Marine Conditions 2008–2019 Report Series: Bacteria in Offshore and Beach Waters

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King County

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Marine Conditions 2008–2019 Report Series: Bacteria in Offshore and Beach Waters

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Cover photo: Quartermaster Harbor taken by Stephanie Jaeger

King County
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1.0 INTRODUCTION

For over 50 years, King County has conducted extensive water quality monitoring to assess conditions in the Central Puget Sound Basin (King County waters). The King County Marine Monitoring Program is managed by scientists in the Water and Land Resources Division within the Department of Natural Resources. The program includes two types of monitoring at offshore and beach locations:

- **Ambient monitoring:** baseline monitoring to assess background conditions, and
- **Outfall monitoring:** monitoring to assess conditions near King County's wastewater treatment plant (TP), combined sewer overflow (CSO), and CSO wet weather treatment station (TS) marine outfalls.

The goals of the Marine Monitoring Program are to characterize water quality and food web (phytoplankton and zooplankton) conditions in King County receiving waters, provide information for management decisions, and evaluate the status and trends of marine waters within King County. These data provide insight into both short and long-term variations and form a baseline from which water quality conditions can be assessed on multiple temporal and spatial scales. Please see *Marine Conditions Report Series 2008–2019: Marine Monitoring Program Overview* (King County, 2022) for a more detailed description of the background and purpose of the Marine Monitoring Program.

This report presents results for the beach and offshore bacteria monitoring component of the program collected from 2008–2019. Two types of bacteria are monitored, fecal coliform and *Enterococcus*. Fecal indicator bacteria are used to identify the potential for illness associated with exposure to pathogens associated with recreational activities in surface waters contaminated by fecal pollution. Fecal coliform and *Enterococcus* bacteria are used as indicators because they are easy to measure and found in the intestinal tract and feces of warm-blooded animals (e.g., humans, dogs, wildlife and waterfowl). These bacteria can enter the marine environment directly from humans and animals, agricultural and stormwater runoff, rivers and streams, and wastewater. Although usually not pathogenic themselves, fecal coliform and *Enterococcus* bacteria in the aquatic environment can indicate the presence of other potentially more harmful threats like viruses. A high bacteria count generally indicates a greater possibility of the presence of pathogens.

Fecal indicator bacteria monitoring data are used to:

- Serve as an indicator of the potential for pathogens to be present
- Provide a basis for the development of site-specific water quality objectives for environmental contaminants
- Identify the need for source controls to reduce the input of contaminants into marine waters

- Assess potential water quality impacts following TP upset discharges by comparing against historical data
- Assist in special studies such as siting new TP outfalls (King County, 2001) and evaluating marine conditions in specific areas with suspected water quality issues (King County, 2014)
- Assess the influence of large-scale and regional climate patterns on riverine and freshwater inputs and water quality
- Evaluate bacteria data against applicable Washington State Water Quality Standards
- Support science-based management decisions
- Support regional efforts and collaborations such as the Puget Sound Ecosystem Monitoring Program (PSEMP) Marine Waters Workgroup marine conditions monthly update meetings, Puget Sound Marine Waters Annual Report (PSEMP Marine Waters Workgroup, 2019), and regional modeling efforts.

Multiple parameters were collected concurrently at each sampling location for both offshore and beach waters. A summary of the types of data collected at each station is provided in *Marine Conditions Report Series 2008–2019: Marine Monitoring Program Overview* (King County, 2022). Results for other Marine Monitoring Program components between 2008–2019 (except pH) are provided in separate reports. These data summary reports are provided in separate reports with hyperlinks (click on titles to access reports) below and include the following topics:

- Marine Monitoring Program overview
- Nutrients in offshore waters
- Nutrients in beach waters
- Dissolved oxygen in offshore waters
- Temperature, salinity, and density in offshore waters
- Temperature and salinity in beach waters
- Water clarity in offshore waters
- Chlorophyll in offshore waters
- Phytoplankton
- Zooplankton
- Chemical and physical parameters and benthic infauna in beach (intertidal) and offshore (subtidal) sediments
- Chemical parameters in clam tissues.

2.0 SAMPLING AND ANALSYIS METHODS

The following sections provide an overview of the sampling, laboratory and data analysis methods used to assess bacteria in beach and offshore waters. A more detailed description of the Marine Monitoring Program and methods can be found in the *Marine Conditions Report Series 2008-2019: Marine Monitoring Program Overview* (King County, 2022) and the Sampling and Analysis Plan (SAP) (King County, 2020; https://your.kingcounty.gov/dnrp/library/2020/kcr3135/kcr3135.pdf).

2.1 Sampling Locations

All sampling sites are located within the Puget Sound Central Basin (Central Basin). Stations are categorized within the Central Basin as north, middle, south, or Duwamish River for the purpose of this report and supporting figures. Stations are also categorized by the following:

- **Central Basin**: all stations except Duwamish River sites
- **Mainstem**: all stations except Elliott Bay, Duwamish River and Quartermaster Harbor sites.

Bacteria can enter the aquatic environment directly or indirectly from humans and animals, stormwater, urban or agriculture runoff, and wastewater outfalls. Samples are collected from 28 beach sites and 20 offshore locations. Period of data record varies between stations since monitoring was initiated at different times and some stations were eliminated in 2010. Stations were chosen to represent ambient conditions and conditions directly influenced by TP and TS outfalls.

Beach samples are collected from 28 ambient (20) and outfall (8) sites within the Central Basin, including one site in Quartermaster Harbor and one in the Duwamish River subestuary (Duwamish River) (Figure 1, Table 1). Beach sampling sites are located close to shore to capture the potential for surface runoff pollution and the impacts from adjacent outfalls.

Data sets for northern beach stations represent some of King County's longest monitoring records, starting in the early 1980's. Middle and Elliott Bay stations were introduced in the late 1980s and southern stations were introduced in the early 1990s. Only one Duwamish River beach station was included in the monitoring program, Duwamish Park (LTTL02), where data were collected from 2007 to 2010.

