TECHNICAL REPORT

Assessment of Fecal Indicator Bacteria Data from 21 Humboldt County Coastal Streams

Planning Unit

Planning and Stewardship Division

North Coast Regional Water Quality Control Board

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California Regional Water Quality Control Board

North Coast Region

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1. Introduction

This technical report evaluates fecal indicator bacteria (FIB) data collected from 21 Humboldt County coastal streams, under the Coastal Pathogen Project, to ascertain whether these streams meet bacterial Water Quality Objectives (Objectives) described in the Water Quality Control Plan for the North Coast Region (Basin Plan) (North Coast Regional Water Quality Control Board, 2018). The Objectives evaluated have been described in Section 1.1 of this report.

Six of the 21 coastal streams evaluated in this technical report were placed on the Section 303(d) List of Impaired Waters (Section 303(d) List) in 2012 for impairment of the Water Contact Recreation (REC-1) beneficial use due to pathogen contamination based on FIB data collected from these coastal streams (State Water Resources Control Board, 2015a). Under the Coastal Pathogen Project, the North Coast Regional Water Quality Control Board (Regional Water Board) conducted both an Impaired Streams Monitoring Study and a Source Assessment Study to evaluate the water quality of impaired and other nearby streams and identify potential sources of fecal contamination within watersheds encompassing impaired coastal water bodies in Humboldt County.

The results of the evaluation conducted in this technical report will be considered in conjunction with the Coastal Pathogen Project Source Assessment report which evaluates Microbial Source Tracking (MST), land coverage, and land use data collected as part of the Coastal Pathogen Project. Recommendations for next steps related to the Coastal Pathogen Project will be provided in the Coastal Pathogen Project Synthesis report.

The 21 coastal streams assessed in this report are displayed in Figure 1.

Figure 1 The locations of the sampling stations in the 21 Coastal Streams Assessed in this Technical Report

1.1. Narrative and Numeric Bacteria Objectives

The Regional Water Board Basin Plan establishes narrative and numeric bacteria Objectives for inland surface waters, enclosed bays, and estuaries for the protection of beneficial uses and the prevention of water quality degradation as required by the Anti-degradation Policy (North Coast Regional Water Quality Control Board, 2018). The 21 streams assessed in this report have been evaluated to determine whether they 1) are consistent with natural background levels and 2) exceed criteria for REC-1 beneficial use. The narrative objective, and the numeric objectives for the protection of REC-1 beneficial use are listed in Table 1 below.

Table 1 Regional Water Board Narrative and Numeric Bacteria Objectives

<table>
<tr><th colspan="4">NARRATIVE OBJECTIVE</th></tr>
<tr><td colspan="4">The bacteriological quality of waters of the North Coast Region shall not be degraded beyond natural background levels.</td></tr>
<tr><th colspan="4">NUMERIC OBJECTIVE FOR THE PROTECTION OF REC-1 BENEFICIAL USE</th></tr>
<tr><td rowspan="3">Applicable Waters</td><td rowspan="2">Objective Elements</td><td colspan="2">Estimated Illness Rate (NGI):
32 per 1,000 water contact recreators</td></tr>
<tr><td colspan="2">Magnitude</td></tr>
<tr><td>Indicator</td><td>GM (cfu/100 mL)</td><td>STV (cfu/100 mL)</td></tr>
<tr><td>All waters where salinity is equal to or less than 1 ppth 95 percent or more of the time</td><td>E. coli</td><td>100</td><td>320</td></tr>
<tr><td>All waters where the salinity is greater than 1 ppth more than 5 percent of the time</td><td>Enterococci</td><td>30</td><td>110</td></tr>
<tr><td colspan="4">The waterbody GM shall not be greater than the applicable GM magnitude in any six-week interval, calculated weekly. The applicable STV shall not be exceeded by more than 10 percent of the samples collected in a CALENDAR MONTH, calculated in a static manner

NGI = National Epidemiological and Environmental Assessment of Recreational Water gastrointestinal illness rate
GM = geometric mean
STV = statistical threshold value
cfu = colony forming units
mL = milliliters
ppth = parts per thousand</td></tr>
</table>

Regional Water Board staff have developed a hypothesis-testing-based evaluation process to assess if FIB concentrations measured in a stream of interest are consistent with natural background levels. A detailed description of this process can be found in the Technical Report entitled “An Interpretation of the North Coast Regional Water Quality Control Board Narrative Natural Background Water Quality Objective for Bacteria” (North Coast Regional Water Quality Control Board, 2023b). A summary of this evaluation process is described in Section 2.4.2 of this report.

The applicable numeric objective for the protection of waters with the REC-1 beneficial use was adopted under the statewide Bacteria Provisions and a Water Quality Standards Variance Policy (Bacteria Provisions), which superseded the Regional numeric objective in 2019 (State Water Resources Control Board, 2019). The statewide Bacteria Provisions will ultimately be incorporated into the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California (State Water Resources Control Board, 2019). The adopted statewide Bacteria Provisions establish objectives for the protection of REC-1 beneficial use based on the United States Environmental Protection Agency (USEPA) federal Recreational Water Quality Criteria (RWQC) estimated illness rate (NGI) of 32 per 1,000 recreators and the associated numeric thresholds based on salinity level. (State Water Resources Control Board, 2018a, 2019; United States Environmental Protection Agency, 2012). The *E. coli* objective applies for fresh waters, and the enterococci objective applies for saline waters as described in Table 1 above (State Water Resources Control Board, 2019). A summary of how these Objectives are evaluated is described in Section 2.4.3 of this report.

2. Methods

2.1. Sample Collection

As described in Section 1, samples were collected under two studies conducted as a part of the Coastal Pathogen Project – the Impaired Streams Monitoring Study, and the Source Assessment Study. For both studies, water grab samples were collected between February 2016 and January 2018. Sample collection was performed according to the monitoring plan and standard operating procedures (SOP) included in the Quality Assurance Project Plan (QAPP) developed for this project (North Coast Regional Water Quality Control Board, 2015).

Samples collected from all six sampling stations[1] of the Impaired Streams Monitoring Study have been evaluated in this report.

Although samples from 26 sampling stations, in total, were collected as part of the Source Assessment Study, FIB data from six of those sampling stations are not included in this technical report since two of the sampling stations are located in roadside ditches, and only one sample each was collected from four sampling stations. Specifically, this report does not evaluate samples that were collected from drainage ditches or other off-stream structures, and it does not evaluate streams with inadequate samples. Further details about the sampling limitations described above can be found in the Technical Memorandum entitled “Exclusion of Specific Source Assessment Study Sampling Stations from Fecal Indicator Bacteria and Microbial Source Tracking Data Assessment” (North Coast Regional Water Quality Control Board, 2023c). Therefore, samples collected from six sampling stations of the Impaired Streams Monitoring Study, and 20 sampling stations of the Source Assessment Study, (a total of 26 sampling stations) have been analyzed in this report.

Of the 26 total sampling stations evaluated in this report, 20 are freshwater while six are saline. Salinity data were not collected during the initial sampling conducted between 2016 and 2018. However, the salinity of each sampling station was determined in 2022 as detailed in Section 2.2.

Samples were collected during dry and wet weather events. Dry weather sampling period samples were collected after 72 hours of dry weather, and wet weather sampling period samples were collected during, or following, storm events that were predicted to generate 0.2 inches or greater of rainfall (North Coast Regional Water Quality Control Board, 2015). Antecedent precipitation data were obtained from the Eureka Woodley Island (ERK) National Weather Service precipitation station, which is the closest

[1] The figures in this technical report use the term “sampling location” when referring to the various sampling stations from where samples were collected as part of the Impaired Streams Monitoring Study and the Source Assessment Study. The terms “sampling location” and “sampling station” are interchangeable.

precipitation station to all sampling stations from both studies (California Department of Water Resources, 2023).

All samples for the Impaired Streams Monitoring Study were collected between February 2016 and January 2018. Dry period samples were collected in February, May, August, and September of 2016, and July and October of 2017. Wet period samples were collected in February, October, November, and December of 2016, December 2017, and January 2018. All samples for the Source Assessment Study were collected between December 2016 and January 2018. Dry period samples were collected in February, October, November, and December 2016, December 2017, and January 2018. Wet period samples were collected in May, August, and September 2016, and July and December 2017.

Replicate samples were collected at a small number of randomly selected sampling stations to serve as field replicates for quality assurance and quality control (QA/QC) purposes. Only the first replicate sample from these sampling stations was included in the data analysis.

Sample collection details for all 26 sampling stations analyzed in this technical report are provided in Table 2 and the locations of all 26 sampling stations analyzed in this technical report are displayed in Figures 2 and 3.

2.2. Identification of Freshwater and Saline Sampling Stations

Salinity data were not collected when the Impaired Streams Monitoring Study and the Source Assessment Study were conducted between 2016 and 2018. The salinity of each sampling station is required in order to compare FIB data to the appropriate statewide REC-1 Objective (*E.coli* for freshwater and enterococcus for saline) as described in Table 1 in Section 1.1 of this technical report. Therefore, the salinity of each sampling station was determined in 2022 using a two-step process comprised of a desktop assessment followed by field confirmation of targeted sampling stations. Detailed information about the salinity determination process can be found in the Technical Memorandum “2022 Salinity Study” (Tracy, 2022). A brief overview is described below.

