BUREAU OF WATER

South Carolina Department of Health and Environmental Control

A Bacteriological Assessment of Surface Water Quality in a Small Sub-Watershed of the Okatee River Basin

June 2021

Technical Report No. 004-2021

S.C. Department of Health and Environmental Control

A Bacteriological Assessment of Surface Water Quality in a Small Sub-Watershed of the Okatee River Basin

Technical Report No. 004-2021

Prepared By:

Nicholas Pangborn, Lindsey Lachenmyer, Kay Wilson, and Lindsey Carter

SCDHEC – Bureau of Water, Aquatic Science Programs

Table of Contents

List of Figures

List of Tables

List of Appendices

Executive Summary

Able Contracting Inc. was a Recovered Material Processing Facility located in Jasper County that collected construction and demolition debris for recycling. The facility had a mound of debris estimated to be 45 feet tall and covered approximately four (4) acres. In June 2019, the accumulated debris caught fire and smoldered, with periodic fire breakouts for several months. The South Carolina Department of Health and Environmental Control and the U.S. Environmental Protection Agency began cleanup efforts in August 2019 to address the ongoing smolder by removing the debris material for proper off-site disposal. The last of the debris pile was cleared on January 6, 2020. This response event became the catalyst for significant interest in the potential effects of the Able Contracting site on the Okatee River.

Three (3) principal observations coalesced around the Able site response event that lead to the bacteriological assessment reported herein; namely:

- Ambient surface water samples collected near the Able Contracting site by Beaufort County Stormwater Management in August 2019 documented unusually high levels of fecal coliforms, *Escherichia coli*, and *Enterococcus* in the waters draining from the Able Property and surrounding developed area (Appendix 1: B1).
- Long-term stormwater monitoring of the unnamed stream draining the highly developed land area that included the Able Contracting site and bacteriological stormwater at SC 170 by Beaufort County Stormwater Management demonstrated generally consistent and enduring elevated bacterial densities in the stream.
- A portion of SCDHEC Shellfish Management Area 18, essentially the reach of the Okatee River from headwaters to the area of Camp St. Mary's dock, is closed to shellfish (oysters, clams, mussels) (SCDHEC, 2020d). Specifically, this closed area is classified as a Restricted Area which means that it is an area exceeding approved area water quality standards; is normally closed for direct harvesting activities; but where harvesting may be allowed by special permit. Shellfish from Restricted Areas may be relocated (relayed) to Approved Areas where they remain sessile for a pre-determined period of time to allow adequate natural cleansing (depuration) of the shell stock.

The objectives of the bacteriological assessment of the specified sub-watershed of the Okatee River in 2020 and reported herein were to:

- Evaluate if sources or drainage areas contributing to elevated bacterial densities could be identified;
- Assess if nutrient levels were elevated and, if so, were the elevated levels associated with high bacteria densities.

Water samples were collected from eighteen (18) sites near the Able Contracting facility and the surrounding Okatee River sub-watershed. Sampling was conducted after one (1) dry event in January and four (4) wet events [three (3) in February and one (1) in September]. The January dry weather sampling event occurred following a three (3) day period with no measurable rainfall. The wet weather sampling events occurred within 24 to 48 hours after a rain event of at least one-half inch of precipitation in 24 hours. Samples collected at each site were analyzed for ammonia-nitrogen, nitrate/nitrite-nitrogen, TKN, total phosphorous, fecal coliforms, *Escherichia coli*, and *Enterococcus*.

In general, nutrient (ammonia-nitrogen, total nitrogen, and total phosphorous) results varied between sites and a consistent trend among sites was not observed for any of the nutrient parameters. No strong relationships were determined for nutrient concentration (ammonia-nitrogen, total nitrogen, and total phosphorous) and bacterial densities (fecal coliforms, *E. coli*, and *Enterococcus*).

Bacterial densities (fecal coliforms, *E. coli*, and *Enterococcus*) varied widely between sites and sampling events. A significant difference was not observed in fecal coliforms, *E. coli*, or *Enterococcus* among sites. However, sites OB20 and OB23 had the greatest geometric mean bacterial densities across all bacterial parameters measured (fecal coliforms, *E. coli*, and *Enterococcus*). The area surrounding OB20 and OB23 may have a source or sources contributing to the elevated bacterial densities; therefore, it would be beneficial to investigate the area further. It would also be advantageous to examine the area surrounding three other sites (OSB9, OSB5, and OSB8) that had elevated bacterial density patterns as well.

A majority of the sites sampled during wet weather events exceeded State water quality standards for fecal coliforms (94%), *E. coli* (65%), and *Enterococcus* (72%). Nonpoint source pollution, such as stormwater and urban runoff, may also be contributing to some of the increased bacterial densities. An Okatee River Watershed Management Plan has recommended best management practices (BMPs) to limit stormwater impact to the Okatee River, such as wetland enhancement or end of pipe improvements (Ward Edwards Engineering, 2015). Other BMPs include septic tank maintenance and implementing rain barrels at residences (SCDHEC, 2010a; Ward Edwards Engineering, 2015). Water quality improvement initiatives, such as BMPs, should continue to be utilized to manage nonpoint source pollution sources to the Okatee River and watershed.

Introduction and Background

Able Contracting Inc. was a Recovered Material Processing Facility located in Jasper County that collected construction and demolition debris for recycling. The facility had a mound of debris estimated to be 45 feet tall and covered approximately four (4) acres. In June 2019, the accumulated debris caught fire and smoldered, with periodic fire breakouts for several months. Local residents were evacuated in August due to elevated levels of acrolein in the air, which is a respiratory irritant at low levels (National Research Council, 2010). The South Carolina Department of Health and Environmental Control (SCDHEC; the Department) and the U.S. Environmental Protection Agency (USEPA) began cleanup efforts in August 2019 to address the ongoing smolder by removing the debris material for proper off-site disposal. The last of the debris pile was cleared on January 6, 2020; the total amount of debris removed was estimated to be approximately 113,000 tons. This response event became the catalyst for significant interest in the potential effects of the Able site on the Okatee River.

