22-DOH-9	22-DOH-9	7/29/2014	13:30	1407025-26	1.8		
22-DOH-9	22-DOH-9	8/12/2014	11:30	1408024-28	1.8		
22-DOH-9	22-DOH-9	8/26/2014	12:15	1408025-22	23		
22-DOH-9	22-DOH-9	8/26/2014	12:15	1408025-23	33		
22-DOH-9	22-DOH-9	9/9/2014	14:45	1409022-25	6.8		
22-DOH-9	22-DOH-9	9/22/2014	18:15	1409023-21	1.8		
22-DOH-9	22-DOH-9	10/7/2014	14:10	1410011-38	1.8		
22-DOH-9	22-DOH-9	10/21/2014	14:15	1410012-31	1.8		
22-DOH-9	22-DOH-9	10/22/2014	14:20	1410064-31	790		
22-DOH-9	22-DOH-9	11/4/2014	12:40	1411012-34	33		
22-DOH-9	22-DOH-9	11/4/2014	12:40	1411012-35	49		
22-DOH-9	22-DOH-9	11/18/2014	13:15	1411013-33	1.8		
22-DOH-9	22-DOH-9	12/2/2014	13:45	1412007-34	1.8		
22-DOH-9	22-DOH-9	12/16/2014	14:05	1412037-33	1.8		
22-DOH-9	22-DOH-9	1/12/2015	16:45	1501021-25	33		
22-DOH-9	22-DOH-9	1/12/2015	16:45	1501021-26	1.8		
22-DOH-9	22-DOH-9	1/27/2015	16:27	1501022-38	2		
22-DOH-9	22-DOH-9	2/10/2015	15:35	1502017-37	23		
22-DOH-9	22-DOH-9	2/24/2015	11:55	1502018-38	1.8		
22-DOH-9	22-DOH-9	3/10/2015	11:35	1503014-34	1.8		
22-DOH-9	22-DOH-9	3/24/2015	13:00	1503015-32	1.8		
22-DOH-9	22-DOH-9	3/24/2015	13:00	1503015-33	1.8		
22-DOH-9	22-DOH-9	4/7/2015	11:50	1504052-33	1.8		
22-NOB-21	22-NOB-21	4/22/2014	11:25	1404044-32	88		
22-NOB-21	22-NOB-21	4/22/2014	11:25	1404044-33	150		
22-NOB-21	22-NOB-21	5/6/2014	12:20	1405032-33	92		
22-NOB-21	22-NOB-21	10/22/2014	13:20	1410064-30	800		
22-NOB-21	22-NOB-21	11/4/2014	12:30	1411012-33	230		
22-NOB-21	22-NOB-21	12/2/2014	12:20	1412007-33	28		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
22-NOB-21	22-NOB-21	12/16/2014	12:45	1412037-32	10		
22-NOB-21	22-NOB-21	12/29/2014	10:50	1412038-27	39		
22-NOB-21	22-NOB-21	12/29/2014	10:50	1412038-28	22		
22-NOB-21	22-NOB-21	1/14/2015	16:10	1501021-33	13		
22-NOB-21	22-NOB-21	1/27/2015	16:15	1501022-36	85		
22-NOB-21	22-NOB-21	2/10/2015	15:20	1502017-34	37		
22-NOB-21	22-NOB-21	2/10/2015	15:20	1502017-35	29		