The desktop assessment was based on a combination of Region 1 staff’s local knowledge of the coastal streams evaluated, along with the use of Geographic Information System (GIS) software by mapping all sampling stations using the “World Topographic Map” and “World Imagery” layers of ArcGIS (ESRI, 2018), and using United States Geological Survey (USGS) elevation data for each sampling station. An elevation cutoff of 50 feet above sea level was used to determine tidal influence. The desktop assessment found that nine sampling stations analyzed in this report were freshwater 100% of the time.

The remaining 17 sampling stations were evaluated by conducting a site visit to each of these stations to collect salinity data during one tidal cycle in order to capture the

highest and lowest tide levels. To determine if the single high tide event sampled was sufficient to delineate freshwater sampling stations from saline sampling stations, the National Oceanic and Atmospheric Administration (NOAA) predicted high-high tide for the date of the site visit was compared to all the tidal predictions for calendar year 2022. This comparison demonstrated that the maximum number of hours that any subsequent tides may exceed the high-high tide of the day of the site visit was less than 3% of the hours in the calendar year. Therefore, any sample station determined to be freshwater during the site visit was considered freshwater since analysis reflected it was freshwater at least 97% of the time, which exceeds the statewide bacteria objectives requirement of 95% frequency. This assessment resulted in staff identifying 11 of the remaining 17 sampling stations as freshwater. For the last six sampling stations, instream salinity data collected during the site visit, and the USGS parameters for saline water, were used to confirm that all six sampling stations were saline. As a result of the 2022 salinity assessment, 20 sampling stations were designated as freshwater and 6 as saline. Salinity details for all 26 sampling stations analyzed in this report are provided in Table 2.

Table 2 Sample Collection Details of the Impaired Streams Monitoring Study and the Source Assessment Study

Station Name	Station Code[c]	Water Type	Number of Samples Collected	
			Dry Sampling Period	Wet Sampling Period
Elk River at Highway 101[a]	110EL1278	Saline	6	5
Gannon Slough near Highway 101[a]	110GS1625	Saline	5	6
Jolly Giant Creek at Samoa Boulevard[a]	110JG0264	Freshwater	5	6
Little River at Highway 10[a]	108LR0663	Saline	5	6

Station Name	Station Code[c]	Water Type	Number of Samples Collected	
			Dry Sampling Period	Wet Sampling Period
Martin Slough at Pine Hill Road[a]	110MS1481	Saline	6	5
Norton Creek at Highway 101[a]	109NR1488	Freshwater	5	6
Campbell Creek at 7th Street[b]	110GS5000	Freshwater	1	3
Campbell Creek at 14th Street and Union Street[b]	110GS6500	Freshwater	1	3
Cooper Gulch at Myrtle Avenue and 8th Street[b]	110CG5000	Freshwater	2	2
Elk River at Zanes Road[b]	110ER6642	Freshwater	2	2
Elk River South Fork at Headwaters Forest[b]	110SF1612	Freshwater	2	2
Freshwater Creek at County Park[b]	110FR4642	Freshwater	2	2
Graham Gulch at Pacific Lumber Camp Road[b]	110GG0100	Freshwater	2	2

Station Name	Station Code[c]	Water Type	Number of Samples Collected	
			Dry Sampling Period	Wet Sampling Period
Grotzman Creek at Bayside Road[b]	110GR0500	Freshwater	2	2
Jacoby Creek at Jacoby Creek Road[b]	110JC6316	Freshwater	2	2
Jacoby Creek at Old Arcata Road[b]	110JC0966	Freshwater	2	2
Liscom Slough at Jackson Road[b]	110UNSJXN	Saline	1	3
Martin Slough at Campton Street and Fern Street[b]	110MS6750	Freshwater	2	2
McDaniel Slough at Q Street[b]	110MD3750	Freshwater	1	3
Mill Creek at Stagecoach Road[b]	108MC1250	Freshwater	2	2
Salmon Creek at Eel River Drive[b]	110SA1720	Freshwater	2	2
Strawberry Creek at Highway 101[b]	108SC0550	Freshwater	2	2

Station Name	Station Code[c]	Water Type	Number of Samples Collected	
			Dry Sampling Period	Wet Sampling Period
Swain Slough at Elk River Road[b]	110SS9000	Saline	2	2
Unnamed Stream at Anker Road[b]	109UNTANKR	Freshwater	2	2
Unnamed Slough at Lanphere Road[b]	110UNSLPHR	Freshwater	1	3
Unnamed Slough at Ranch Road[b]	110UNSRNCH	Freshwater	2	2

[a] Impaired Streams Monitoring Study

[b]Source Assessment Study

[c] The sampling station code has been developed according to the Surface Water Ambient Monitoring Program (SWAMP) naming convention for sampling stations. SWAMP requires a numeric 3-digit code for the hydrologic unit of the stream being sampled followed by a random 6-digit code, which, in Region 1, consists of a 2-letter code for the stream name, and a 4-digit code signifying the distance of the sampling station from the mouth of the stream. Codes for unnamed streams required an adjustment to the commonly used naming convention, resulting in a seven-letter code.