Three (3) principal observations coalesced around the Able site response event that lead to the bacteriological assessment reported herein; namely:

- Ambient surface water samples collected near the Able Contracting site by Beaufort County Stormwater Management in August 2019 documented unusually elevated levels of fecal coliforms, *Escherichia coli*, and *Enterococcus* in the waters draining from the Able Property and surrounding developed area (Appendix 1: B1).
- Long-term stormwater monitoring of the unnamed stream draining the highly-developed land area that included the Able Contracting site and bacteriological stormwater at SC 170 by Beaufort County Stormwater Management demonstrated generally consistent and enduring elevated bacterial densities in the stream.
- A portion of SCDHEC Shellfish Management Area 18, essentially the reach of the Okatee River from headwaters to the area of Camp St. Mary's dock, is closed to shellfish (oysters, clams, mussels) (SCDHEC, 2020d). Specifically, this closed area is classified as a Restricted Area which means that it is an area exceeding approved area water quality standards; is normally closed for direct harvesting activities; but where harvesting may be allowed by special permit. Shellfish from Restricted Areas may be relocated (relayed) to Approved Areas where they remain sessile for a pre-determined period of time to allow adequate natural cleansing (depuration) of the shellstock.

Potential chemical analyte inputs from the Able site to the Okatee River were also assessed in a separate study from the bacteriological assessment reported herein (SCDHEC 2020a).

Elevated levels of pathogenic bacteria in water are a concern since they can increase health risks, such as gastrointestinal illness (Pruss, 1998). South Carolina has promulgated bacteriological water quality standards to protect human health upon shellfish consumption and recreational activities, such as swimming (Table 1) (SCDHEC, 2020b). The standards are based on the most probable number (MPN) per 100 milliliters (mL) analytical technique, an analytical testing statistical measure used to estimate viable numbers of bacteria in a sample. The bacteriological parameters specified in the State Water Quality Standards are indicators of bacteriological quality; they are not, except for a few specific genetic strains of *Escherichia coli* (*E. coli*), pathogenic. These are good indicator parameters because they are associated with fecal wastes generated from mammals, natural fauna, and from malfunctioning wastewater treatment collection/treatment systems, malfunctioning septic tanks, and stormwater runoff.

The Okatee River is a riverine tidal estuary that has tidal creek headwaters located at Okatee Creek and Malind Creek (Huang, Changsheng, Blanton, & Andrade, 2007). The water depth of the Okatee River ranges from 6.5 feet to 13 feet in the creek headwaters to 50 feet near the mouth of the river (Huang, Changsheng, Blanton, & Andrade, 2007). Moore et al. (2006) estimated an average water residence time of 3.4 days in the Okatee River based on radium isotopes and reported an average neap tidal range of 8.5 feet. The Okatee River is hydraulically connected with Chechessee Creek, Callawassie Creek and Sawmill Creek and is the major tributary to the Colleton River (Figure 1). The Colleton River connects to the Chechessee River proper and then flows into Port Royal Sound outside of Hilton Head Island. The Okatee River and its tributaries are classified as Outstanding Resource Waters [ORW] (SCDHEC, 2010b; SCDHEC, 2020c). Per SCDHEC (2020b), *Numeric and narrative criteria for ORW shall be those applicable to the classification of the waterbody immediately prior to reclassification to Class ORW.* Accordingly, the underlying classification for the Okatee River and its tributaries is Shellfish Harvesting Waters (SFH). These are tidal saltwaters protected for shellfish harvesting and uses listed in Class SA and Class SB (SCDHEC, 2020c). Consequently, data developed from fecal coliform and *Enterococcus* testing are the operative datasets to inform the status of compliance with State Water Quality Standards.

The Okatee River is surrounded by multi-use land development with a majority of the development open space or medium intensity (Figure 2). Approximately 28% of the land use in the Okatee River drainage basin is residential, industrial, and agricultural (SCDHEC, SCDNR, & NOAA, 2000; Ward Edwards Engineering, 2015). Land-use development has continued apace in the general Beaufort-Jasper Counties area as indicated by population increases. The populations reported in the 2000 Federal census were 120,937 and 20,678 for Beaufort and Jasper Counties, respectively (U.S. Census Bureau, 2003). In 2010, the populations reported in the Federal census were 162,233 and 24,777 for Beaufort and Jasper Counties, respectively (SCAC, 2019). These counts represent approximately 34% and 20% increases. It is not anticipated that the 2020 census counts will show reversals of these observations. Significant development of the landscape on large areal-scales and/or in high density enclaves pose significant challenges, more often due to nonpoint source inputs, to maintaining desired water quality in associated surface water systems. Anecdotal observations made during implementation of this assessment indicated that the portion of the Okatee River system under study drained a highly- and densely-developed landscape. The Okatee River proper is reported to be heavily utilized by nearby residents for fishing, crabbing, and other recreational activities. Those waters have been closed (restricted) to shellfish gathering for quite a number of years due to elevated bacterial densities.

Table 1: South Carolina water quality standards for the corresponding bacteria tests and their respective uses (SCDHEC, 2020b).

Bacteriological Parameter	Application	South Carolina Standard[a] (MPN/ 100mL)[b]	
		Discrete (Single) Sample	Mean of Samples
Fecal Coliform	Shellfish Harvesting	43	14[c]
Escherichia coli	Recreational – Freshwater	349	126[c]
Enterococcus	Recreational – Saltwater/Estuarine	104	35[c]

a. SCDHEC Regulation 61-68, 2020
b. MPN/100 mL = most probable number per 100 milliliters
c. based on four (4) samples from the same location in a 30-day period

Purpose of Study

The Bureau of Water (BOW) developed this Okatee River Sub-Watershed Bacteria Assessment to address questions related to the elevated bacterial densities in the Okatee River sub-watershed represented by draining to the SC Highway 170 crossing used by Beaufort County as a routine stormwater monitoring point. This project determined bacteria levels and nutrient concentrations, in the small but densely-developed watershed associated with the Able Contracting facility and Okatee River. Increases in bacteria densities are often associated with stormwater runoff; thus, wet weather events were targeted for sampling. The data were used to determine whether elevated nutrient results were associated with elevated bacterial densities and whether there were identifiable sources contributing to the elevated bacterial densities.