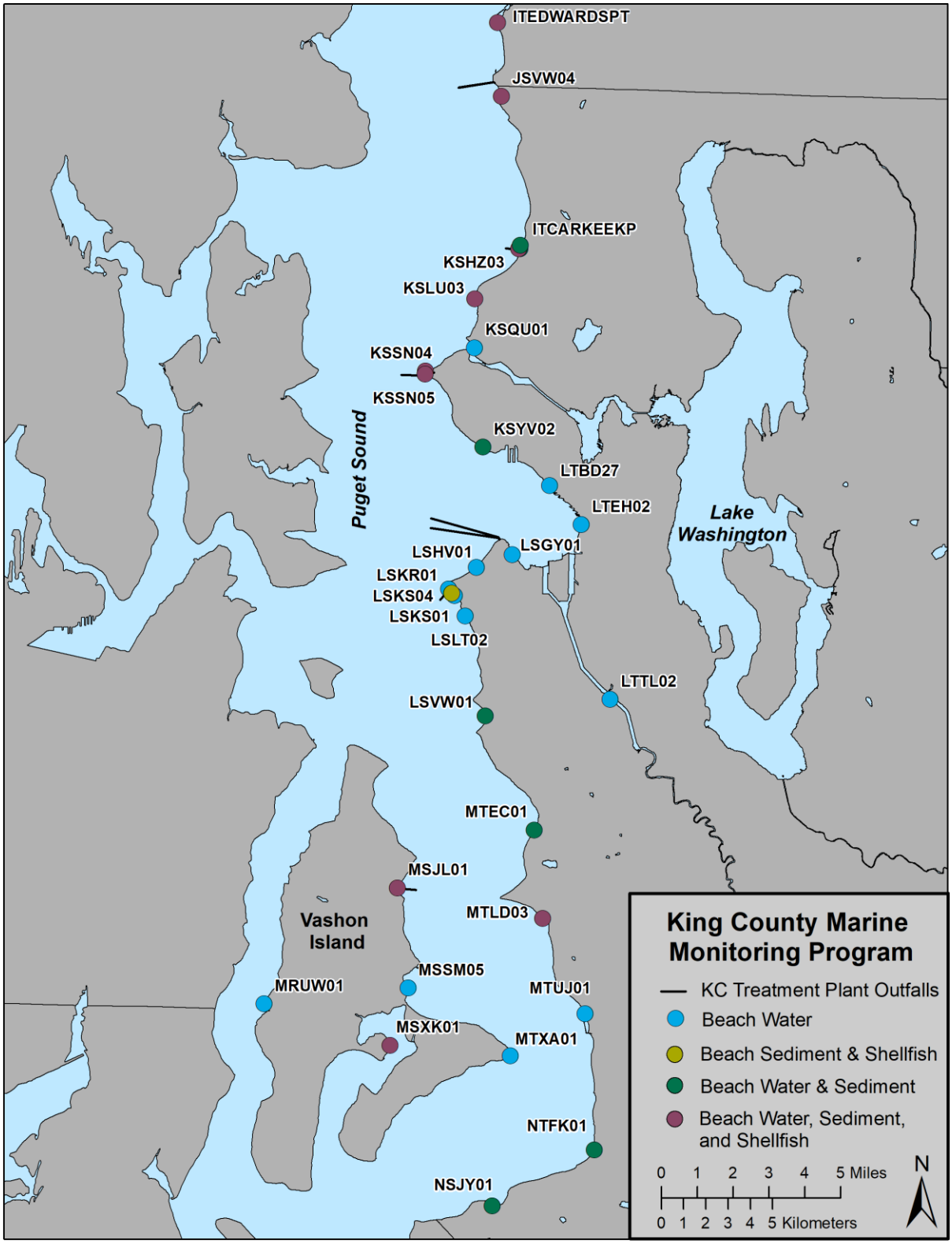

Figure 1. Map of King County beach water marine monitoring locations; bacteria are monitored at all water sites.

Table 1. Beach bacteria monitoring station information listed from north to south.

Locator Name	Station Name	Monitoring Region	Station Type	Sampling Period
ITEDWARDSPT	Edwards Point	North	Ambient	2000 – 2010
JSVW04	Point Wells	North	Ambient	1984 – present
ITCARKEEKP	Carkeek Park	North	Ambient	2000 – present
KSHZ03	Carkeek Park – Piper's Creek Outflow	North	Outfall	1984 – present
KSLU03	Golden Gardens Park	North	Ambient	1984 – present
KSQU01	Mouth of Lake Washington Ship Canal	North	Ambient	1984 – 2010
KSSN04	West Point North Beach	North	Outfall	1984 – present
KSSN05	West Point South Beach	North	Outfall	1984 – present
KSYV02	Magnolia CSO	Middle	Outfall	1985 – present
LTBD27	SAM Sculpture Park	Middle – Elliott Bay	Ambient	2007 – present
LTEH02	Seattle Waterfront – ferry terminal	Middle – Elliott Bay	Ambient	1984 – 2010
LSGY01	Seacrest Park	Middle – Elliott Bay	Ambient	1997 – present
LSHV01	Alki Beach	Middle	Ambient	1985 – present
LSKR01	Alki TS outfall	Middle	Outfall	1985 – present
LSKS01	Constellation Park – Alki TS outfall	Middle	Outfall	1984 – present
LSLT02	Me-Kwa-Mooks Park	Middle	Ambient	2007 – 2010
LTTL02	Duwamish River Park	Duwamish River	Ambient	2007 – 2010
LSVW01	Fauntleroy Cove	Middle	Ambient	1984 – present
MTEC01	Seahurst Park	South	Ambient	1989 – 2010
MSJL01	Vashon TP outfall	South	Outfall	2002 – present
MTLD03	Normandy Park	South	Outfall	1998 – present
MSSM05	Tramp Harbor	South	Ambient	1990 – present
MRUW01	Lisabuela Park	South	Ambient	2007 – 2010
MTUJ01	Des Moines Creek Park	South	Ambient	2007 – present
MSXK01	Burton Acres Park	South – Quartermaster Harbor	Ambient	2007 – present
MTXA01	Point Robinson Park	South	Ambient	2007 – 2010
NTFK01	Redondo Beach	South	Ambient	2007 – present
NSJY01	Dumas Bay Park	South	Ambient	2007 – present

Offshore water samples are collected from 20 offshore ambient (12) and outfall (8) locations within the Central Basin, including two in Quartermaster Harbor and four in the Duwamish River (Figure 2, Table 2).

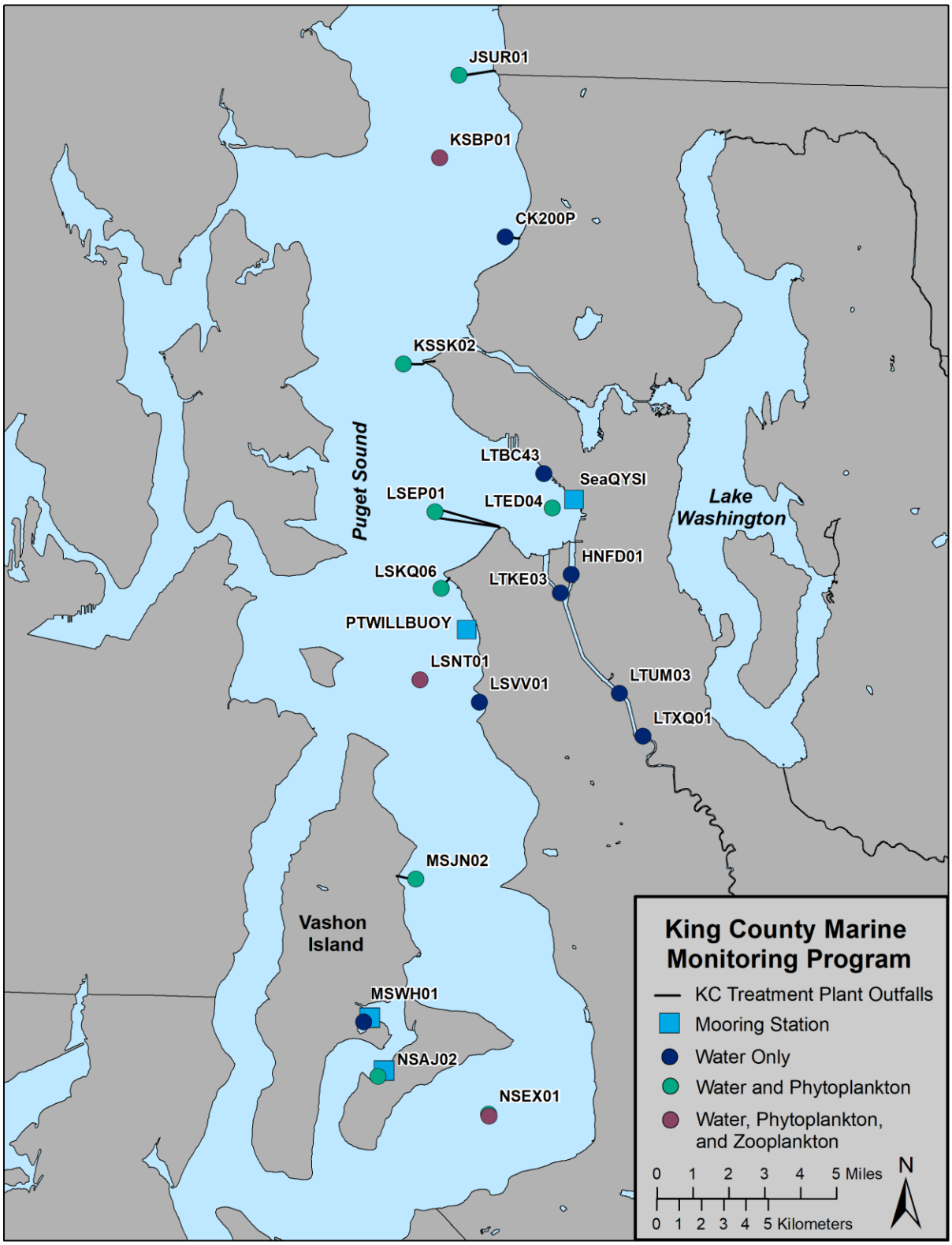

Figure 2. Map of King County offshore marine monitoring stations; bacteria are monitored at all water sites.

Table 2. Offshore bacteria monitoring station information listed north to south.