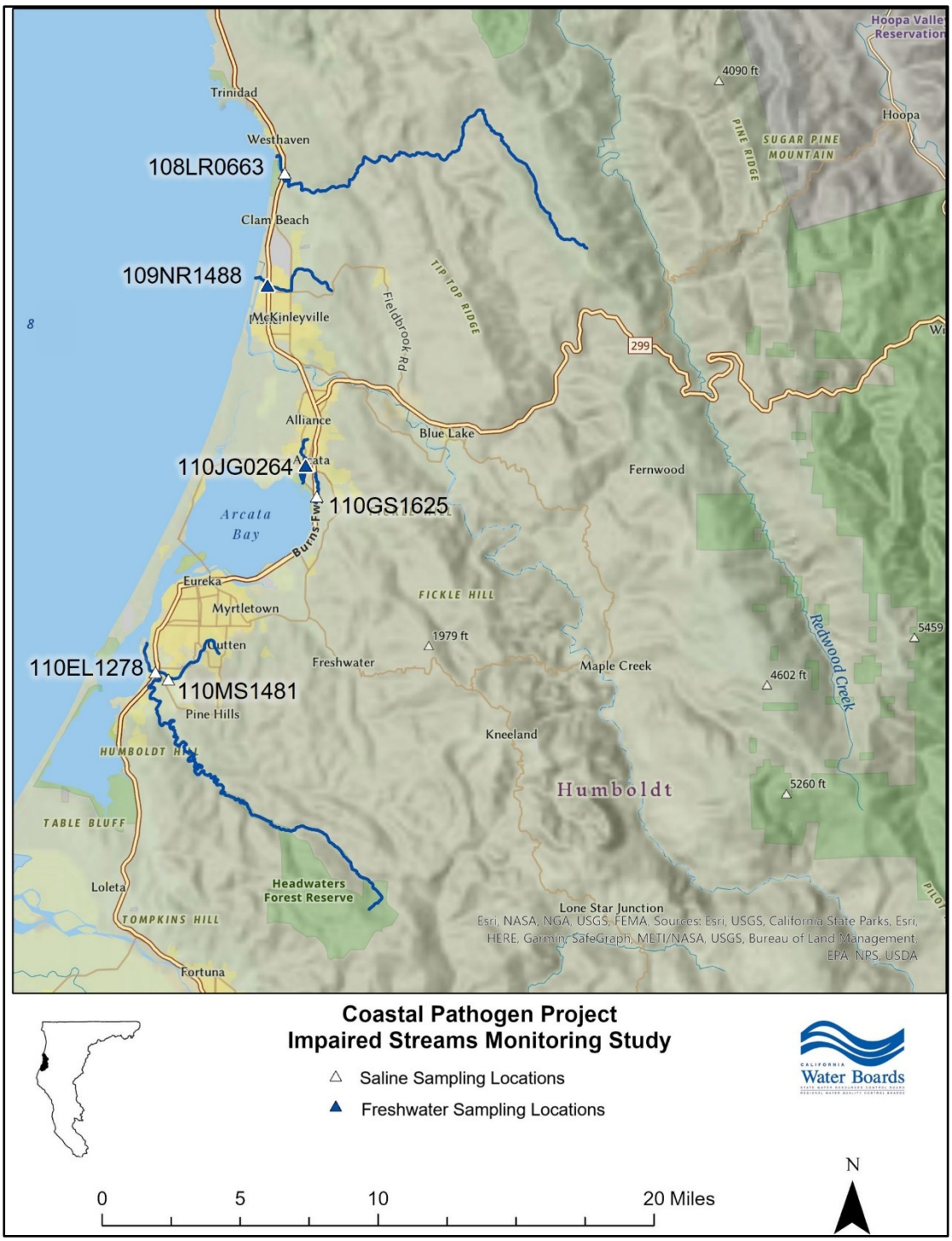

Figure 2 Sampling Stations of the Impaired Streams Monitoring Study

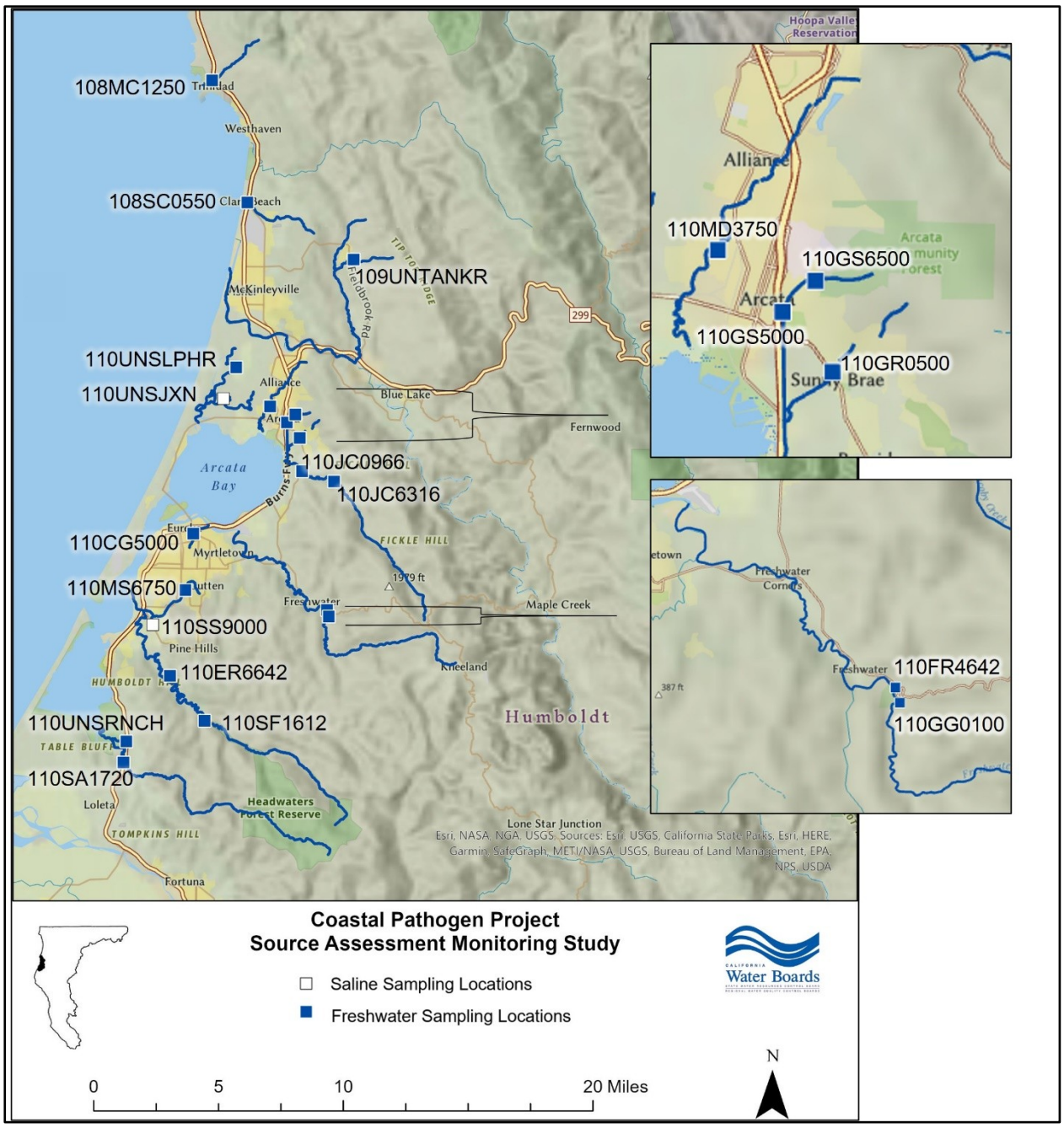

Figure 3 Sampling Stations of the Source Assessment Study

2.3. Laboratory Analysis of FIB Samples

Samples collected from all 26 sampling stations assessed in this report were analyzed by the Humboldt County Public Health Laboratory according to the standard operating procedures described in the QAPP for the Coastal Pathogen Project (North Coast Regional Water Quality Control Board, 2015). All samples were analyzed for the detection and enumeration of *E. coli* and enterococci. The Colilert and Enterolert tests were used for the detection and enumeration of *E. coli* and enterococci, respectively, according to the USEPA Standard Method 9223B (Enzyme Substrate Coliform Test) (Standard Methods, 2016). However, only *E. coli* data from two freshwater sampling stations with a sufficient number of samples were evaluated for consistency with the narrative Natural Background Objective for bacteria as described in Section 2.4.2. *E. coli* data from freshwater sampling stations, and enterococci data from saline sampling stations were evaluated for the comparison with the REC-1 Objective as described in Section 2.4.3.

2.4. Data Analysis

FIB data for all samples of the Coastal Pathogen Project, including the Impaired Streams Monitoring Study and the Source Assessment Study, are available in the California Environmental Data Exchange Network (CEDEN) database (https://ceden.waterboards.ca.gov/) (State Water Resources Control Board, 2023), under the Project “Coastal Pathogen Project 2016-2018”.

Data were preprocessed and then analyzed to compare *E. coli* and enterococci concentrations to the Regional Water Board narrative Natural Background Objective for bacteria and the REC-1 Objectives described in Section 1.1 of this report. An FIB data summary (median, maximum, and minimum concentrations of *E. coli* or enterococci) was also conducted, and a statistical and graphical comparison of *E. coli* or enterococci concentrations in dry and wet sampling periods has also been provided in this report.

2.4.1. Data Preprocessing

Before data analysis was conducted FIB data were preprocessed as described below.

For a given sampling station, for all sampling dates where replicate samples were collected, only the first sample collected was included in the data analysis.

The percentage of non-detects (samples with FIB concentration below the lower method detection limit) in all samples analyzed for the detection and enumeration of *E. coli* and enterococci were 5% and 13% respectively. These samples were assigned the value of the lower method detection limit as per the guidance by the United States Environmental Protection Agency regarding datasets with less than 15% non-detects (United States Environmental Protection Agency, 2000). Due to a laboratory error 0.6% of total samples analyzed had *E. coli* and enterococci values above the upper method detection limit. These samples were assigned the value of the upper method detection

limit. The laboratory error was that these samples were not diluted, as required by the Coastal Pathogen Project QAPP, prior to analysis for the detection and enumeration of *E. coli* and enterococci.

2.4.2. Comparison of *E. coli* data to the Natural Background Bacteria Objective

Regional Water Board Staff have developed an ecoregion-based process as one interpretation of the Regional Water Board narrative Natural Background Objective for Bacteria. A detailed description of the general hypothesis-testing-based evaluation process developed for North Coast ecoregions is provided in a Technical Report entitled An Interpretation of the North Coast Regional Water Quality Control Board Narrative Natural Background Water Quality Objective for Bacteria" (North Coast Regional Water Quality Control Board, 2023b). An adaptation of this approach specific to the Coast Range can be found in a Technical Report entitled "An Interpretation of the North Coast Regional Water Quality Control Board Narrative Natural Background Water Quality Objective for Bacteria – Coast Range Ecoregion" (North Coast Regional Water Quality Control Board, 2023a). All 26 sampling stations assessed in this technical report are in the Coast Range Ecoregion. A brief description of the assessment process is provided below.

As written, the assessment is carried out by ecoregion for a specific (dry or wet) sampling period. Briefly, to determine whether FIB levels from a stream being assessed are consistent with natural background levels, the *E. coli* (or enterococci) concentrations in the freshwater (or saline) stream being evaluated are compared to freshwater (or saline) natural background *E. coli* (or enterococci) concentrations of that ecoregion.

In order to assess whether a particular freshwater (or saline) stream in a specific ecoregion is consistent with freshwater (or saline) natural background for that ecoregion and sampling period, the following process is used – dry or wet sampling period *E. coli* (or enterococci) data collected from that stream are compared to the dry or wet sampling period natural background *E. coli* (enterococci) dataset for that ecoregion using a the Wilcoxon Rank Sum Test to evaluate the following hypotheses:

The null hypothesis (H_0): The median *E.coli* (or enterococci) concentration in samples collected from a freshwater (or saline) stream being assessed in a particular ecoregion is less than or equal to the median *E. coli* (or enterococci) concentration in the minimally disturbed freshwater (or saline) streams dataset for that ecoregion.

The alternative hypothesis (H_A): The median *E.coli* (or enterococci) concentration in samples collected from a freshwater (or saline) stream being assessed in a particular ecoregion is greater than the median *E. coli* (or enterococci) concentration in the minimally disturbed freshwater (or saline) streams dataset for that ecoregion.

A p value < 0.05 was assumed to be statistically significant.

When assessing a particular stream to evaluate whether it is consistent with the Regional Water Board narrative Natural Background Bacterial Objective for its ecoregion, if the results of the Wilcoxon Rank Sum test indicate a p value < 0.05 then the null hypothesis can be rejected, and the evaluation result is that the stream is not consistent with the narrative Natural Background Bacterial Objective. If the results of the Wilcoxon Rank Sum test indicate a p value > 0.05 it cannot be conversely determined that that stream is consistent with the narrative Natural Background Objective. In this case, the test result indicates that there is insufficient evidence to show that there are any differences between the two datasets being compared, and it is likely that more samples may need to be collected and evaluated to make a determination.