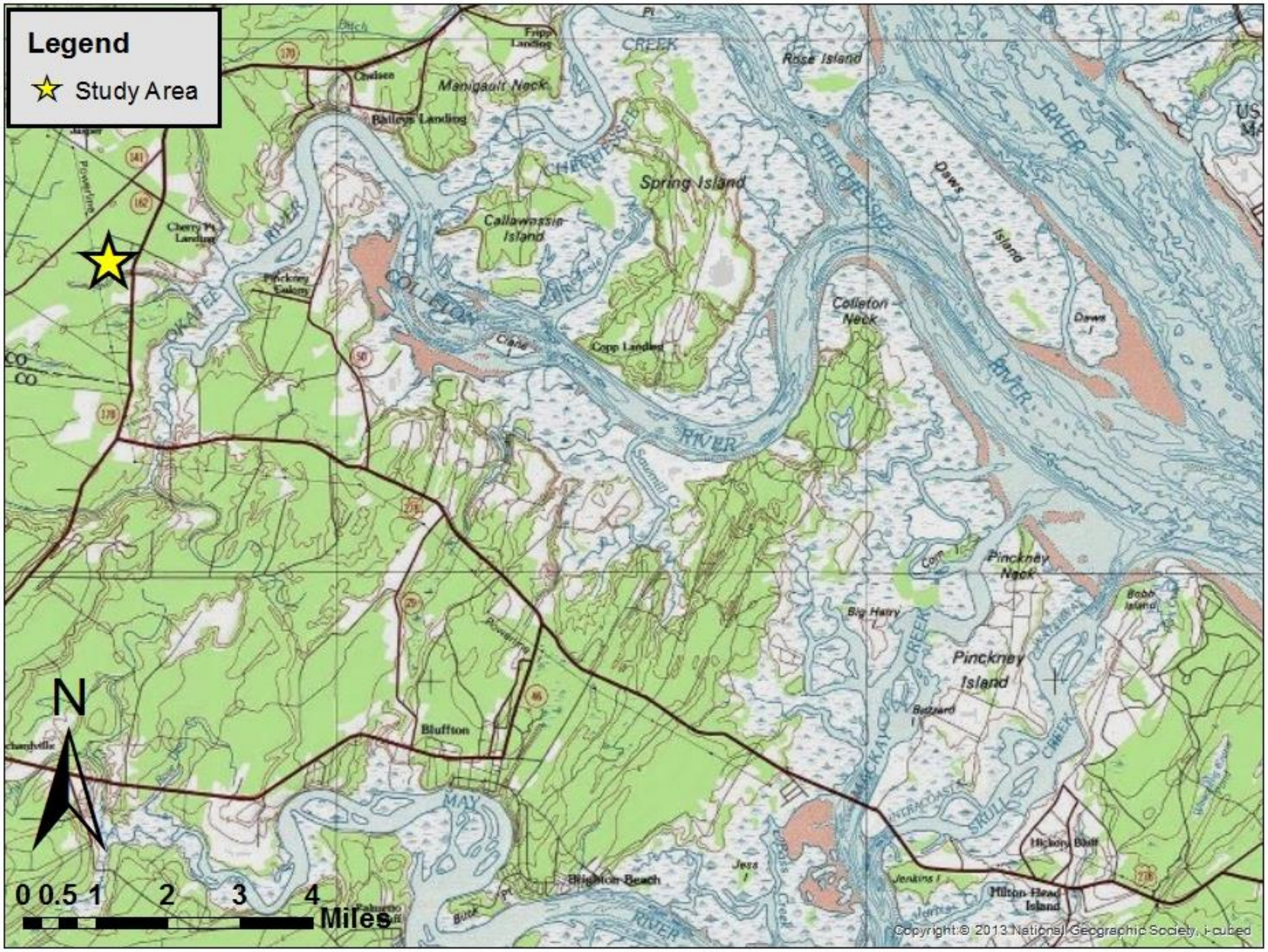


Figure 1: Topographical map of the Okatee River connecting to the Colleton River, which then connects to the Chechessee River.