Locator	Station name	Monitoring Region	Station Type	First Year of Record	Average Depth (m)
JSUR01	Point Wells	North	Outfall	2005	178
KSBP01	Point Jefferson	North	Ambient	1966	262
CK200P	Carkeek Outfall	North	Outfall	2000	63
KSSK02	West Point Outfall	North	Outfall	1997	65
LTBC43	Elliott West Outfall	Middle – Elliott Bay	Outfall	2005	17.5
LTED04	South Central Elliott Bay	Middle – Elliott Bay	Ambient	1997	85
SEAQYSI	Seattle Aquarium		Ambient	2006	16
LSEP01	South Plant Outfall	Middle	Outfall	1997	185
HNFD01	East Waterway	Duwamish River	Ambient	2008	17
LTKE03	Harbor Island Marina	Duwamish River	Ambient	2005	12.5
LSKQ06	Alki Outfall	Middle	Outfall	1987	43
LSNT01	Point Williams	Middle	Ambient	1988	205
PTWILLBUOY	Point Williams Buoy		Ambient	2013	167
LTUM03	South Park Bridge	Duwamish River	Ambient	2005	7.5
LSVV01	Fauntleroy Cove	Middle	Ambient	2007	12.5
LTXQ01	Henderson/MLK Outfall	Duwamish River	Outfall	2009	1
MSJN02	Vashon Outfall	South	Outfall	2005	63
MSWH01	Inner Quartermaster Harbor	South – Quartermaster Harbor	Ambient	2006	5.5
NSAJ02	Dockton Park	South – Quartermaster Harbor	Ambient	2006	9
NSEX01	East Passage	South	Ambient	2003	173

2.2 Sampling Methods

Water samples for bacteria analysis were collected by the King County Environmental Laboratory (KCEL) in accordance with the *Recommended Guidelines for Sampling Marine Sediment, Water Column, and Tissues in Puget Sound* (PSEP; 1991, 1997) and the KCEL Standard Operating Procedure (SOP) for each parameter.

Beach water samples were collected monthly from a single depth at approximately hip-depth by inverting sterilized sample containers just above the water surface, then sinking

the bottle down to approximately three to six inches below the water surface. No specific tidal height or tidal stage are targeted in to collect samples from a variety of conditions.

Offshore water samples were collected monthly from 2008-2013 and twice monthly 2014-2019, except monthly in January and December. Fecal indicator bacteria are analyzed from the 1m depth at all offshore stations and additional depths that varies for each location. The depth of additional bacteria samples is dependent upon the expected trapping depth of the effluent plume. Samples are collected with an underwater rosette unit equipped with twelve five-liter Niskin sampling bottles deployed from the research boat. The rosette system is combined with the hydrographic profiling system and the water samples are collected on the upcast at specific depths. Once the bottles are on deck, sterilized sample bottles are filled from the Niskin following the proper techniques detailed in the SOPs. The two Quartermaster Harbor stations (MSWH01 and NSAJ02) and one Duwamish River subestuary station (LTXQ01) are sampled off a dock or bridge.

2.3 Laboratory Procedures

Fecal coliform bacteria analysis is performed according to Standard Method (SM) 9222 D (APHA 2017) and KCEL SOP #5006 (KCEL, 2014). Appropriate dilutions, if necessary, are prepared using APHA buffered water as the diluent. The sample and its dilutions are filtered through a sterile 0.45 μm nitrocellulose membrane. The membrane is then applied to an mFC agar plate. After incubation at 44.5 ± 0.2˚C for 24 ± 2 hours, all colonies with a characteristic blue color are counted. The number of colonies per 100 mL of sample is calculated based on the colonies counted and the dilutions used per plate.

Enterococci bacteria analysis is conducted according to method SM9230 C (APHA 2017) and KCEL SOP #5012 (KCEL, 2012). Appropriate dilutions of the sample, if necessary, are prepared using APHA buffered water as the diluent. The sample and its dilutions are filtered through a sterile 0.45 μm nitrocellulose membrane. The membrane is then applied to mE agar plates. After incubation on the mE agar plate at 41 ± 0.5˚C for 48 ± 3 hours, the filter is transferred to EIA agar and incubated for an additional 20-30 minutes. All colonies that have a red to pink color with a black or reddish-brown precipitate are counted. The number of colonies per 100 mL is calculated based on the colonies counted and the dilutions used per plate.

All analyses were performed using appropriate QC procedures. QC measures include method blanks, check standards, and laboratory duplicates. The MDL for both fecal coliform and *Enterococci* bacteria is 1 colony forming unit per 100 milliliters (CFU/100 ml). There is no reporting limit for these two parameters.

2.4 Data Analysis

Bacteria data are compared to Washington State Water Quality Standards (WQS). In 2019 the Washington State Department of Ecology (Ecology) revised the marine WQS to follow EPA's 2012 Recreational Water Quality Criteria (WQC) recommendations. The revised WQS for bacteria (WAC 173-201A-210 3(b)) were adopted in January 2021 and represent a shift

from using fecal coliform as the indicator bacteria to *Enterococcus.* The new WQS indicate that Enterococci levels within an averaging period must not exceed a geometric mean (geomean criterion) concentration of 30 colony forming units (CFU)/100 mL, and not more than 10 % of all samples (or single sample when < 10 samples collected) collected within the averaging period exceed the 110 CFU/100 mL (peak criterion) (WAC 173-201A-210 3(b)).

The previous fecal coliform based WQC were 14 CFU/100 mL (geomean) and 43 CFU/100 mL (peak). Although *Enterococcus* has replaced fecal coliform as the indicator bacteria for primary contact recreation, fecal coliform based WQS still apply as the criteria to protect shellfish harvesting areas.

The bacteria results presented here were compared to the WQS to identify areas with potential bacteria issues and provide context for data interpretation. These comparisons were not intended to describe criteria exceedances from a regulatory perspective. The data presented here were collected monthly, and in general, determination of a regulatory exceedance requires more frequently collected data (e.g., multiple/day, weekly).

Data analysis included comparison of results for single samples (2008-2019) to the peak WQC (110 CFU/100 ml). For regulatory purposes, the geomean WQC (30 CFU/100 ml) is typically compared to results for monthly average bacteria counts in samples collected at a higher frequency; however, since the monitoring program collects samples monthly, geomeans were calculated based on the rolling average of the 12 most recent surface (<2 m) samples.

3.0 RESULTS

Figure 3 (a) and (b) shows *Enterococcus* results plotted against concurrent fecal coliform results for offshore and beach sampling locations. The low levels of fecal coliform bacteria detected in offshore surface water samples (2008-2019) are consistent with previous reports and confirm that elevated bacteria levels are generally limited to sites close to shore near freshwater sources and human activities like the Duwamish River sites.