22-NOB-21	22-NOB-21	3/24/2015	14:50	1503015-30	260		
22-NOB-21	22-NOB-21	3/24/2015	14:50	1503015-31	140		
22-NOB-21	22-NOB-21	4/7/2015	12:25	1504052-32	45		
22-NOB-22	22-NOB-22	4/22/2014	11:30	1404044-35	800		
22-NOB-22	22-NOB-22	5/6/2014	12:30	1405032-35	560		
22-NOB-22	22-NOB-22	10/22/2014	13:25	1410064-32	800		
22-NOB-22	22-NOB-22	10/22/2014	13:25	1410064-33	800		
22-NOB-22	22-NOB-22	11/4/2014	12:35	1411012-36	640		
22-NOB-22	22-NOB-22	12/2/2014	12:10	1412007-35	80		
22-NOB-22	22-NOB-22	12/16/2014	12:35	1412037-34	28		
22-NOB-22	22-NOB-22	12/29/2014	10:45	1412038-29	24		
22-NOB-22	22-NOB-22	1/14/2015	16:00	1501021-34	35		
22-NOB-22	22-NOB-22	1/27/2015	16:10	1501022-39	110		
22-NOB-22	22-NOB-22	2/10/2015	15:25	1502017-38	16		
22-NOB-22	22-NOB-22	3/24/2015	14:45	1503015-34	29		
22-NOB-23	22-NOB-23	4/22/2014	13:05	1404044-36	460		
22-NOB-23	22-NOB-23	5/6/2014	12:45	1405032-36	57		
22-NOB-23	22-NOB-23	11/4/2014	12:20	1411012-37	1500		
22-NOB-23	22-NOB-23	12/2/2014	11:30	1412007-36	43		
22-NOB-23	22-NOB-23	12/16/2014	12:15	1412037-35	32		
22-NOB-23	22-NOB-23	12/29/2014	10:30	1412038-30	12		
22-NOB-23	22-NOB-23	1/14/2015	16:20	1501021-35	12		
22-NOB-23	22-NOB-23	1/27/2015	15:50	1501022-41	29		
22-NOB-23	22-NOB-23	2/10/2015	14:50	1502017-40	6		
22-NOB-23	22-NOB-23	3/24/2015	14:35	1503015-35	55		
22-NOB-24	22-NOB-24	4/22/2014	13:10	1404044-37	420		
22-NOB-24	22-NOB-24	5/6/2014	12:55	1405032-37	61		
22-NOB-24	22-NOB-24	11/4/2014	12:25	1411012-38	1200		
22-NOB-24	22-NOB-24	12/2/2014	11:45	1412007-37	14		
22-NOB-24	22-NOB-24	12/16/2014	12:05	1412037-36	18		
22-NOB-24	22-NOB-24	1/27/2015	15:40	1501022-43	7		
22-NOB-24	22-NOB-24	2/10/2015	15:00	1502017-42	1		
22-NOB-25	22-NOB-25	4/22/2014	13:45	1404044-38	16		
22-NOB-25	22-NOB-25	5/6/2014	13:00	1405032-38	230		
22-NOB-25	22-NOB-25	11/4/2014	11:50	1411012-39	600		
22-NOB-25	22-NOB-25	12/2/2014	11:15	1412007-38	920		