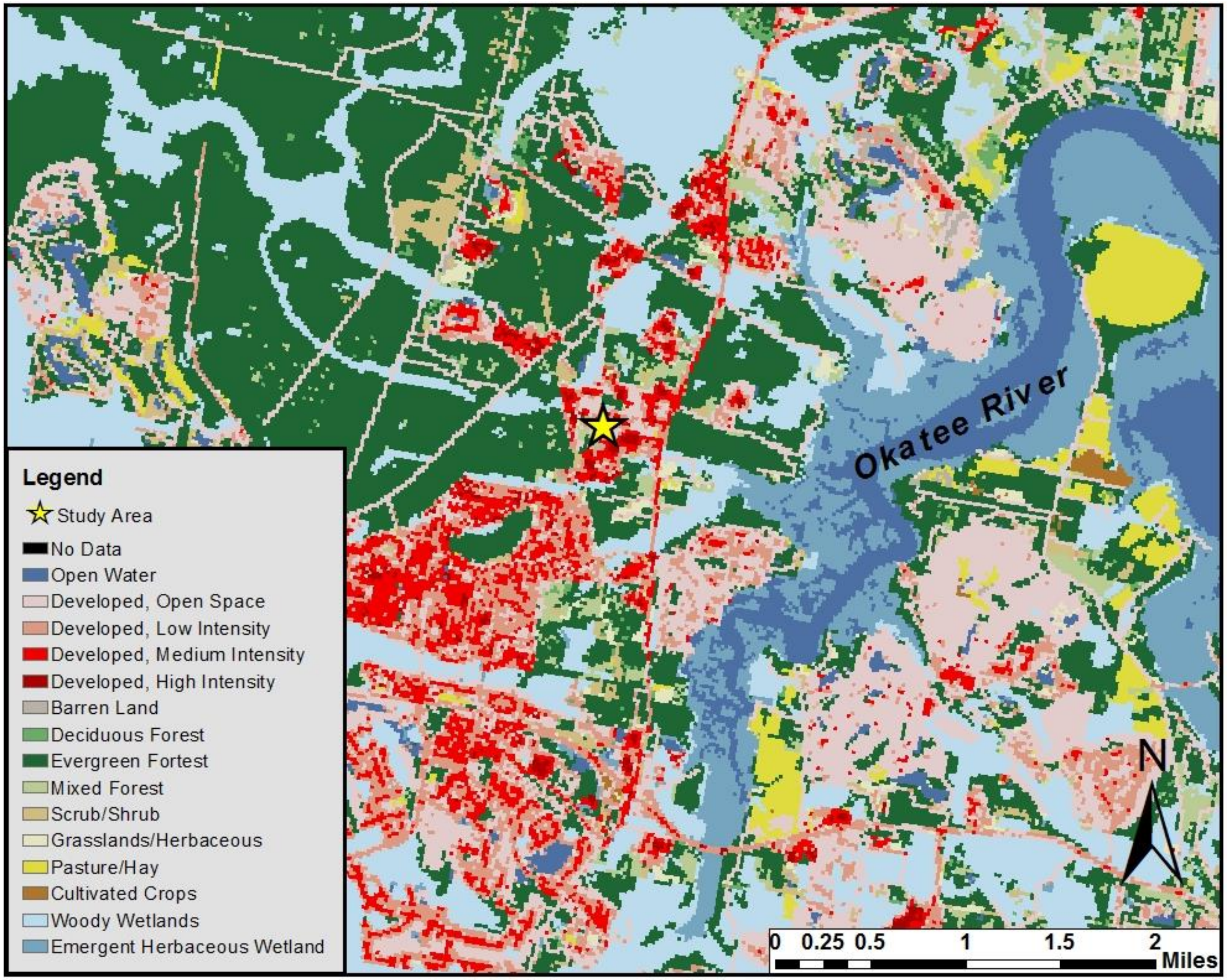


Figure 2: Land use map of the study area and areas surrounding the Okatee River. Land cover data is from the 2016 National Land Cover Database.

Methods

SCDHEC BOW, Aquatic Science Programs (ASP) conducted this Assessment in 2020 that comprised collection of surface water samples from one (1) dry weather event and following four (4) different wet weather events at 18 sites in the noted sub-watershed draining into the Okatee River (Figure 3, Figure 4, Figure 5, and Table 2). A dry weather event was defined as at least 72 hours with no precipitation; a wet weather event was defined as sampling within 24 to 48 hours after a rain event of one-half inch or more in 24 hours. Precipitation data were obtained from the Southeast Regional River Forecast Group. Three (3) sites (OSB2, OSB14, OB9) were tidally influenced and were collected on ebbing tides.

Three (3) of the four (4) wet weather events occurred in February 2020; the last wet weather event occurred in September 2020 (Table 3). Sampling sites were determined from site reconnaissance and prior sampling by Beaufort County Stormwater Management (see Okatee River Area Bacteria Special Study QAPP, included as Appendix 1 of this report). Site OB20 was adjusted prior to sampling; updated coordinates and description are provided in Table 2. Two (2) sites (OSB19 and OSB14) were selected to serves as control sites. These were located outside of the watershed because no appropriate control sites could be identified within the watershed.

During surface water sample collection, in-stream field parameters measured consisted of luminescent dissolved oxygen (LDO), pH, specific conductivity, salinity, and water temperature following established Standard Operating Procedures [SOPs] (SCDHEC, 2018c).

Surface water samples were collected for nutrient analyses during four (4) of the sampling events. Water samples for bacteriological analyses were collected during all five (5) sampling events. A total of 72 nutrient water samples and 90 bacteria water samples were collected. The sample collection, handling, and preservation was conducted following SCDHEC SOPs (SCDHEC, 2018a, 2018b).

Water samples for nutrient coverage were analyzed for ammonia-nitrogen, Total Kjeldahl Nitrogen (TKN), nitrate/nitrite-nitrogen, and total phosphorous at SCDHEC Analytical and Radiological Environmental Services Division (ARESD) according to the methods in the approved QAPP, Appendix 1. TKN and nitrate/nitrite-nitrogen values were summed to report total nitrogen. Water samples for bacteriological coverage were analyzed for fecal coliforms, *Escherichia coli* (*E. coli*), and *Enterococcus* at the SCDHEC BEHS Beaufort Regional Lab according to the methods in the approved QAPP, Appendix 1.

Figure 3: Satellite view of the Okatee River watershed. Sampling sites (white markers) are depicted in relation to the Able Contracting site. Yellow markers denote control sites OSB19 and OSB14.