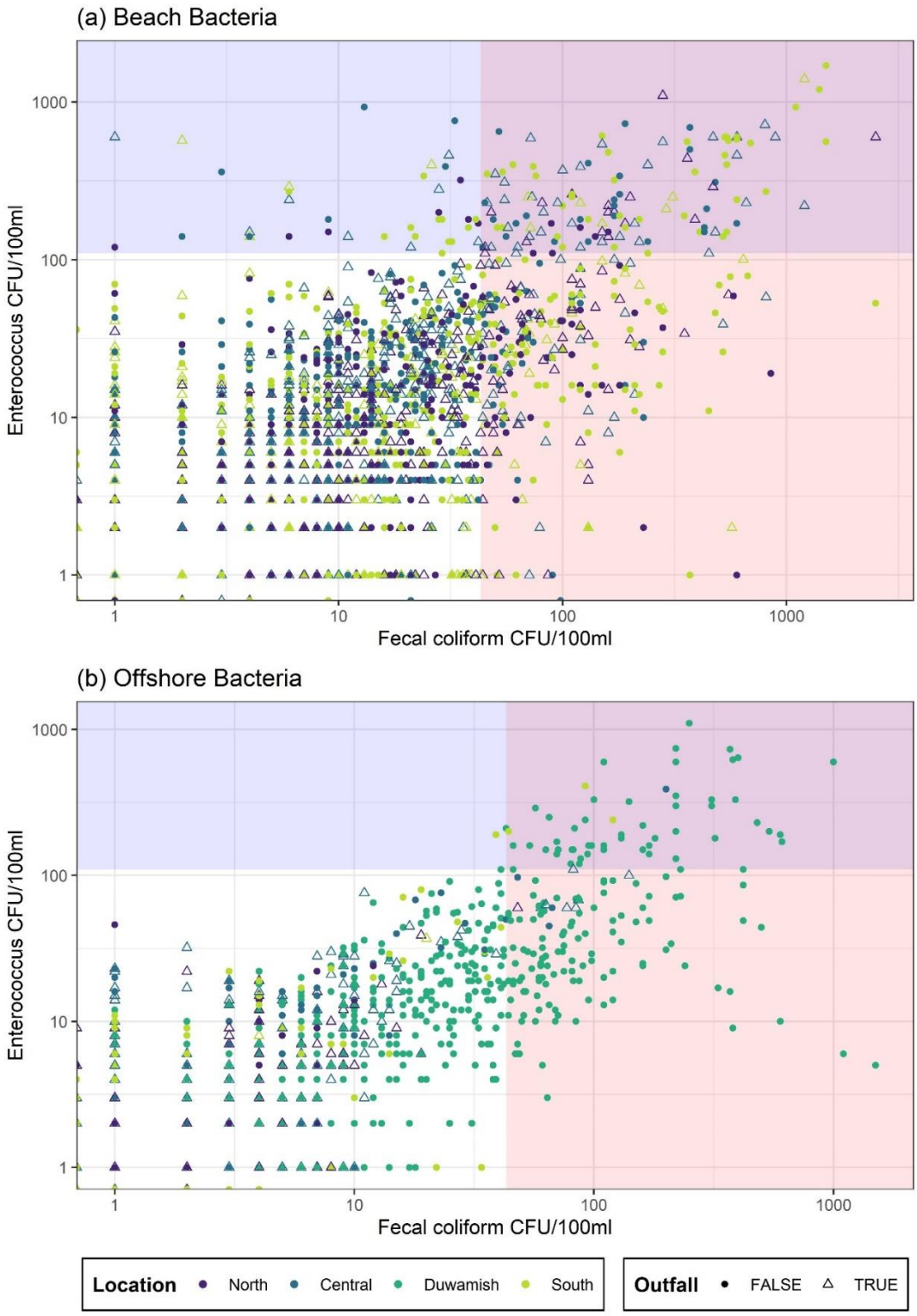

Figure 3. ***Enterococcus*** **results plotted against concurrent fecal coliform results in surface waters (<2 m) at (a) beach and (b) offshore stations. Blue shaded area represents levels >** ***Enterococcus*** **peak criteria (110 CFU/100 mL). Red shaded area represents levels > fecal coliform peak criteria (43 CFU/100 mL). Outfall stations = triangles, ambient stations = circles.**

3.1 Offshore Waters Results

Bacteria results in offshore waters (2008-2019) indicate that bacteria levels in samples from nine of 21 stations were above at least one of the peak WQC for E*nterococcus* (≥ 110 CFU/100 mL) or fecal coliform (≥ 43 CFU/100 mL) (Figure 4). Most (94%) of the elevated bacteria levels occurred in samples from sites in the Duwamish River, while the remainder occurred at the Elliott Bay, and Quartermaster Harbor stations. These findings are not unexpected due to the proximity of the Duwamish River stations to many point and non-point bacteria sources within the river, as well as upstream sources (e.g., stormwater runoff). Bacteria levels in freshwater are generally much higher than in saltwater due to the sources mentioned above, as well as the longer period of survival in freshwater.

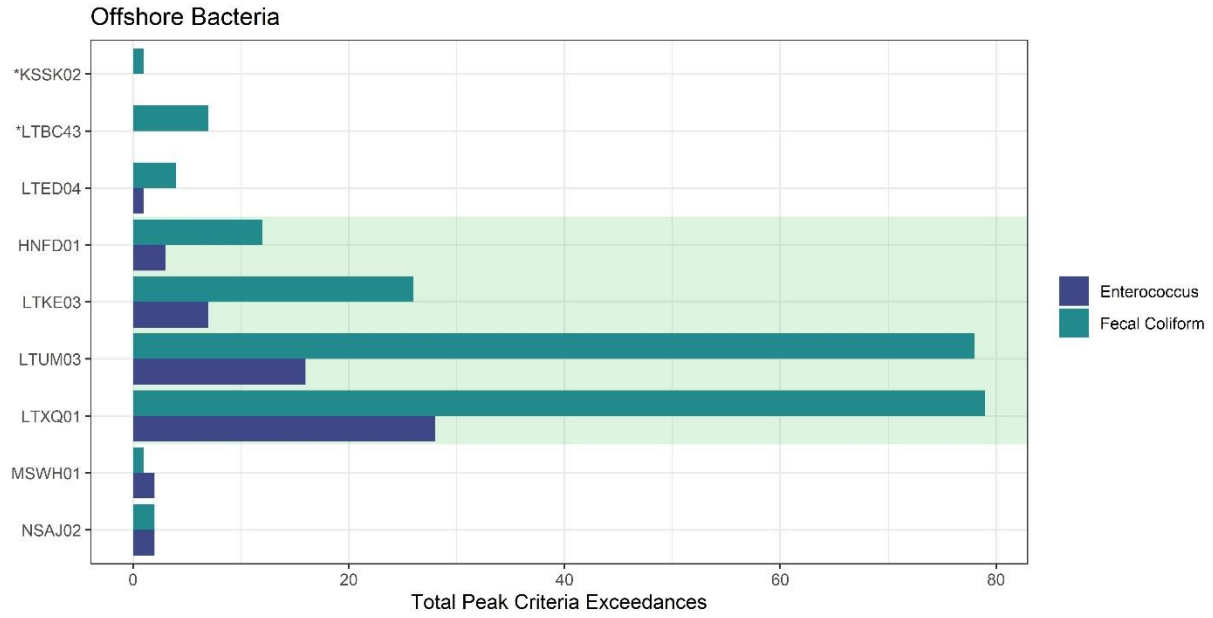

Figure 4. Number of samples with bacteria levels > peak WQC for *Enterococcus* (> 110 CFU/100 mL) and fecal coliform (> 43 CFU/100 mL) (2008-2019). *Indicates outfall stations; green highlight indicates Duwamish River stations.

Levels of fecal coliform and *Enterococcus* in the Central Basin decrease significantly at depths. (Figure 5). *Enterococcus* and fecal coliform values drop below 40 CFU/100 mL at depths of 50 meters and below 10 CFU/100 mL at depths of 150 meters.

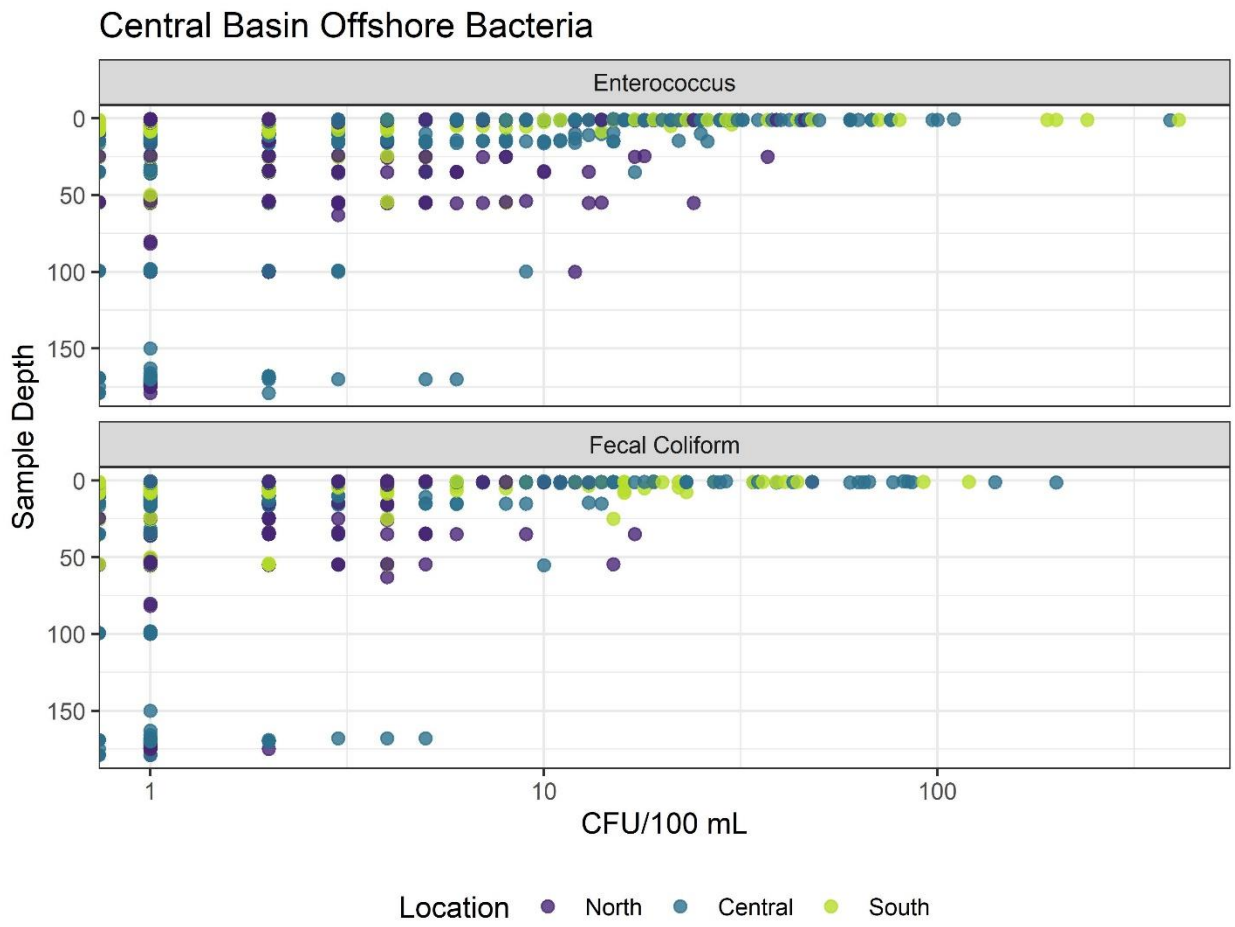

Figure 5. ***Enterococcus*** **and fecal coliform results at Central Basin offshore stations by depth (2008-2019).**

Bacteria results for samples collected at depth for Duwamish River stations show a similar pattern with reduced concentrations at deeper depths (Figure 6). *Enterococcus* and fecal coliform values drop below 50 CFU/100 mL at depths of 10 meters. Note that Duwamish River stations have a max sampling depth around 15 meters.