Table B-2 (continued). FC (cfu/100 mL), *E. coli* (cfu/100 mL), and *Klebsiella* (%) data.

EIM Location ID	Study Location ID	Date	Time	Sample ID	Fecal Coliform	*E. coli*	*Klebsiella*
22-NOB-25	22-NOB-25	12/16/2014	11:50	1412037-37	17		
22-NOB-25	22-NOB-25	12/29/2014	10:15	1412038-32	7		
22-NOB-25	22-NOB-25	1/14/2015	12:15	1501021-37	3		
22-NOB-25	22-NOB-25	1/27/2015	15:15	1501022-45	12		
22-NOB-25	22-NOB-25	2/10/2015	14:25	1502017-44	25		
22-NOB-25	22-NOB-25	2/24/2015	13:15	1502018-45	4		
22-NOB-25	22-NOB-25	3/24/2015	14:25	1503015-37	17		
22-NOB-26	22-NOB-26	4/22/2014	13:30	1404044-39	450		
22-NOB-26	22-NOB-26	5/6/2014	13:15	1405032-39	230		
22-NOB-26	22-NOB-26	11/4/2014	12:00	1411012-40	1000		
22-NOB-26	22-NOB-26	12/2/2014	11:00	1412007-39	8		
22-NOB-26	22-NOB-26	12/16/2014	11:40	1412037-38	300		
22-NOB-26	22-NOB-26	12/29/2014	10:10	1412038-33	15		
22-NOB-26	22-NOB-26	1/14/2015	12:00	1501021-38	9		
22-NOB-26	22-NOB-26	1/27/2015	15:07	1501022-47	18		
22-NOB-26	22-NOB-26	2/10/2015	14:10	1502017-46	32		
22-NOB-26	22-NOB-26	3/24/2015	14:15	1503015-38	92		
22-NOB-27	22-NOB-27	4/22/2014	14:00	1404044-40	460		
22-NOB-27	22-NOB-27	5/6/2014	13:35	1405032-40	36		
22-NOB-27	22-NOB-27	11/4/2014	11:30	1411012-41	320		
22-NOB-27	22-NOB-27	11/18/2014	10:00	1411013-39	8		
22-NOB-27	22-NOB-27	12/16/2014	11:25	1412037-39	81		
22-NOB-27	22-NOB-27	12/29/2014	10:00	1412038-34	96		
22-NOB-27	22-NOB-27	1/14/2015	11:40	1501021-39	44		
22-NOB-27	22-NOB-27	1/27/2015	14:37	1501022-49	21		
22-NOB-27	22-NOB-27	2/10/2015	13:40	1502017-48	6		
22-NOB-27	22-NOB-27	2/24/2015	12:50	1502018-49	1		
22-NOB-27	22-NOB-27	3/24/2015	14:00	1503015-39	44		
22-NOB-27	22-NOB-27	4/7/2015	12:00	1504052-39	18		
22-NOB-28	22-NOB-28	4/22/2014	14:05	1404044-41	35		
22-NOB-28	22-NOB-28	5/6/2014	13:25	1405032-41	100		
22-NOB-28	22-NOB-28	11/4/2014	11:40	1411012-42	890		
22-NOB-28	22-NOB-28	11/18/2014	10:15	1411013-40	630		
22-NOB-28	22-NOB-28	12/2/2014	10:30	1412007-41	69		
22-NOB-28	22-NOB-28	12/16/2014	11:15	1412037-40	240		
22-NOB-28	22-NOB-28	12/29/2014	9:55	1412038-35	55		
22-NOB-28	22-NOB-28	1/14/2015	11:30	1501021-40	52		
22-NOB-28	22-NOB-28	1/27/2015	14:23	1501022-51	43		
22-NOB-28	22-NOB-28	2/10/2015	13:30	1502017-50	140		
22-NOB-28	22-NOB-28	3/24/2015	13:45	1503015-40	61		

Appendix C. Glossary, Acronyms, and Abbreviations

Glossary

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.

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

Fecal coliform bacteria (FC): That portion of the coliform group which is present in the 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.

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

Greywater: Wastewater from baths, sinks, washing machines, and some kitchen appliances. It does not include discharge from toilets or fecal-contaminated wastewater of any kind.

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

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

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

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

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

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

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.

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

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

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

Acronyms and Abbreviations

BMP	Best management practice
BST	Bacterial Source Tracking
DOH	Washington State Department of Health
E. coli	Escherichia coli
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
FC	Fecal coliform bacteria
GHC	Grays Harbor County
GIS	Geographic Information System software
MEL	Manchester Environmental Laboratory
MF	Membrane filter
MPN	Most probable number

MQO	Measurement quality objective
MS4	Municipal separate storm sewers
NPDES	(See Glossary above)
OSS	On-site septic system
QA	Quality assurance
QC	Quality control
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
TMDL	(See Glossary above)
UV	Ultraviolet
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area
WWTP	Wastewater treatment plant

Units of Measurement

cfu/100 mL	colony forming units per 100 milliliters
ppb	parts per billion