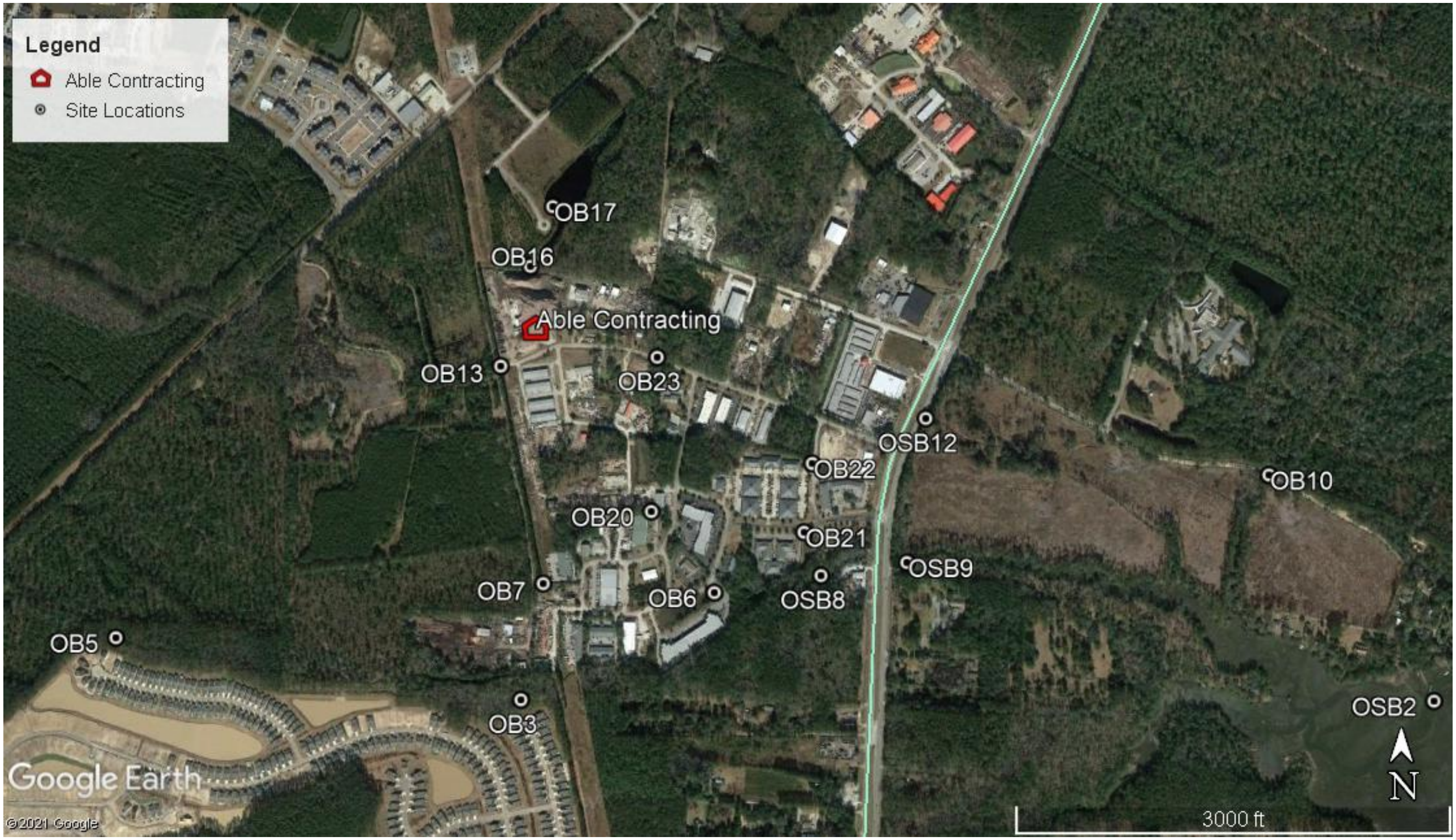


Figure 4: Satellite view of the focused sampling area in the Okatee River watershed. Sampling sites (white markers) are depicted in relation to the Able Contracting site. The control sites, OSB19 and OSB14, are not shown.

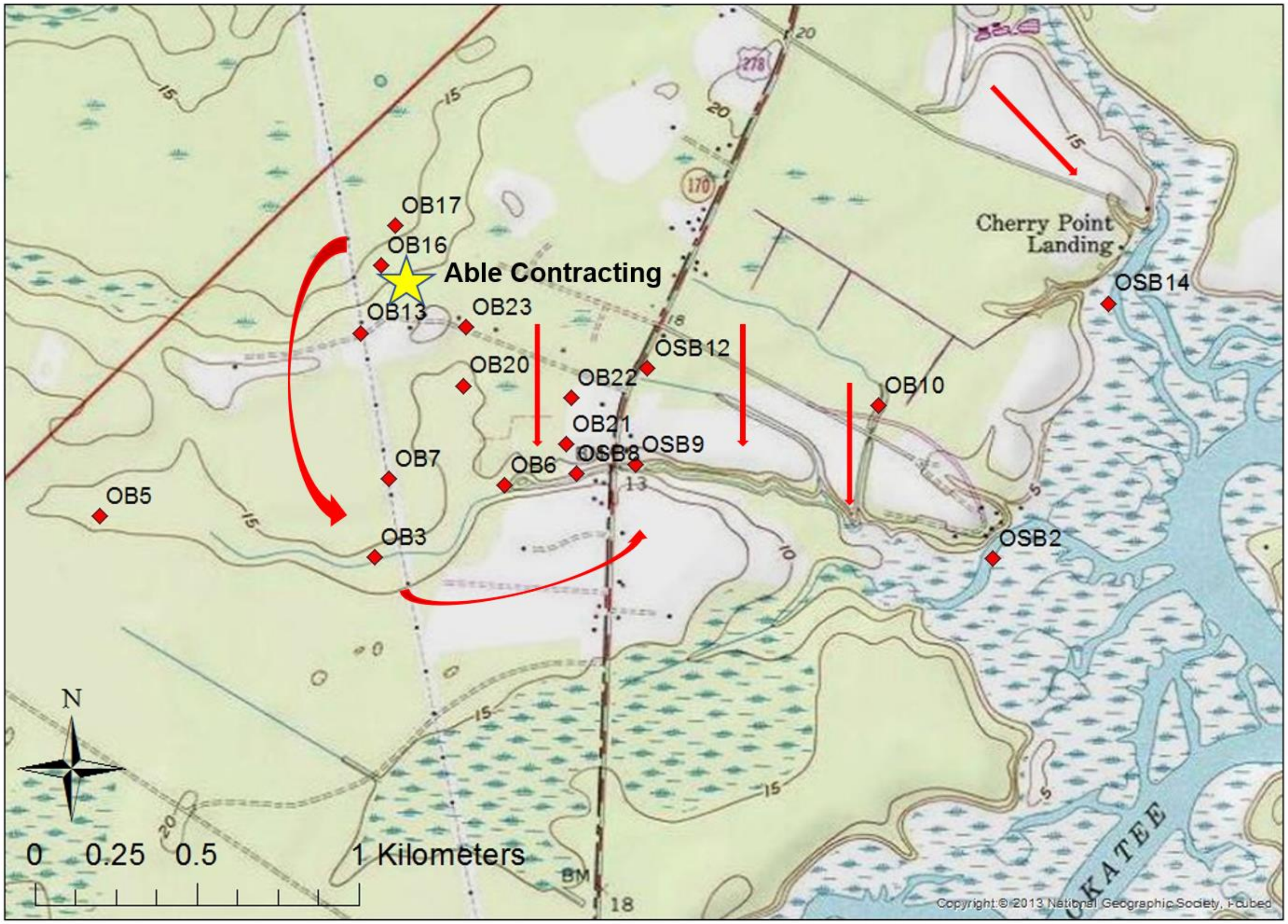


Figure 5: Topographical map of the Okatee watershed with observed surface water flows represented by red arrows. Control site OSB19 is north of the sampling area upstream of OSB14 (see Figure 3).