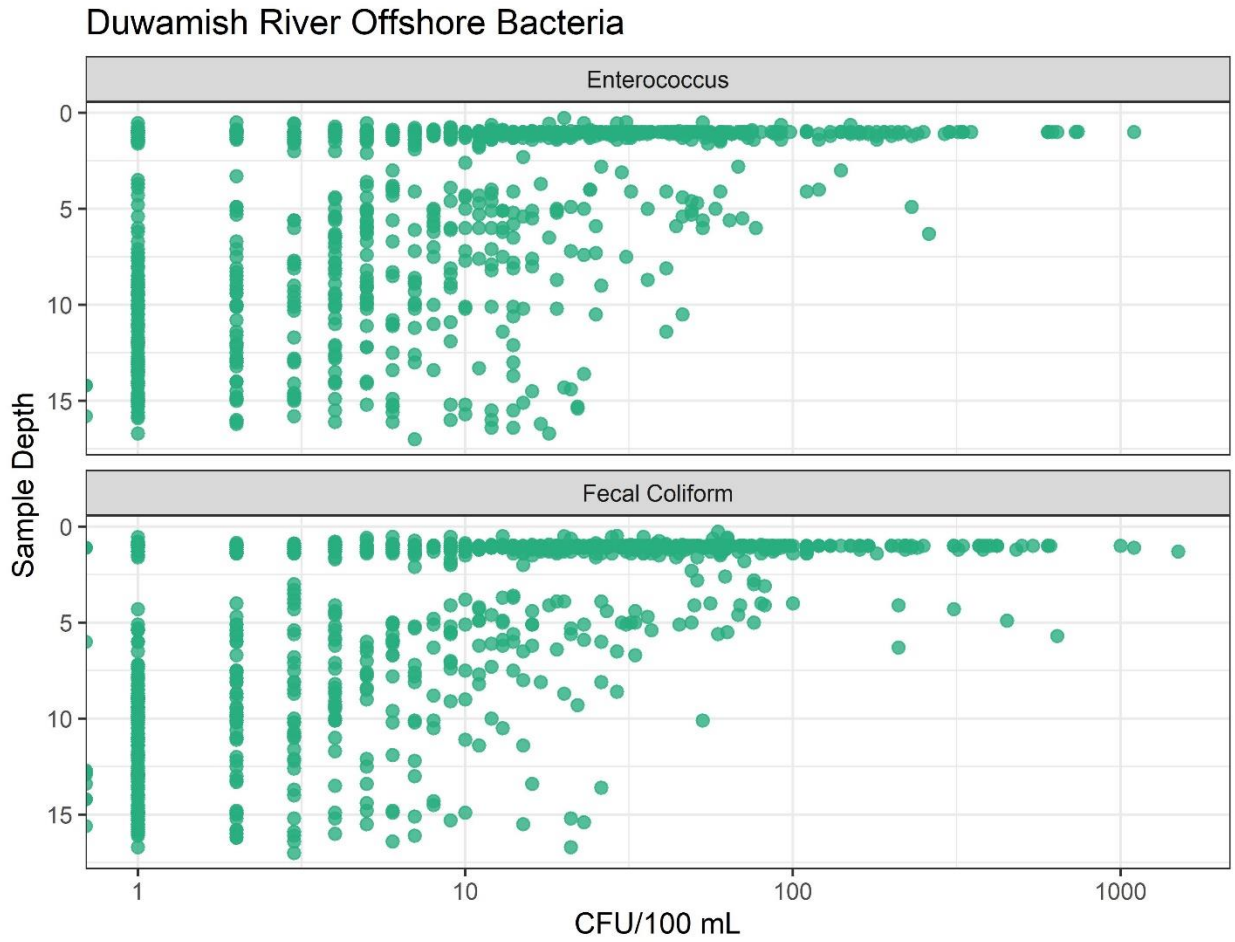

Figure 6. Enterococcus and fecal coliform results at Duwamish River offshore stations by depth (2008-2019).

A 12-month rolling geometric mean was calculated for all offshore surface (<2 m) samples (2008-2019) to determine concentration change over time. Each point in Figure 7 and Figure 8 represents the geometric mean calculated from the previous 12 months. Central Basin geometric mean results for *Enterococcus* and fecal coliform show spatial variation (Figure 7). The highest geometric mean *Enterococcus* concentrations occurred at Elliott West Outfall (LTBC43) in 2019 with a geomean of 11.2 CFU/100 mL The highest geometric mean fecal coliform concentrations also occurred at the Elliott West Outfall with a geomean of 6.7 CFU/100 mL in December of 2015. The Elliott West Wet Weather Treatment Station is the largest CSO control facility in the County's wastewater conveyance system and untreated flows are expected to occur on average once per year, contributing to high bacteria concentrations.

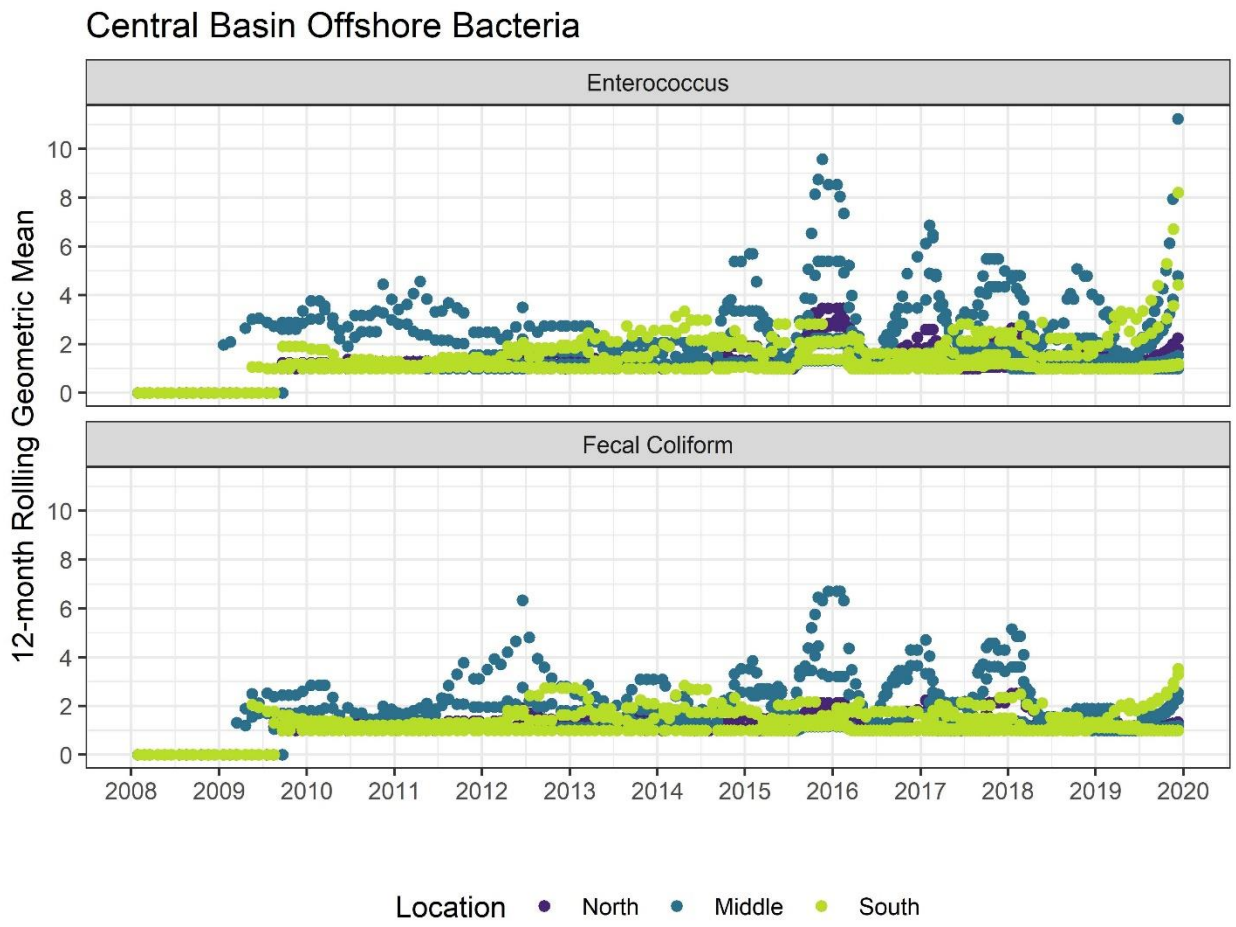

Figure 7. ***Enterococcus*** **and fecal coliform 12-month rolling geometric mean at Central Basin offshore stations.**