However, due to the nature of statistical testing and hypothesis-based evaluation, the finding that a stream is not consistent with the narrative Natural Background Objective should not be evaluated in isolation, and should only be used as a line of evidence along with exceedance assessments, and data summaries to make an informed decision.

It should be noted that Regional Water Board staff recommend that a minimum number of five samples should be collected from the stream being assessed for consistency with the Natural Background Objective. This is because at least five samples are required for the calculation of a geometric mean of the REC-1 Objective, and often a stream being assessed for consistency with the Natural Background Bacterial Objective will most likely also be undergoing assessment of exceedance of the REC-1 Objective.

All 26 coastal stream sampling stations of the Coastal Pathogen Project are in the Coast Range ecoregion, therefore they are assessed for consistency with the Coast Range ecoregion natural background levels. Currently, the only natural background data available for the Coast Range ecoregion are *E. coli* data from freshwater minimally disturbed streams. Therefore, only the 20 freshwater stations can be considered for evaluation of consistency with the narrative Natural Background Objective. Furthermore, of those 20 sampling stations, only two freshwater stream sampling stations have at least five samples available per sampling period – Jolly Giant Creek at Samoa Boulevard, and Norton Creek at Highway 101. Therefore, only *E. coli* data from these two sampling stations were assessed for consistency with the Regional Water Board narrative Natural Background Bacterial Objective using the method described above.

An additional factor that should be noted when interpreting the results of the assessment of the Jolly Giant Creek at Samoa Boulevard and Norton Creek at Highway 101 sampling stations is the difference between the sample size of the *E. coli* dataset for each of these two sampling stations and the sample size of the Coast Range ecoregion minimally disturbed stream *E. coli* dataset. The current Coast Range ecoregion minimally disturbed freshwater stream dataset consists of 58 dry sampling period samples and 37 wet sampling period samples whereas the datasets of the two sampling stations being evaluated consist of five dry sampling period and six wet sampling period samples each. This large difference in sample sizes between the

groups being compared – five dry (or six wet) sampling period samples, and 58 dry (or 37 wet) sampling period samples, results in uncertainty when interpreting evaluation results because the power of a statistical test (i.e. the ability of the test to detect whether an actual difference exists between the two groups being compared) decreases as the sample sizes of the two groups being compared become more unequal. A loss of power can increase the chance that the null hypothesis being examined is mistakenly rejected, and an incorrect assessment conclusion is reached. Therefore, the assessment reported in this document should not be considered in isolation, but as one of several lines of evidence, as recommended above. The limitation described above is a result of 1) the sampling for the minimally disturbed stream dataset having been conducted before the interpretation process described in this section was developed, 2) Impaired Stream Monitoring Study sampling having occurred before the current geometric mean-based Objective threshold being developed. This limitation can be overcome by using the consistency testing results, as one of several lines of evidence about the water quality of the stream being evaluated.

All calculations were performed using R (version 4.1.2) and matrixTests (version 0.1.9.1) (Koncevicius, 2021; R Foundation for Statistical Computing, 2022).

2.4.3. Comparison of FIB data to the REC-1 Objective

FIB data collected from all 26 sampling stations were assessed for exceedance of the Regional Water Board REC-1 Objectives as described in Table 1 in Section 1.1 of this report. The REC-1 Objectives establish two numeric thresholds applicable to waters with REC-1 beneficial use depending on salinity level (State Water Resources Control Board, 2019). The *E. coli* Objective element applies to fresh waters and the enterococci Objective element applies to saline waters as described in Table 1 in Section 1.1 (State Water Resources Control Board, 2019). As indicated in Table 2, of the 26 sampling stations evaluated in this technical report, 20 are freshwater sampling stations, while six are saline sampling stations. Therefore, *E. coli* data were assessed from the 20 freshwater sampling stations, and enterococci data were assessed from the six saline sampling stations.

Data from each sampling station were evaluated for three assessment periods: 1) all data for one assessment year (year-Round assessment), November 1 of Calendar Year 1 through October 31 of Calendar Year 2; 2) data from one winter season (winter assessment period), November 1 through March 31 of an assessment year; and 3) data from one summer season (summer assessment period), April 1 through October 31 of an assessment year. Where sufficient data were available, Geometric Means and Statistical Threshold Values were calculated for each assessment period and sampling station to determine whether they exceeded the applicable REC-1 Objective threshold. All data analysis was conducted using R (version 4.1.2).

2.4.3.1. Calculation of the Geometric Mean parameter of the REC-1 Objective

A geometric mean (GM) is defined as the nth root of the product of n numbers (State Water Resources Control Board, 2019). The REC-1 numeric Water Quality Objectives requires the calculation of a six-week rolling geometric mean. This type of GM is calculated over a period of six-weeks using a timeframe that rolls ahead one week at a time in order to calculate each GM (Figure 4). To calculate a single six-week rolling GM a minimum of five grab samples are required within each six-week period. If sufficient grab samples are not available for a particular assessment period (year-round, winter, and summer) then a GM cannot be calculated for that assessment period. This process of GM calculation follows the guidelines for FIB data assessment under the listing policy as established in the statewide numeric bacteria Water Quality Objectives for the protection of REC-1 (State Water Resources Control Board, 2015b, 2019).

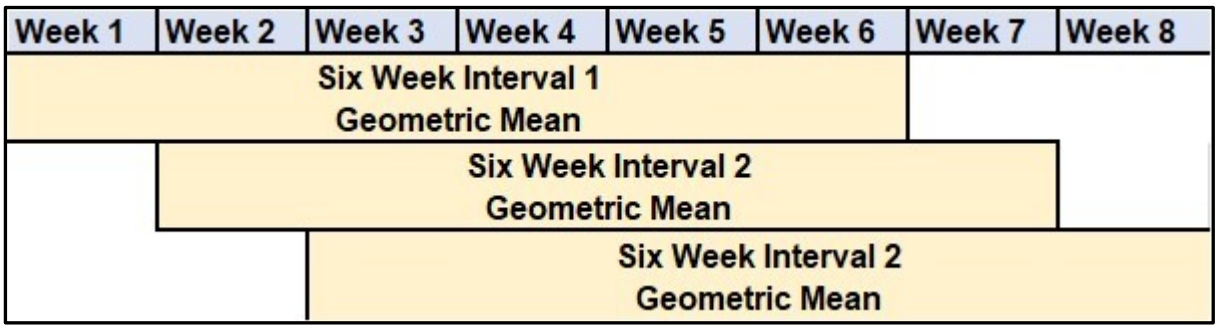

Figure 4 Intervals for the Calculation of a Six-week Rolling Geometric Mean

2.4.3.2. Calculation of the Statistical Threshold Value parameter of the REC-1 Objective

A Statistical Threshold Value is a set value that approximates the 90th percentile of the water quality distribution of a bacterial population (State Water Resources Control Board, 2019). A minimum of one grab sample is required to calculate an STV. An STV is calculated using a static window covering a timeframe of one calendar month. If more than 10 percent of the month's grab samples exceed the STV, then that month is considered to violate the objective.

An insufficient number of samples were collected from all 26 sampling stations to calculate a six-week rolling GM. Therefore, only STVs were calculated for each sampling station. For each sampling station, assessment period, and FIB type, the following two calculations were performed: 1) the total number of STV calculations that could be computed per sampling station (Total Number of Calculations), and 2) the number of exceedances of the applicable REC-1 Water Quality Objective STV threshold (Number of Exceedances). All calculations were performed using R (version 4.1.2) (R Foundation for Statistical Computing, 2022).

2.4.4. Summary and Comparison of Dry and Wet Sampling Period FIB Concentrations

As is typical for environmental data, FIB data collected from all sampling stations during both dry and wet sampling periods did not follow a normal distribution (Helsel et al., 2020). Since the FIB data were not normally distributed, non-parametric data analysis methods were used for summary statistics. Data that are not normally distributed are often assessed using non-parametric analysis methods since these methods are free of assumptions about how the data are distributed, and are minimally affected by extreme values. Medians were used as a measure of central tendency, and the Wilcoxon Rank Sum Test was used to determine whether FIB data collected during the dry sampling period were statistically significantly different from FIB data collected during the wet sampling period for each sampling station assessed. A p value < 0.05 was assumed to be statistically significant. All data analysis was conducted using R (version 4.1.2).

3. Results

3.1. Comparison of *E. coli* Data to the Natural Background Objective

For both the Jolly Giant Creek at Samoa Boulevard, and Norton Creek at Highway 101 sampling stations, for both the dry, and wet, sampling periods, the median *E. coli* concentrations were statistically significantly higher ($p < 0.05$) than the median *E. coli* concentrations from the Coast Range ecoregion minimally disturbed freshwater stream dataset. This indicates that these sampling stations are not consistent with the Regional Water Board narrative Natural Background Bacterial Objective for the Coast Range ecoregion for both the dry and wet sampling period assessment periods.

3.2. Comparison of FIB Data to the REC-1 Objective

E. coli data from all 20 freshwater sampling stations were compared to the REC-1 Objective for *E. coli* in fresh waters; and enterococci data from all six saline sampling stations were compared to the REC-1 Objective for enterococci in saline waters, as described in Table 1 in Section 1.1 of this report.