Table 2: Sampling location descriptions, approximate water body size, and site coordinates.

Site	Site Description	Waterbody Size		Location	
		Width	Depth	Latitude	Longitude
OB17	Pond at end of Kingsmore Crescent	138,750 ft^2 [a]	9 in[b]	32.3259	-80.9415
OB16	Ditch just south of Kingsmore Crescent	7.5 ft	1.7 ft	32.3248	-80.9420
OB13	Ditch at Schinger Ave	7 ft	6 in	32.3229	-80.9427
OB23	Impounded ditch north of Schinger Ave west of intersection with Browns Cove Rd	5 ft	5 in	32.3231	-80.9392
OSB12	Drain to unnamed creek at SC HWY 170 between Schinger Ave and Pearlstine Dr	4 ft	5 in	32.3220	-80.9333
OB22	Ditch and pipe confluence west of Old Coach Rd halfway between Schinger Ave and Riverwalk	1.5 ft	3 in	32.3211	-80.9358
OB20	Ditch system behind Animal Hospital parallel to retention pond between Browns Cove Rd and Mackinlay Way	4 ft	8 in	32.3215	-80.9393
OB21	Pipe to ditch system outflow of drainage to north of Riverwalk Blvd and Old Coach Rd	4 ft	1.3 ft	32.3198	-80.9360
OB7	Ditch to pipe from ditch along Schinger Ave	7 ft	10 in	32.3189	-80.9418
OB6	Outflow of stormwater pond adjacent to Browns Cove Rd	39,450 ft^2 [a]	1.1 ft[b]	32.3187	-80.9380
OSB8	Unnamed creek to Okatee River draining industrial park upstream of SC HWY 170 across from Williams Dr	7 ft	9 in	32.3190	-80.9356
OSB9	Unnamed creek to Okatee River draining industrial park downstream of SC HWY 170 next to Williams Dr	9.5 ft [c]	1.2 ft[c]	32.3193	-80.9337
OB5	Unnamed creek flowing to industrial area storm water at the end of Schlinger Ave. headwater to OB3 Intermittent	7.5 ft	1 ft	32.3179	-80.9512
OB3	Unnamed creek flowing to industrial area storm water at the end of Schlinger Ave. Intermittent	6 ft	10 in	32.3167	-80.9422
OB10	Unnamed creek at Cherry Point Rd downstream from Okatie Elementary School	5.5 ft	6 in	32.3209	-80.9257
OSB2	Unnamed creek to Okatee River due south at bend in Cherry Point Rd N	25 ft [c]	3 ft [c]	32.3167	-80.9219
OSB19[d]	Unnamed creek to Okatee River at SC HWY 170 north of Oldfield Way	7 ft	1.5 ft	32.3489	-80.9241
OSB14[d]	Unnamed creek to Okatee River at the adjacent end of Cherry Point Rd N	25 ft[c]	5 ft [c]	32.3237	-80.9182

a. Approximate pond surface area in square feet (ft^2)
b. Approximate depth of where sample was taken in the pond
c. Approximate stream size in feet at generally mid-ebb tide; all samples collected on ebbing tide
d. Control site

Table 3: Sampling dates and respective weather event. The 24-hour rainfall total for each wet weather event is also provided.

Sampling Event Number	2020 Sampling Date	Event Type	Samples Collected	Rainfall [a]
1	January 22	Dry	Nutrients and Bacteria	0.00 in
2	February 7	Wet	Nutrients and Bacteria	0.91 in
3	February 21	Wet	Nutrients and Bacteria	0.80 in
4	February 26	Wet	Nutrients and Bacteria	0.72 in
5	September 30	Wet	Bacteria	0.50 in

a. Data obtained from Southeast Regional River Forecast Group

Statistical Analyses

Arithmetic mean nutrient concentrations were calculated. The standard error of the arithmetic mean (MSE) was computed via:

$$MSE = (SD/\sqrt{n})$$

Where: SD = standard deviation of x
$\sqrt{n}$ = square root of the sample size

Mean bacteriological density calculations for the wet weather events were made via the n^{th} root method to yield geometric mean densities. Dispersion around the geometric mean (e.g., standard deviation, standard error) was not calculated because those descriptors are expressed as single numbers to represent a range equidistant around the mean. This concept works for an arithmetic mean because the uncertainty associated with estimating the mean is symmetrical about the mean itself. That is not true for the geometric mean which, being the antilog of the mean of the log, produces asymmetrical expressions around the mean. Therefore, an additive/subtractive function around the geometric mean is not appropriate.

Pearson correlation coefficients were used to determine if there were linear relationships between nutrient concentrations (ammonia-nitrogen, total nitrogen, and total phosphorous) versus bacteria densities (fecal coliform, *E. coli*, and *Enterococcus*) for the wet weather events. Pearson correlation matrix output values range from -1 to 1, where values closer to -1 indicate a strong inverse relationship and values closer to 1 indicate a strong positive relationship. Matrix values that are closer to zero indicates no linear relationship. All Pearson correlation data analyses were made using Microsoft Excel.

The nonparametric Kruskal-Wallis H test was performed to compare bacterial densities (fecal coliforms, *E. coli*, and *Enterococcus*) between sites using R statistical software (R Core Team, 2019). Significant results were determined at $p=0.05$.