In contrast to Central Basin stations, the Duwamish River, experienced dramatically higher geometric mean values (Figure 8). The highest geometric mean *Enterococcus* concentrations occurred at the Henderson/MLK Outfall station (LTXQ01) with a geomean of 240.2 CFU/100 mL in December of 2019. The highest geometric mean fecal coliform concentrations also occurred at the Henderson/MLK Outfall station with a geomean of 194.4 CFU/100 mL in October of 2019. All other Duwamish River stations experienced *Enterococcus* geometric means < 50 CFU/100 mL and fecal coliform geometric means < 75 CFU/100 mL. The Henderson/MLK Wet Weather Treatment Station stores combined wastewater and stormwater flow during high rain events. Flow is then transported to the West Point TP or discharges to the Duwamish River (after primary treatment and disinfection) via outfall pipes. The Henderson/MLK Outfall station is also the furthest upstream site in the Duwamish River and is closer to freshwater sources and contributions from stormwater runoff.

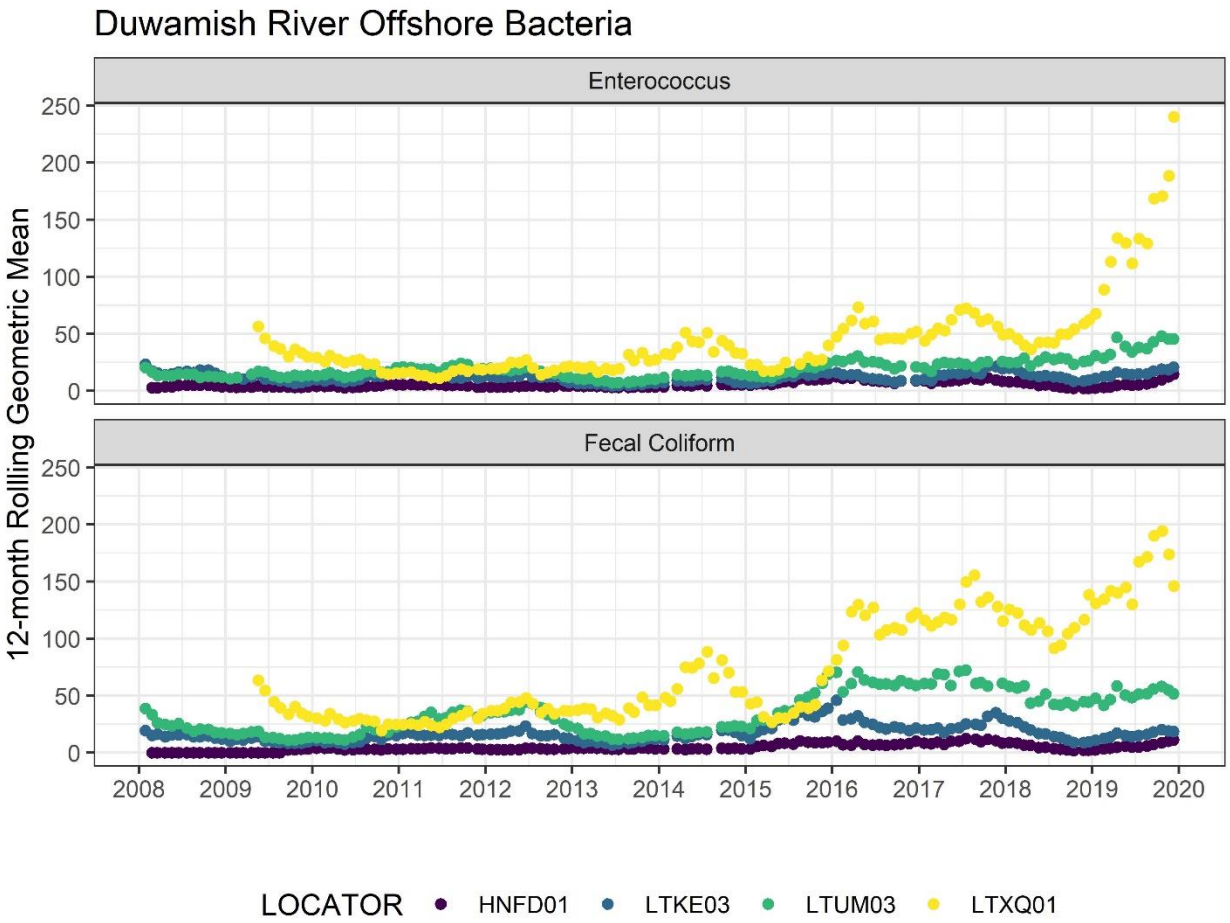

Figure 8. ***Enterococcus*** **and fecal coliform 12-month rolling geometric mean at Duwamish River offshore stations.**

3.2 Beach Waters Results

Fecal coliform levels at beach stations were generally higher and more heterogeneous than offshore stations (Figure 3 (a)) due to their closer proximity to freshwater sources and contribution from stormwater runoff. Levels of both E*nterococcus* and fecal coliform (2008-2019) in single samples from beach stations were above the peak WQC at least once (Figure 9). Bacteria levels at three sites, Piper's Creek mouth (KSHZ03), Des Moines Creek Park (MTUJ01) and Redondo Beach (NTFK01), were above the peak WQC at least once every year.