For both freshwater and saline sampling stations, the data collected from any of the 26 sampling stations assessed were not sufficient to calculate a six-week rolling GM for any assessment period. As described in Section 2.4.3.1, a minimum of five grab samples are required within each six-week period to calculate a single six-week rolling GM. As described in Section 2.4.3.2, a minimum of one grab sample is required to calculate an STV. Therefore, only STVs were calculated for each sampling station and assessment period. The assessment results for all 20 freshwater sampling stations are detailed in Table 3, and the assessment results for all six saline sampling stations are detailed in Table 4. Figures 5, 6, 7, and 8 are graphical representations of the exceedances of the STV threshold of the REC-1 Objective by *E. coli* concentrations at five freshwater sampling stations per figure. Figure 9 is a graphical representation of the exceedance of the STV threshold of the REC-1 Objective by the enterococcus concentrations measured at the five saline sampling stations.

Table 3 Exceedance of the *E. coli* STV Threshold of the REC-1 Freshwater Objective for Fresh Waters by Assessment Period

Freshwater Sampling Station Name	Number of Exceedances/Total Number of Calculations (STV)[a]		
	Year-Round	Winter	Summer
Jolly Giant Creek at Samoa Boulevard	9/11	3/5	6/6
Norton Creek at Highway 101	4/11	1/5	3/6
Campbell Creek at 14th Street and Union Street	1/4	1/3	0/1
Campbell Creek at 7th Street	2/4	1/3	1/1
Cooper Gulch at Myrtle Avenue and 8th Street	4/4	2/2	2/2
Elk River at Zanes Road	2/4	0/2	0/2
Elk River South Fork at Headwaters Forest	0/4	0/2	0/2

Freshwater Sampling Station Name	Number of Exceedances/Total Number of Calculations (STV)[a]		
	Year-Round	Winter	Summer
Freshwater Creek at County Park	0/4	0/2	0/2
Graham Gulch at Pacific Lumber Camp Road	0/4	0/2	0/2
Grotzman Creek at Bayside Road	2/4	1/2	1/2
Jacoby Creek at Jacoby Creek Road	0/4	0/2	0/2
Jacoby Creek at Old Arcata Road	2/4	1/2	1/2
Martin Slough at Campton Street and Fern Street	1/4	0/2	1/2
McDaniel Slough at Q Street	2/4	1/3	1/1

Freshwater Sampling Station Name	Number of Exceedances/Total Number of Calculations (STV)[a]		
	Year-Round	Winter	Summer
Mill Creek at Stagecoach Road	0/4	0/2	0/2
Salmon Creek at Eel River Drive	1/4	1/2	0/2
Strawberry Creek at Highway 101	0/4	0/2	0/2
Unnamed Slough at Lanphere Road	3/4	2/3	1/1
Unnamed Slough at Ranch Road	2/4	1/2	1/2
Unnamed Stream at Anker Road	0/4	0/2	0/2

[a]The first number refers to the total number of exceedances of the *E.coli* STV threshold per the statewide REC-1 Water Quality Objectives for fresh waters for a particular assessment period at a particular sampling station, and the second number refers to the total number of *E.coli* STVs calculated for a particular assessment period at a particular sampling station. (e.g. 9/11 means there were 9 exceedances of the *E.coli* STV threshold out of 11 total STVs calculated.)

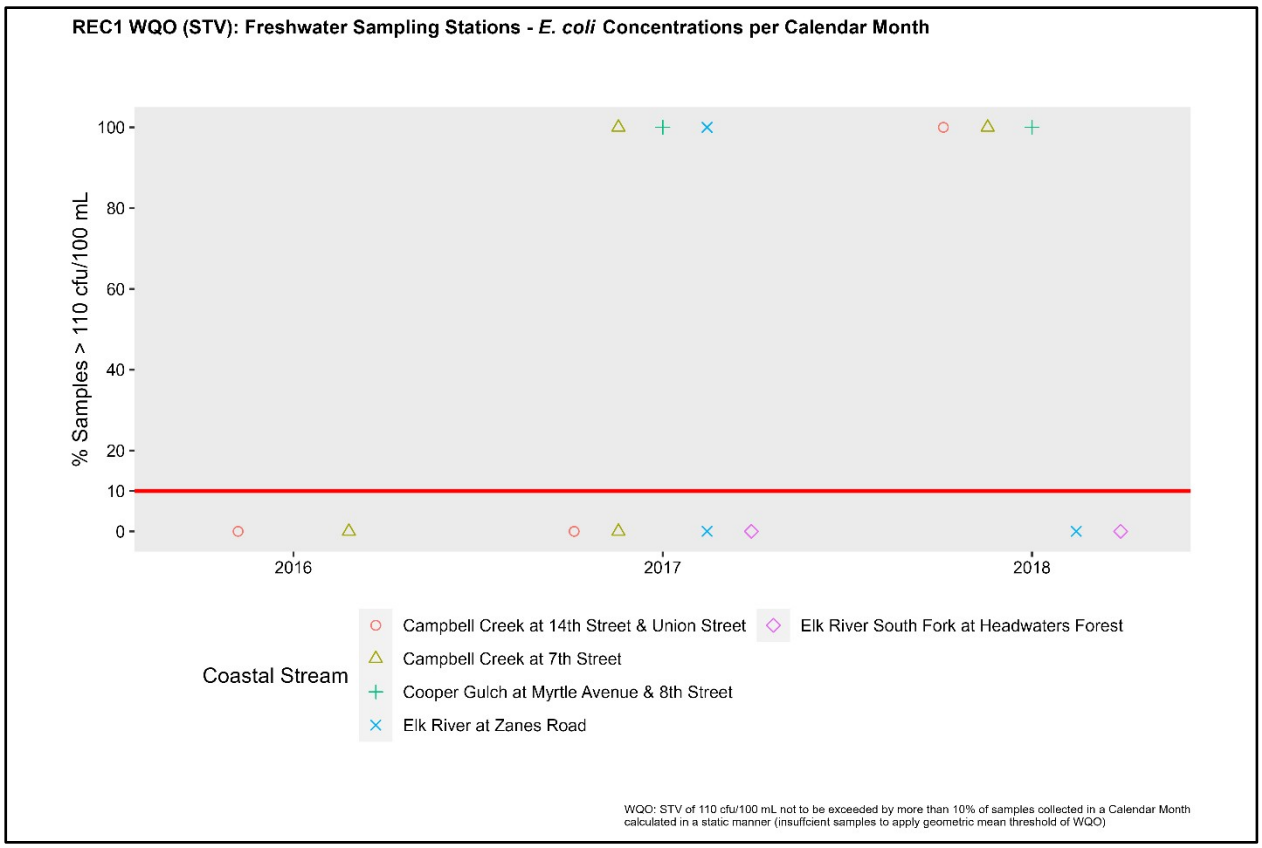

Figure 5 Exceedances of the STV threshold of the REC-1 WQO by *E. coli* Concentrations measured at Freshwater Sampling Stations

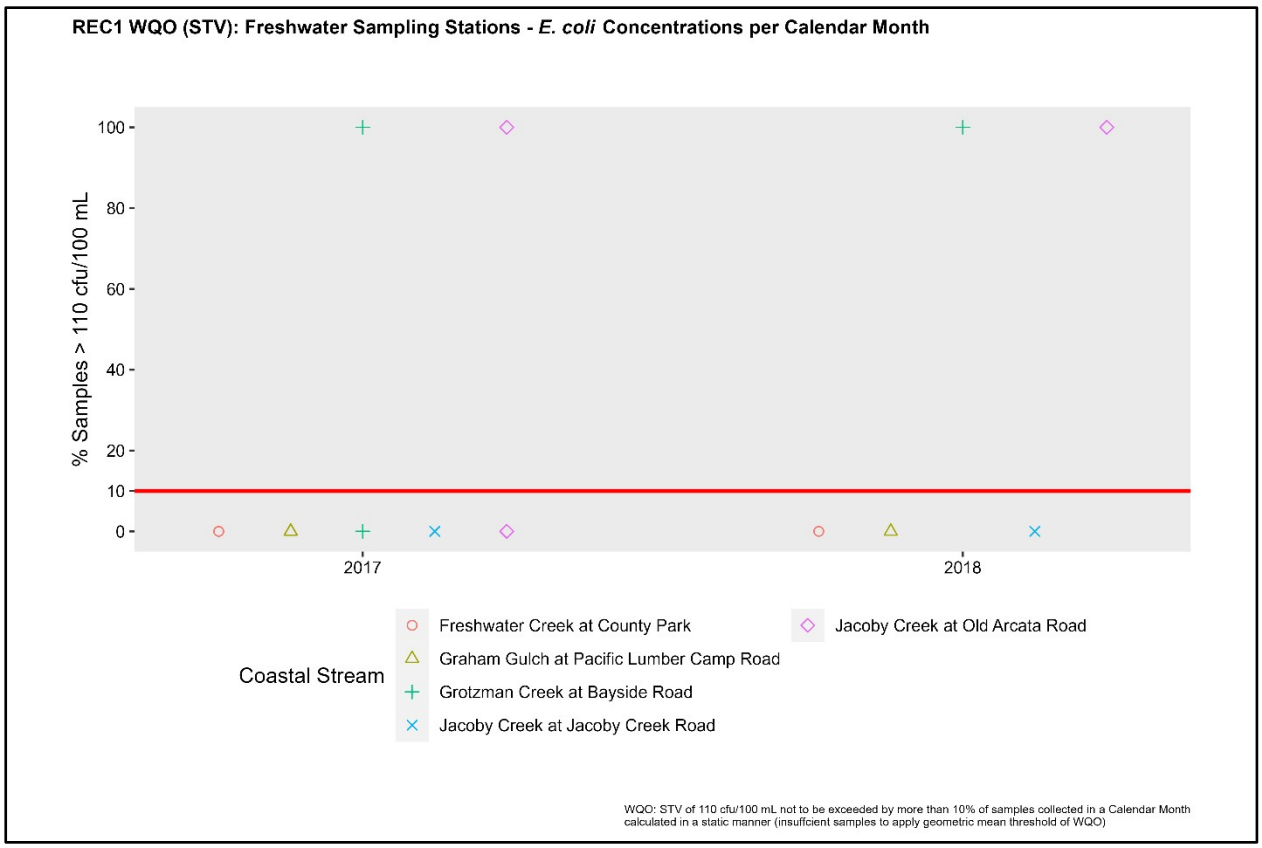

Figure 6 Exceedances of the STV threshold of the REC-1 WQO by *E. coli* Concentrations measured at Freshwater Sampling Stations