Results and Discussion

Data Quality Review

The water physical parameters that were measured in the field (LDO, pH, specific conductivity, salinity, and water temperature) did not meet quality assurance and quality control requirements due to calibration and verification issues. Thus, the data were not used in this report.

Sixty-eight of the 72 samples analyzed for TKN and nitrate/nitrite-nitrogen passed all laboratory quality control requirements. The four (4) samples rejected for use in the database were flagged by the laboratory as affected by salinity interference. All samples analyzed for ammonia-nitrogen and total phosphorous passed quality control requirements. Eighty-seven of the 90 samples analyzed for fecal coliforms passed all laboratory quality control requirements. Three (3) of the 90 fecal coliform bacteria samples were reported as laboratory error. All samples analyzed for *E. coli* and *Enterococcus* passed all laboratory quality control requirements. Samples that did not pass quality assurance and quality control were not used in the results or analyses.

Nutrients

Results varied between sites for ammonia-nitrogen (Figure 6), total nitrogen (Figure 7), and total phosphorous (Figure 8). A consistent pattern was not observed between the dry event and wet weather events in ammonia-nitrogen, total nitrogen, and total phosphorous concentration.

Ammonia-nitrogen concentrations ranged from the detection limit [0.050 milligrams per liter (mg/L)] at several sites to 7.50 mg/L immediately north and upgradient of the Able site at OB16 during the dry weather event (Figure 6). Site OB17, which is also north of the Able site, had the greatest average wet weather event ammonia-nitrogen concentration ($\bar{x}$=4.43 mg/L, MSE=1.07). Refer to Appendix 2 for ammonia-nitrogen concentrations of individual sites by sampling date.

TKN concentrations ranged from 0.1 mg/L at OB21 (pipe/ditch drainage system west of Hwy 170) during the dry weather event to 10 mg/L at OB17 and OB16. Nitrate/nitrite-nitrogen concentrations ranged from the detection limit (0.020 mg/L) at several sites to 0.82 mg/L at OB22 (pipe/ditch drainage system west of Hwy 170) during the dry weather event. TKN and nitrate/nitrite-nitrogen concentrations were used in calculating total nitrogen. Refer to Appendices 3 and 4 for TKN and nitrate/nitrite-nitrogen concentrations, respectively, of individual sites by sampling date.

Total nitrogen (i.e, TKN + NO_3/NO_2-N) concentrations ranged from a minimum reported concentration of 0.16 mg/L at OB23 (immediately southeast of the Able site) during a wet weather event to 10.02 mg/L for the dry weather event at sites OB16 and OB17 (Figure 7). Site OB17 had the greatest average wet weather total nitrogen concentration ($\bar{x}$=8.35 mg/L, MSE=1.07); OB6, an outflow from a stormwater pond below the Able site, had the lowest average wet weather total nitrogen concentration ($\bar{x}$=0.41 mg/L, MSE=0.11). Refer to Appendix 5 for total nitrogen concentrations of individual sites by sampling date.

Total phosphorous concentrations ranged from the detection limit (0.020 mg/L) at several sites (OB3, OB22, and OB19) to 0.60 mg/L at OB20 (adjacent to an animal hospital) during the dry weather event (Figure 8). Site OB20 also had the greatest average wet weather total phosphorous concentration ($\bar{x}$=0.38 mg/L, MSE=0.08); OB3 had the lowest average wet weather total phosphorous concentration ($\bar{x}$=0.021 mg/L, MSE=<0.01). Refer to Appendix 6 for total phosphorous concentrations of individual sites by sampling date.

Ammonia-nitrogen, total nitrogen, and total phosphorous did not strongly correlate with fecal coliforms, *E. coli*, or *Enterococcus*; Pearson correlation coefficients ranged from -0.20 to 0.51 (Table 4). Ammonia-nitrogen and total nitrogen did show an overall weak negative relationship with fecal coliforms, *E. coli*, and *Enterococcus*. However, total phosphorous had an overall weak positive relationship with fecal coliforms, *E. coli*, and *Enterococcus*. A stronger correlation and higher nutrient values were anticipated if there were issues with septic systems in the area.