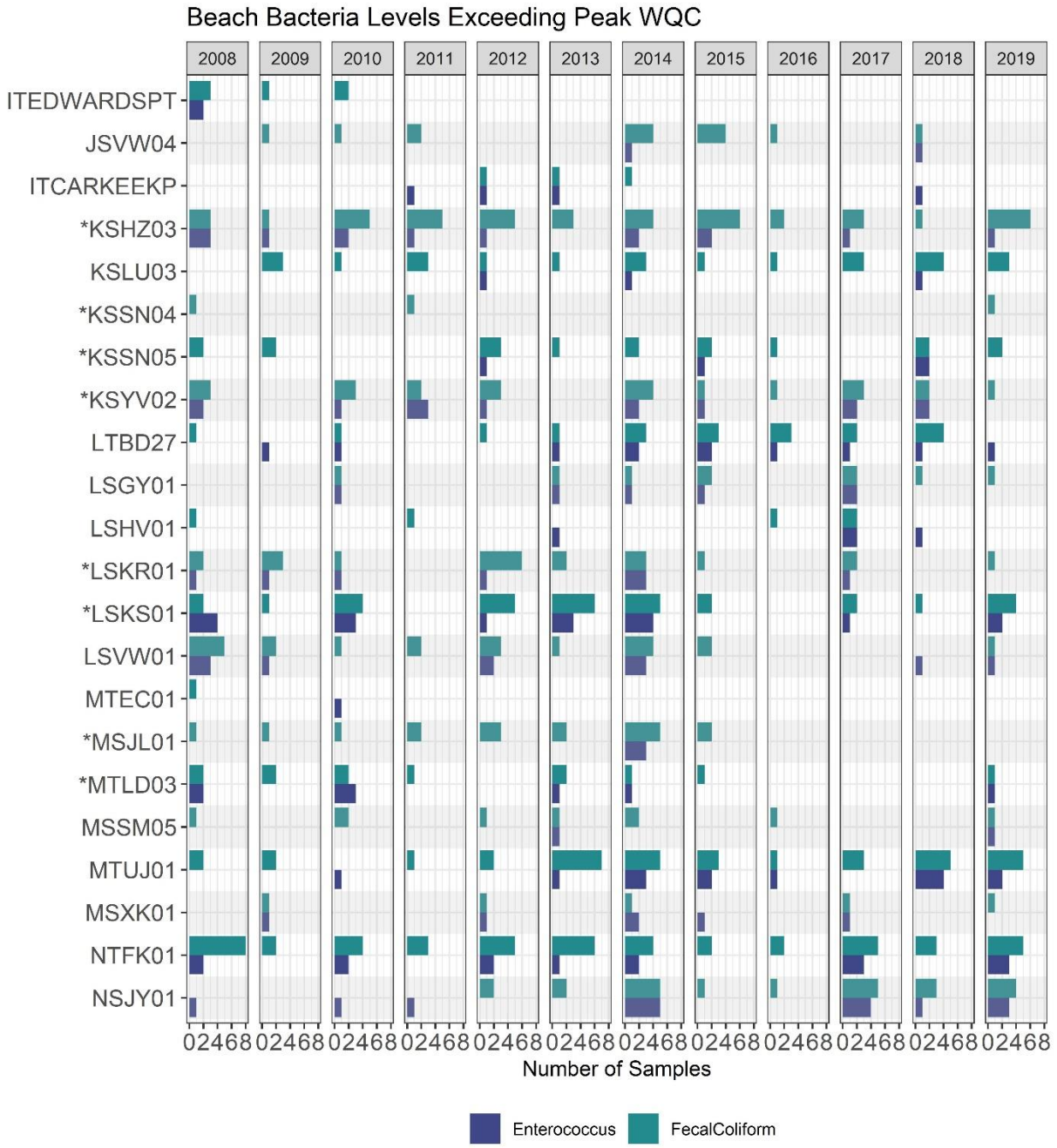

Figure 9. Number of samples with bacteria levels > peak WQC for *Enterococcus* (> 110 CFU/100 mL) and fecal coliform (> 43 CFU/100 mL) (2008-2019). *Indicates outfall stations.

The Piper's Creek outflow station (KSHZ03) is located at the mouth of Piper's Creek. Bacteria concentrations are often elevated at this location due to inputs from both the outfall and other bacteria sources in the watershed. In contrast, an adjacent location, Carkeek Park (ITCARKEEKP), just outside the immediate influence of the creek typically experiences lower bacteria levels (Figure 10).

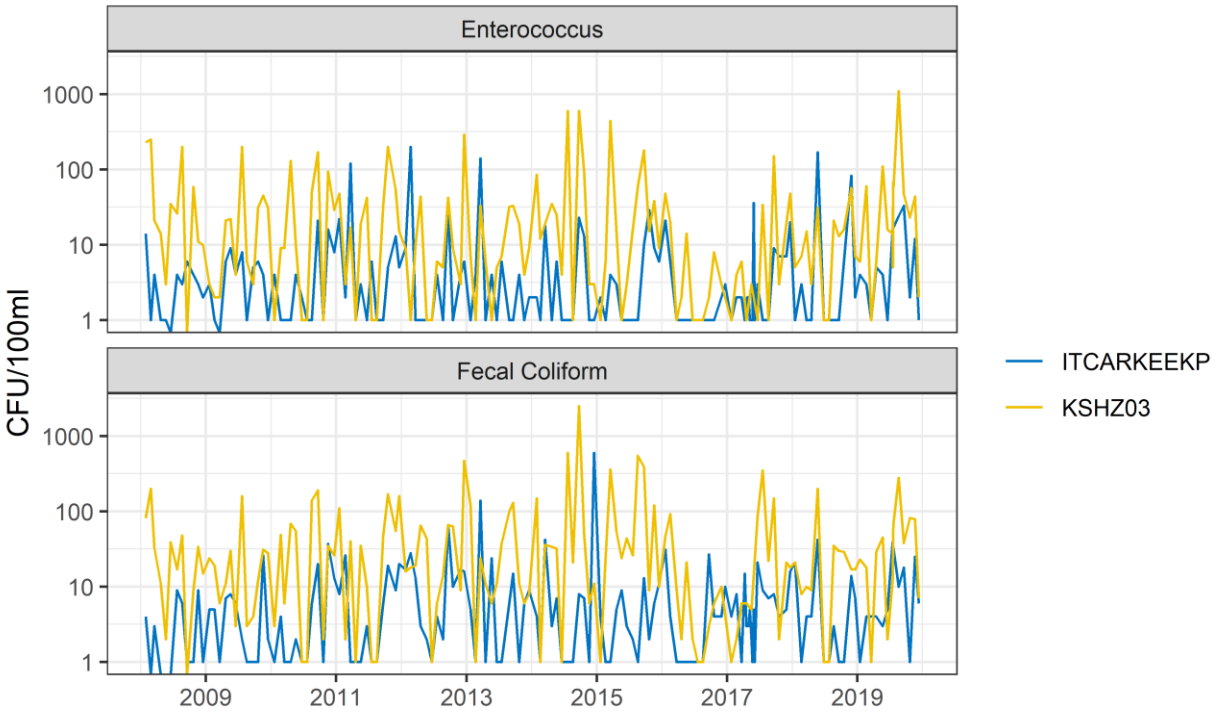

Figure 10. **Time series plot of bacteria results (CFU/100 mL) (2008-2019) for Carkeek Park – Piper's Creek Outflow (KSHZ03) and Carkeek Park (ITCARKEEKP) stations.**

A 12-month rolling geometric mean was calculated for all beach samples (2008-2019) to determine concentration change over time. Each point in represents the geometric mean calculated from the previous 12 months. Bacteria levels at 15 of the 22 beach stations were above WQC (geomean) at least once (Figure 11). The highest geometric mean *Enterococcus* concentrations occurred at Dumas Bay (NSJY01), with a geomean of 233 CFU/100 mL in October of 2019. The highest geometric mean fecal coliform concentrations also occurred at Dumas Bay, with a geomean of 121.6 CFU/100 mL in December of 2019. Dumas Bay is the southern most beach monitoring station and experiences influence of freshwater inputs from Joes Creek and the Puyallup River, which are potential pathways for bacteria to enter the marine environment.