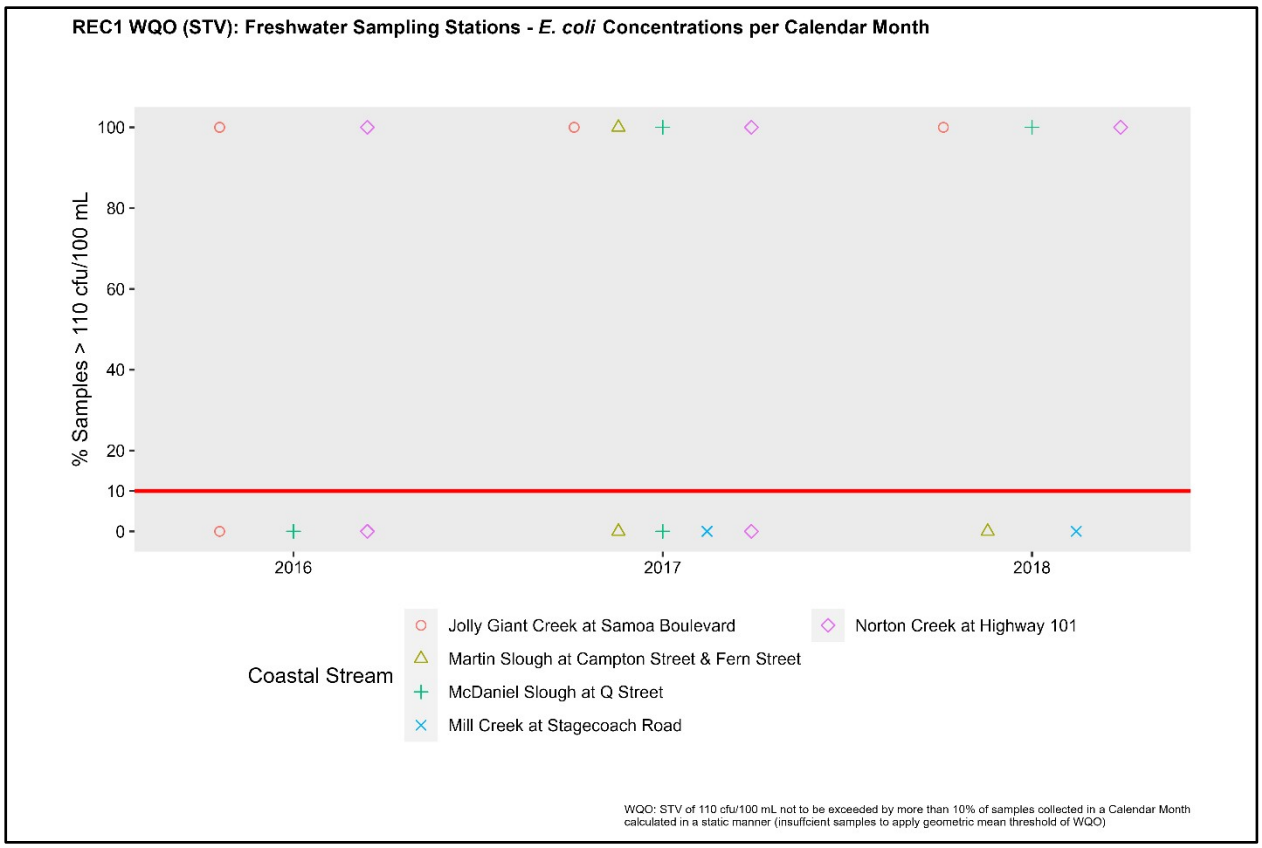

Figure 7 Exceedances of the STV threshold of the REC-1 WQO by *E. coli* Concentrations measured at Freshwater Sampling Stations

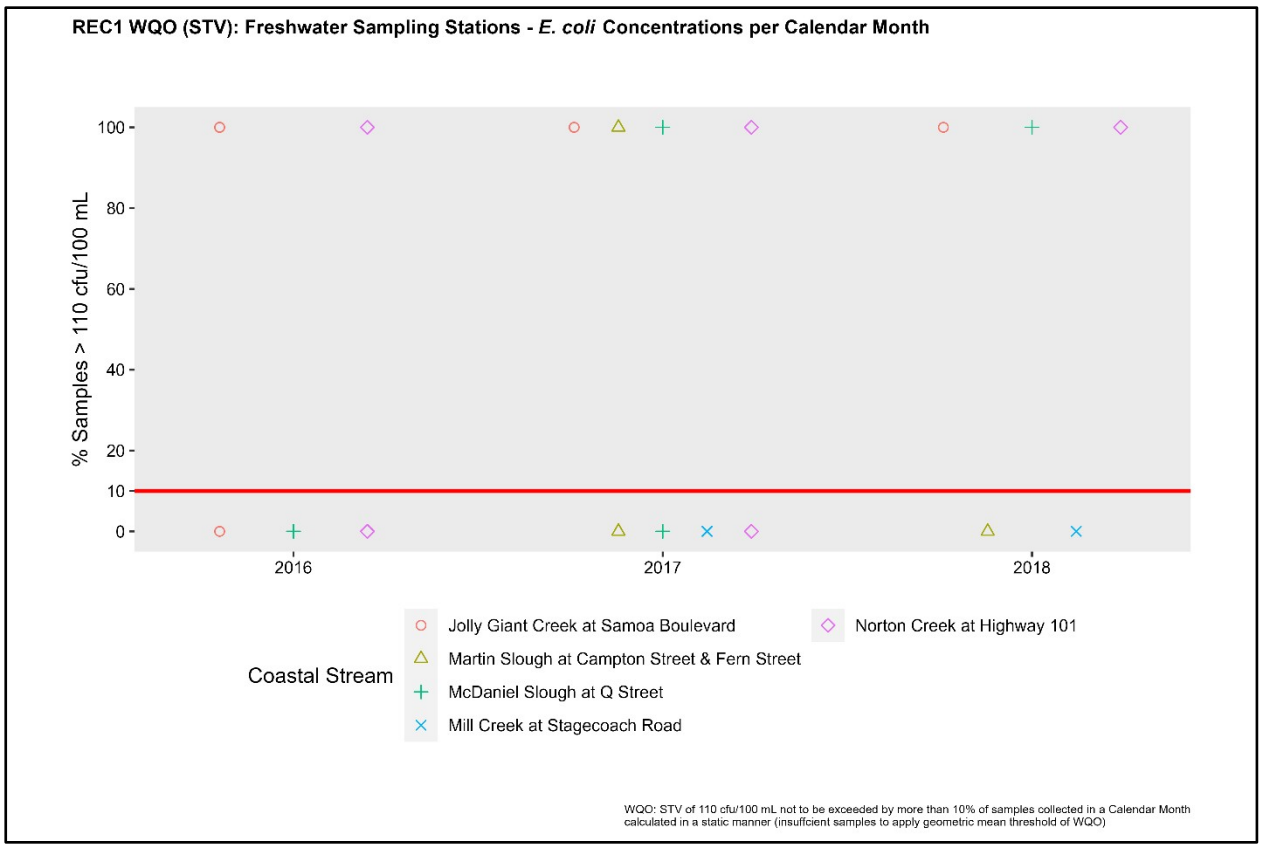

Figure 8 Exceedances of the STV threshold of the REC-1 WQO by *E. coli* Concentrations measured at Freshwater Sampling Stations

Table 4 Exceedance of the Enterococci STV Threshold of the Statewide Bacteria Water Quality Objective for REC-1 in Saline Waters by Assessment Period

Saline Sampling Station Name	Number of Exceedances/Total Number of Calculations[a] (STV)		
	Year-Round	Winter	Summer
Elk River at Highway 101	6/11	3/5	3/6
Gannon Slough at Highway 101	3/11	1/5	2/6
Little River at Highway 101	0/11	0/5	0/6
Martin Slough at Pine Hill Road	6/11	3/5	3/6
Liscom Slough at Jackson Road	3/4	3/3	0/1
Swain Slough at Elk River Road	2/4	1/2	1/2

[a]The first number refers to the total number of exceedances of the enterococci STV threshold per the statewide REC-1 Water Quality Objectives for saline waters for a particular assessment period at a particular sampling station, and the second number refers to the total number of enterococci STVs calculated for a particular assessment period at a particular sampling station. (E.g. 6/11 means there were 6 exceedances of the enterococci STV threshold out of 11 total STVs calculated.)