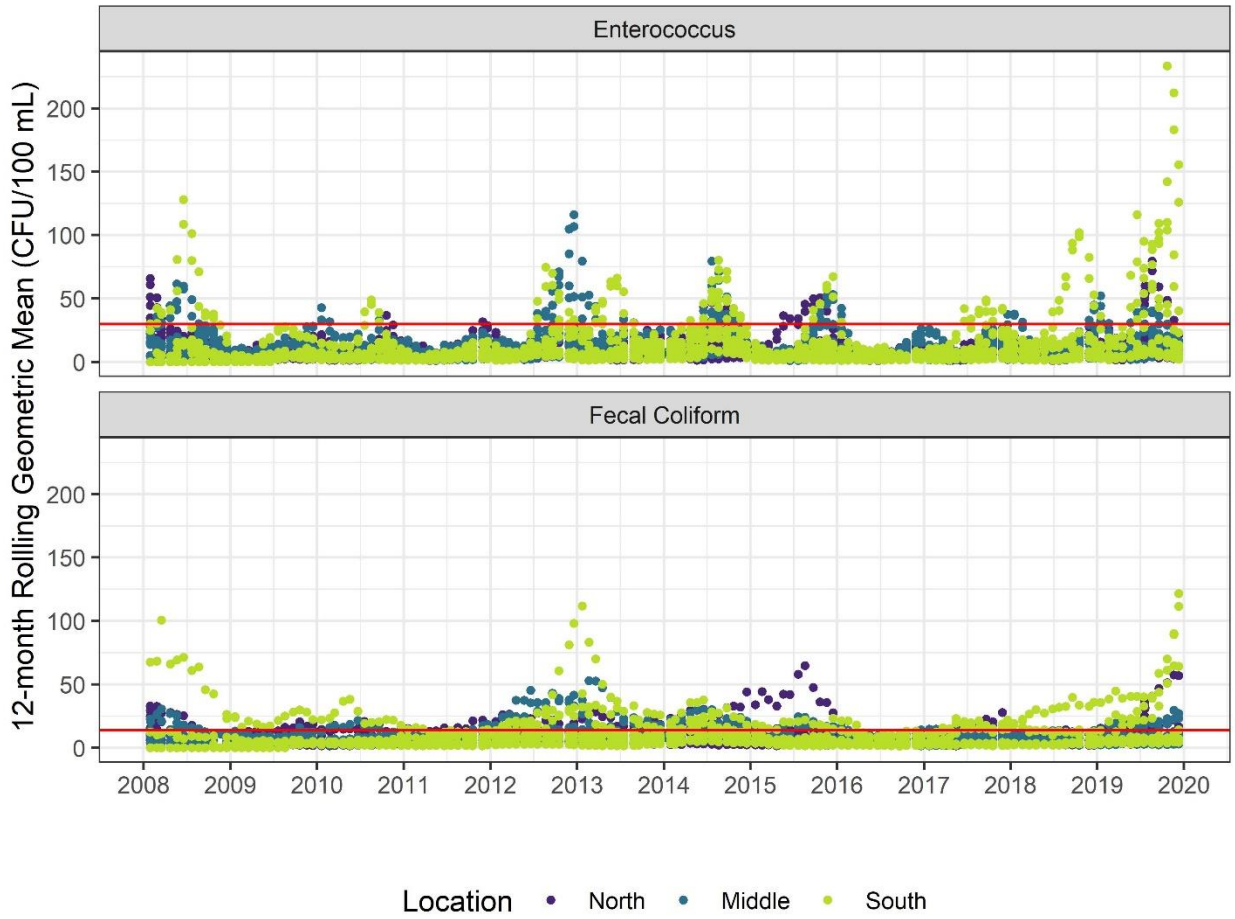

Figure 11. ***Enterococcus*** **and fecal coliform 12-month rolling geometric mean at Central Basin beach stations. Red line represents WQC (geomean) for** ***Enterococcus*** **(≥ 30 CFU/100 mL) and fecal coliform (≥ 14 CFU/100 mL).**

Bacteria levels at the Piper's Creek outflow outfall station (KSHZ03) were > fecal coliform WQC at least once every year. Bacteria levels at this station have routinely been above the WQC for over 20 years. Several bacteria source-tracking and reduction efforts in the Carkeek/Thornton Creek watersheds have occurred during this time and are on-going (See project website at Thornton Creek Basin - Sewer Study and Upgrade - King County). Bacteria levels at the ambient station (Carkeek Park, ITCARKEEKP) just north of the Piper's Creek station, were significantly lower and not above the WQC (Figure 12). Bacteria levels at ITCARKEEKP, and six other stations, including one outfall station (West Point South Beach, KSSN05) were < WQC.

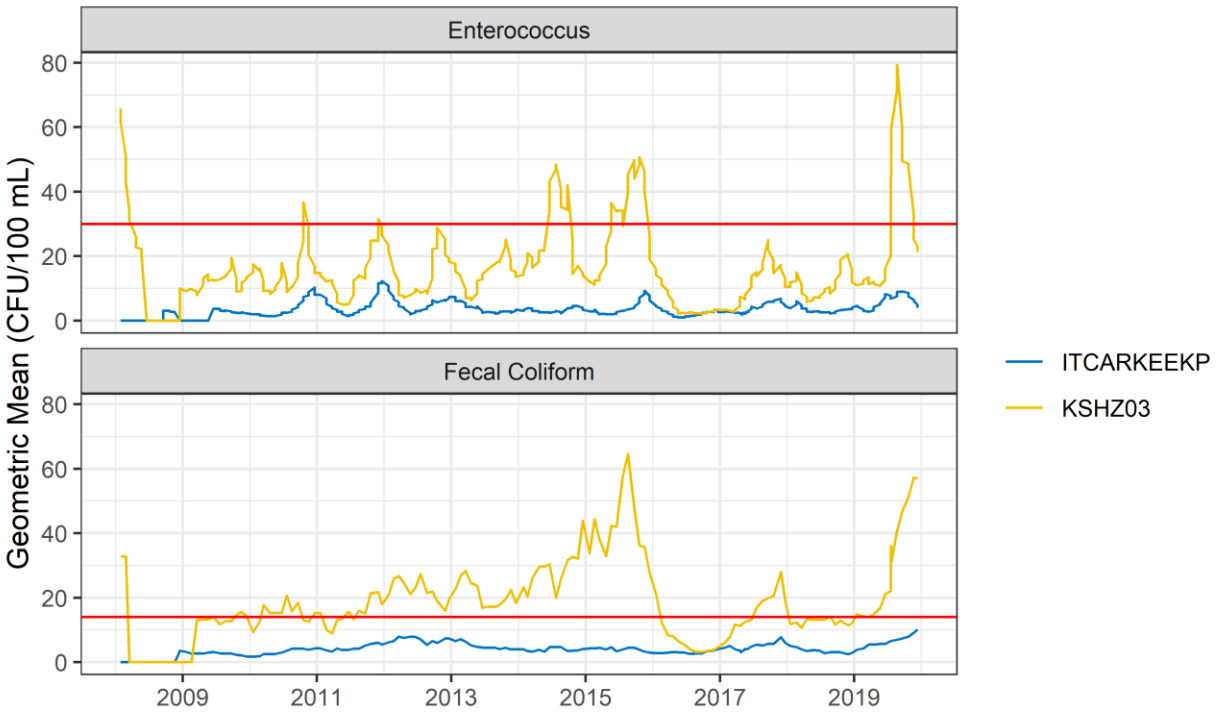

Figure 12. Time series plot of bacteria results for Carkeek Park – Piper's Creek Outflow (KSHZ03) and Carkeek Park (ITCARKEEKP). Red line represents WQC (geomean) for *Enterococcus* (≥ 30 CFU/100 mL) and fecal coliform (≥ 14 CFU/100 mL).

4.0 SUMMARY

King County monitors indicator bacteria on a monthly basis at 22 beach and 21 offshore locations (ambient and outfall stations) in the Central Basin. Surface samples (<2 meters) and samples at depths were collected twice monthly (except monthly in Jan and Dec) at offshore locations, while beach samples were collected monthly. These data are used to determine if sites have chronic bacteria problems and evaluate how concentrations are changing over time.

Bacteria concentrations during the reporting period (2008-2019) were low at all offshore stations, continuing a trend seen over many years of bacteria monitoring in marine offshore waters (Summary reports for previous data collected can be found in the annual *Water Quality Status Report for Marine Waters* accessible at: https://green2.kingcounty.gov/ScienceLibrary/default.aspx?&CategoryID=2). Areas with slightly higher bacteria concentrations included stations in the Duwamish River, and a few sites located near freshwater inputs.

Highlights:

- Bacteria levels (2008-2019) at 9 of 21 offshore stations were above at least one peak WQC for E*nterococcus* or fecal coliform (E*nterococcus* ≥ 110 CFU/100 mL and fecal coliform ≥ 43 CFU/100 mL). Most elevated concentrations were detected at Duwamish River and Elliott Bay stations.

- Most (94%) bacteria levels above peak WQC were measured at Duwamish River stations; East Waterway (HNFD01), Harbor Island Marina (LTKE03), South Park Bridge (LTUM03), and Henderson/MLK Outfall (LTXQ01). This is not unexpected due to the proximity of the Duwamish River to many point and non-point sources both within the river and in upstream area that receive stormwater runoff.
- Bacteria levels above the geomean WQC (fecal coliform ≥ 14 CFU/100 mL and *Enterococcus* ≥ 30 CFU/100 mL) were measured at least once for both parameters at only three offshore sites, Harbor Island Marina (LTKE03), South Park Bridge (LTUM03), and Henderson/MLK (LTXQ01).
- Fecal coliform levels at beach station(s) were generally higher and more heterogeneous than levels seen at offshore stations due to their proximity to freshwater sources and inputs from stormwater runoff.
- Bacteria levels at the 22 beach stations were above either the E*nterococcus* or fecal coliform peak WQC (E*nterococcus* ≥ 110 CFU/100 mL and fecal coliform ≥ 43 CFU/100 mL) at least once.
- Bacteria levels at Piper's Creek mouth (KSHZ03), Des Moines Creek Park (MTUJ01) and Redondo Beach (NTFK01) stations were above the geomean or peak WQC at least once each year. All three of these sites have nearby freshwater inputs, which are potential pathways for bacteria to enter the marine environment.

- Bacteria levels at the Piper's Creek outfall station (KSHZ03) were above the geomean WQC for fecal coliform at least once every year. Bacteria levels at this station have routinely been above WQC for more than 20 years. Several bacteria source-tracking and reduction efforts in the Carkeek/Thornton Creek watersheds have occurred during this time and are on-going (See project website at Thornton Creek Basin - Sewer Study and Upgrade - King County). Significantly lower bacteria levels are typically detected at the ambient station just north of the Piper's Creek station (ITCARKEEKP).

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