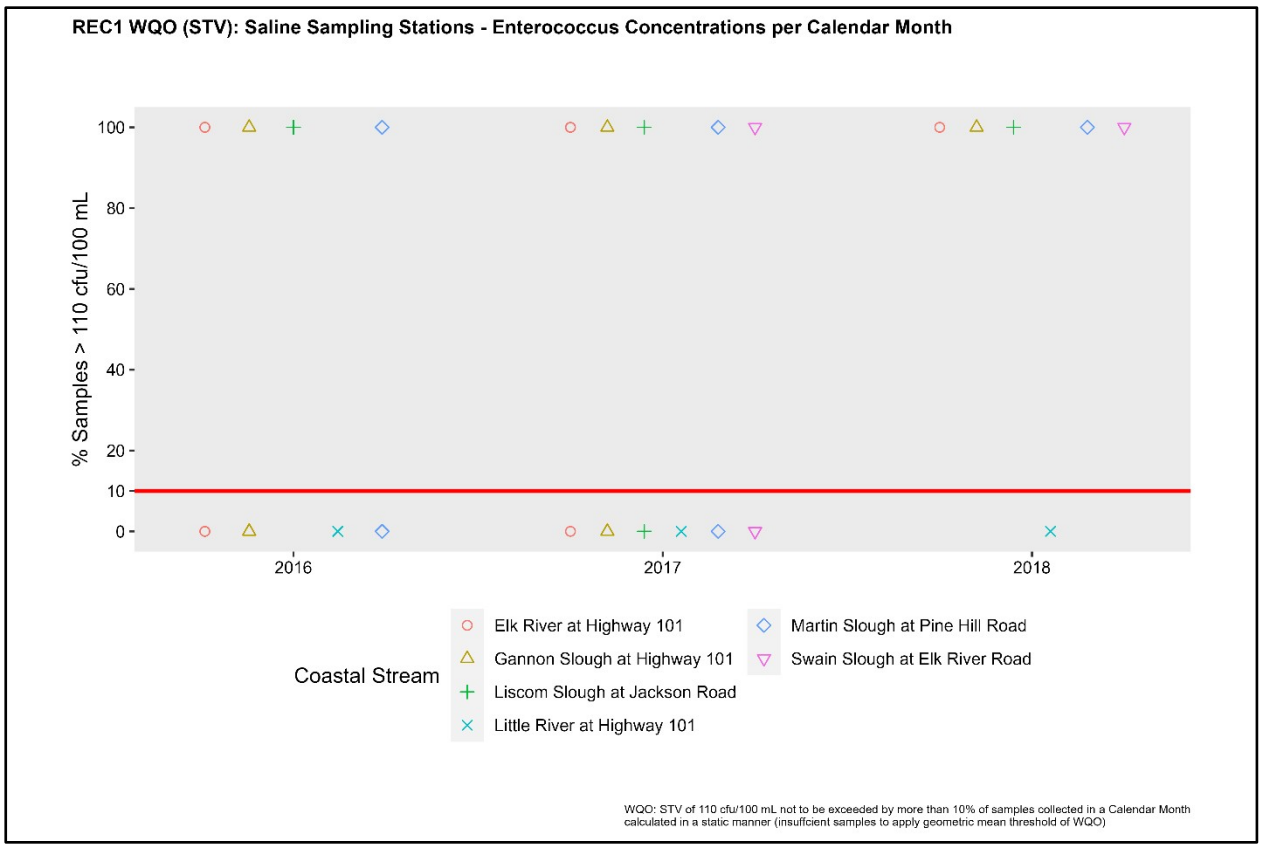

Figure 9 Exceedances of the STV threshold of the REC-1 WQO by Enterococcus Concentrations measured at Saline Sampling Stations

3.3. Summary and Comparison of Dry and Wet Sampling Period FIB Concentrations

The FIB data from all 20 freshwater, and six saline, sampling stations for the dry and wet sampling periods are summarized (number of samples collected, minimum, median, and maximum concentrations) in Tables A1 and A2 in Appendix A of this document. A brief overview of the summary is provided below.

E. coli concentrations measured in samples collected from all 20 freshwater sampling stations ranged from 10 MPN/100 mL to 5475 MPN/100 mL in the dry sampling period, and 10 MPN/100 mL to 5172 MPN/100 mL in the wet sampling period. Enterococci concentrations measured in samples collected from all six saline sampling stations ranged from 10 MPN/100 mL to 1119 MPN/100 mL in the dry sampling period, and 10 MPN/100 mL to 2419.6 MPN/100 mL in the wet sampling period.

FIB data collected in the dry sampling period were compared to FIB data collected in the wet sampling period to assess the seasonal variability in FIB concentrations in the streams assessed in this report. In total, *E. coli* and enterococci data from six sampling stations were assessed. Too few samples were collected from the other 20 sampling stations to be able to conduct a meaningful comparison of dry and wet sampling period data, or to generate meaningful plots illustrating differences between dry and wet sampling periods. Specifically, two dry sampling period samples, and two wet sampling period samples, were collected from 15 sampling stations, and one dry sampling period sample, and three wet sampling period samples, were collected from five sampling stations.

Enterococci concentrations measured in samples collected from the Elk River at Highway 101 sampling station, which is a saline sampling station, during the wet sampling period were found to be statistically significantly higher (p value < 0.05) compared to samples collected from this location during the dry sampling period. No other sampling stations evaluated had significant differences between dry and wet sampling periods of either *E. coli* or enterococci concentrations.

Figure 10 illustrates the distribution of dry and wet sampling period *E.coli* and enterococcus concentrations measured in the two freshwater sampling stations (Jolly Giant Creek at Samoa Boulevard and Norton Creek at Highway 101), and four saline sampling stations (Elk River at Highway 101, Gannon Slough at Highway 101, Little River at Highway 101 and Martin Slough at Pine Hill Road) since these are the only sampling stations from where at least 5 samples were collected per sampling period, allowing for a meaningful comparison of dry and wet sampling period FIB concentrations.

Figure 10 is a violin plot that displays both the distribution and density of the data. The length of a violin plot shows the range of the data values, and the width shows how frequently a particular value occurs in the dataset. Wider regions indicate that a value

occurs more frequently, while narrower regions indicate that a value occurs less frequently.

Figure 10 Dry and Wet Sampling Period *E. coli* and Enterococcus Concentrations measured at Freshwater and Saline Sampling Stations with at least 5 samples per Sampling Period

4. Discussion

The aim of this technical report was to present an assessment of FIB data collected, between 2016 and 2018, from 26 Humboldt County coastal stream sampling stations in order to identify whether these sampling stations are consistent with the Regional Water Board narrative natural background Objective and numeric REC-1 Objectives. While this technical report does not make any specific findings about evidence of impairment or pollution for any of the sampling stations evaluated, it is intended to provide information to support the development of lines of evidence that will be utilized to determine next steps as necessary, in response to any pathogen risk in these waterbodies.

4.1. Summary of Natural Background and REC-1 Objective Evaluation Findings

The results from sampling stations in Jolly Giant Creek at Samoa Boulevard and Norton Creek at Highway 101 were found inconsistent with the Regional Water Board narrative Natural Background Bacterial Objective for the Coast Range ecoregion for both the dry and wet sampling periods. Thirteen freshwater, and five saline, sampling stations had at least one exceedance of the REC-1 Objective for the year-round, winter, or summer assessment periods (Table 5). Seven freshwater sampling stations, and one saline sampling station had no exceedances of the REC-1 Objective for the year-round, winter, or summer assessment periods (Table 6).

4.1.1. Sampling Stations With Exceedances of the REC-1 Objective

Table 5 Sampling Stations With At Least One Exceedance of the REC-1 Objective (Year-Round, Winter, or Summer)

Sampling Stations with Exceedances of the Freshwater *E.coli* REC-1 Objective
Jolly Giant Creek at Samoa Boulevard
Norton Creek at Highway 101
Campbell Creek at 14th Street and Union Street
Campbell Creek at 7th Street
Cooper Gulch at Myrtle Avenue and 8th Street
Elk River at Zanes Road
Grotzman Creek at Bayside Road
Jacoby Creek at Old Arcata Road
Martin Slough at Campton Street and Fern Street

Sampling Stations with Exceedances of the Freshwater *E.coli* REC-1 Objective
McDaniel Slough at Q Street
Salmon Creek at Eel River Drive
Unnamed Slough at Lanphere Road
Unnamed Slough at Ranch Road
Sampling Stations with Exceedances of the Saline Enterococci REC-1 Objective
Elk River at Highway 101
Gannon Slough at Highway 101
Martin Slough at Pine Hill Road
Liscom Slough at Jackson Road
Swain Slough at Elk River Road

4.1.2. Sampling Stations Without Exceedances of the REC-1 Objective

Table 6 Sampling Stations Without Exceedances of the REC-1 Objective (Year-Round, Winter, or Summer)

Sampling Stations without Exceedances of the REC-1 Objective
Freshwater Sampling Stations (NO Exceedance of *E. coli* Objective Element)
Elk River South Fork at Headwaters Forest
Freshwater Creek at County Park
Graham Gulch at Pacific Lumber Camp Road
Jacoby Creek at Jacoby Creek Road
Mill Creek at Stagecoach Road
Strawberry Creek at Highway 101
Unnamed Stream at Anker Road
Saline Sampling Stations (NO Exceedance of Enterococci Objective Element)
Little River at Highway 101

4.2. Summary of the comparison of FIB data collected in the Dry and Wet Sampling Periods

Only the enterococci concentrations measured in samples collected from the Elk River at Highway 101, a saline sampling station, during the wet sampling period were found to be statistically significantly higher (p value < 0.05) compared to samples collected from that location during the dry sampling period.

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Appendix A: FIB Summary Tables

Table A 1 *E. coli* Data Summary for Freshwater Sampling Stations

Freshwater Sampling Station Name	Sampling Period	Number of Samples	*E. coli* Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Jolly Giant Creek at Samoa Boulevard	Dry	5	379	809	5475
Jolly Giant Creek at Samoa Boulevard	Wet	6	109	360	1183
Norton Creek at Highway 101	Dry	5	75	175	439
Norton Creek at Highway 101	Wet	6	41	63	583
Campbell Creek at 14th Street and Union Street	Dry	1	119	119	119
Campbell Creek at 14th Street and Union Street	Wet	3	41	63	836

Freshwater Sampling Station Name	Sampling Period	Number of Samples	*E. coli* Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Campbell Creek at 7th Street	Dry	1	504	504	504
Campbell Creek at 7th Street	Wet	3	10	231	1314
Cooper Gulch at Myrtle Avenue and 8th Street	Dry	2	860	896.5	933
Cooper Gulch at Myrtle Avenue and 8th Street	Wet	2	364	625	886
Elk River at Zanes Road	Dry	2	697	710	723
Elk River at Zanes Road	Wet	2	31	70	109

Freshwater Sampling Station Name	Sampling Period	Number of Samples	*E. coli* Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Elk River South Fork at Headwaters Forest	Dry	2	10	10	10
Elk River South Fork at Headwaters Forest	Wet	2	10	20	30
Freshwater Creek at County Park	Dry	2	41	52	63
Freshwater Creek at County Park	Wet	2	10	36.5	63
Graham Gulch at Pacific Lumber Camp Road	Dry	2	10	20	30
Graham Gulch at Pacific Lumber Camp Road	Wet	2	10	15	20

Freshwater Sampling Station Name	Sampling Period	Number of Samples	*E. coli* Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Grotzman Creek at Bayside Road	Dry	2	75	386	697
Grotzman Creek at Bayside Road	Wet	2	86	1581	3076
Jacoby Creek at Jacoby Creek Road	Dry	2	20	41.5	63
Jacoby Creek at Jacoby Creek Road	Wet	2	52	117.5	183
Jacoby Creek at Old Arcata Road	Dry	2	272	357.5	443
Jacoby Creek at Old Arcata Road	Wet	2	20	710.5	1401

Freshwater Sampling Station Name	Sampling Period	Number of Samples	*E. coli* Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Martin Slough at Campton Street and Fern Street	Dry	2	187	401.5	616
Martin Slough at Campton Street and Fern Street	Wet	2	63	99	135
McDaniel Slough at Q Street	Dry	1	703	703	703
McDaniel Slough at Q Street	Wet	3	30	52	771
Mill Creek at Stagecoach Road	Dry	2	10	10	10
Mill Creek at Stagecoach Road	Wet	2	20	156	292

Freshwater Sampling Station Name	Sampling Period	Number of Samples	*E. coli* Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Salmon Creek at Eel River Drive	Dry	2	10	47	84
Salmon Creek at Eel River Drive	Wet	2	85	234.5	384
Strawberry Creek at Highway 101	Dry	2	31	41.5	52
Strawberry Creek at Highway 101	Wet	2	52	63	74
Unnamed Slough at Lanphere Road	Dry	1	422	422	422
Unnamed Slough at Lanphere Road	Wet	3	10	545	5172

Freshwater Sampling Station Name	Sampling Period	Number of Samples	*E. coli* Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Unnamed Slough at Ranch Road	Dry	2	320	455.5	591
Unnamed Slough at Ranch Road	Wet	2	63	668.5	1274
Unnamed Stream at Anker Road	Dry	2	10	10	10
Unnamed Stream at Anker Road	Wet	2	10	60	110

[a]MPN – Most Probable Number

Table A 2 Enterococci Data Summary for Freshwater and Saline Sampling Stations

Saline Sampling Station Name	Sampling Period	Number of Samples	Enterococci Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Elk River at Highway 101	Dry	6	10	35.5	199
Elk River at Highway 101	Wet	5	52	259	480
Gannon Slough at Highway 101	Dry	5	10	84	583
Gannon Slough at Highway 101	Wet	6	10	52	2359
Jolly Giant Creek at Samoa Boulevard	Dry	5	97	884	4106
Jolly Giant Creek at Samoa Boulevard	Wet	6	10	118	1259

Saline Sampling Station Name	Sampling Period	Number of Samples	Enterococci Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Little River at Highway 101	Dry	5	10	31	85
Little River at Highway 101	Wet	6	10	15	98
Martin Slough at Pine Hill Road	Dry	6	10	41.5	1119
Martin Slough at Pine Hill Road	Wet	5	20	529	2419.6
Norton Creek at Highway 101	Dry	5	20	226	573
Norton Creek at Highway 101	Wet	6	20	97.5	2359

Saline Sampling Station Name	Sampling Period	Number of Samples	Enterococci Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Campbell Creek at 14th Street and Union Street	Dry	1	10	10	10
Campbell Creek at 14th Street and Union Street	Wet	3	52	63	11199
Campbell Creek at 7th Street	Dry	1	839	839	839
Campbell Creek at 7th Street	Wet	3	10	158	5172
Cooper Gulch at Myrtle Avenue and 8th Street	Dry	2	563	899.5	1236
Cooper Gulch at Myrtle Avenue and 8th Street	Wet	2	269	466	663

Saline Sampling Station Name	Sampling Period	Number of Samples	Enterococci Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Elk River at Zanes Road	Dry	2	85	97	109
Elk River at Zanes Road	Wet	2	10	31	52
Elk River South Fork at Headwaters Forest	Dry	2	10	10	10
Elk River South Fork at Headwaters Forest	Wet	2	10	20.5	31
Freshwater Creek at County Park	Dry	2	20	53	86
Freshwater Creek at County Park	Wet	2	10	31	52

Saline Sampling Station Name	Sampling Period	Number of Samples	Enterococci Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Graham Gulch at Pacific Lumber Camp Road	Dry	2	10	20.5	31
Graham Gulch at Pacific Lumber Camp Road	Wet	2	10	15	20
Grotzman Creek at Bayside Road	Dry	2	63	188	313
Grotzman Creek at Bayside Road	Wet	2	216	8772.5	17329
Jacoby Creek at Jacoby Creek Road	Dry	2	226	555	884
Jacoby Creek at Jacoby Creek Road	Wet	2	10	543	1076

Saline Sampling Station Name	Sampling Period	Number of Samples	Enterococci Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Jacoby Creek at Old Arcata Road	Dry	2	441	461	481
Jacoby Creek at Old Arcata Road	Wet	2	86	1870	3654
Liscom Slough at Jackson Road	Dry	1	10	10	10
Liscom Slough at Jackson Road	Wet	3	155	185	1467
Martin Slough at Campton Street and Fern Street	Dry	2	187	636.5	1086
Martin Slough at Campton Street and Fern Street	Wet	2	85	129	173

Saline Sampling Station Name	Sampling Period	Number of Samples	Enterococci Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
McDaniel Slough at Q Street	Dry	1	959	959	959
McDaniel Slough at Q Street	Wet	3	31	85	3255
Mill Creek at Stagecoach Road	Dry	2	10	65.5	121
Mill Creek at Stagecoach Road	Wet	2	10	1941.5	3873
Salmon Creek at Eel River Drive	Dry	2	10	157.5	305
Salmon Creek at Eel River Drive	Wet	2	63	69	75

Saline Sampling Station Name	Sampling Period	Number of Samples	Enterococci Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Strawberry Creek at Highway 101	Dry	2	41	173	305
Strawberry Creek at Highway 101	Wet	2	31	222.5	414
Swain Slough at Elk River Road	Dry	2	41	120	199
Swain Slough at Elk River Road	Wet	2	52	282	512
Unnamed Slough at Lanphere Road	Dry	1	538	538	538
Unnamed Slough at Lanphere Road	Wet	3	10	598	14136

Saline Sampling Station Name	Sampling Period	Number of Samples	Enterococci Concentration (MPN/100 mL)[a]		
			Minimum	Median	Maximum
Unnamed Slough at Ranch Road	Dry	2	20	901	1782
Unnamed Slough at Ranch Road	Wet	2	10	315	620
Unnamed Stream at Anker Road	Dry	2	10	104.5	199
Unnamed Stream at Anker Road	Wet	2	10	152.5	295

[a]MPN – Most Probable Number