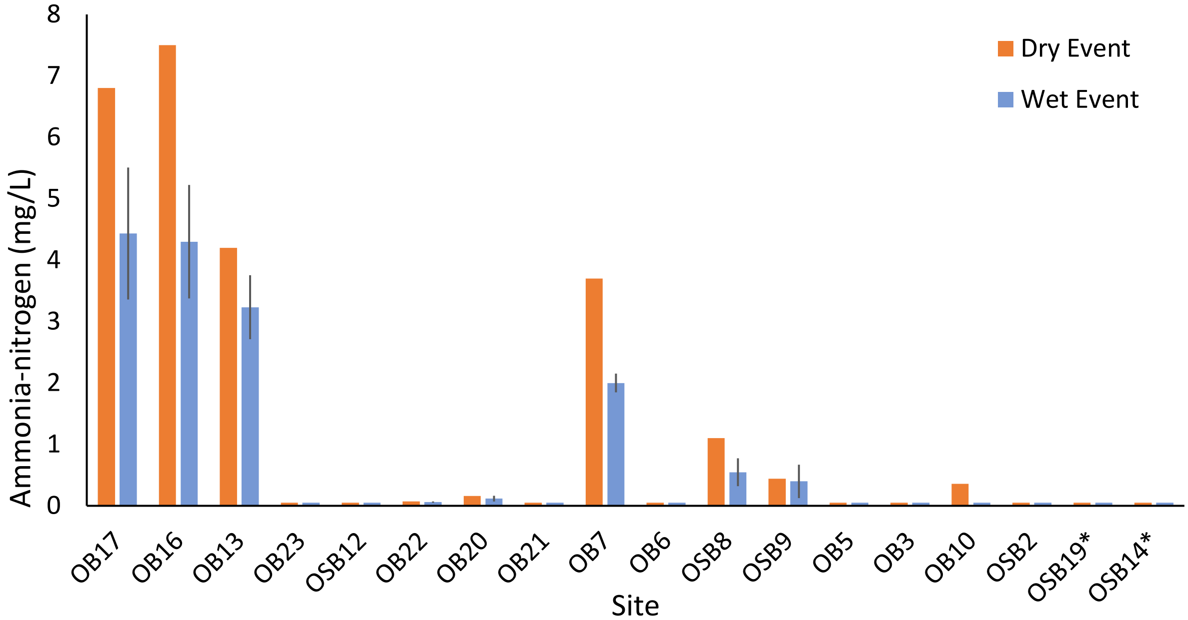


Figure 6: Ammonia-nitrogen concentrations (mg/L) per site by event type. Sites are organized by the northern most sites in the watershed and from west to east. The control sites are marked with an asterisk (OSB19 and OSB14). There is no associated standard error for the dry event results as this type of sampling occurred only once. The error bars represent +/- one (1) standard error of the mean.

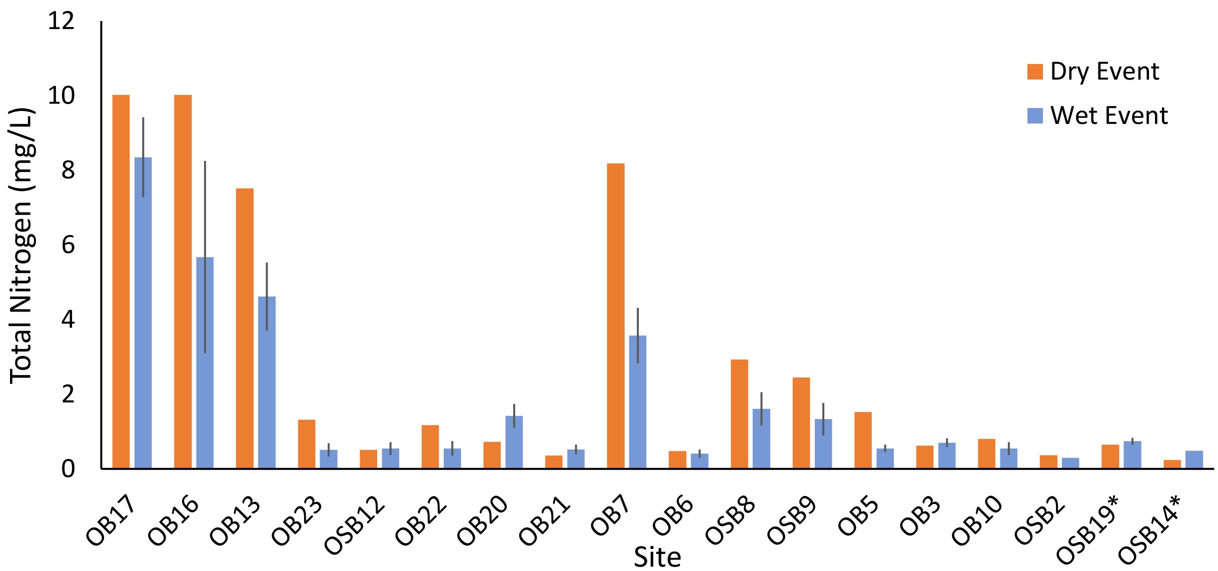


Figure 7: Total nitrogen concentrations (mg/L) per site by event type. Sites are organized by the northern most sites in the watershed and from west to east. The control sites are marked with an asterisk (OSB19 and OSB14). There is no associated standard error for the dry event results as this type of sampling occurred only once. The error bars represent +/- one (1) standard error of the mean.

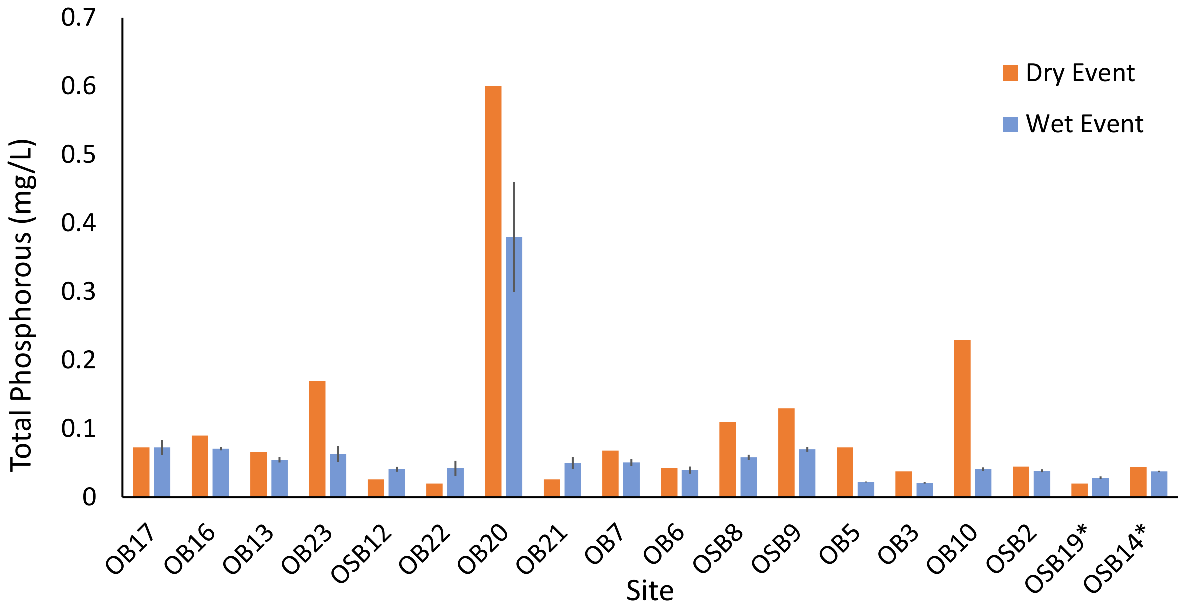


Figure 8: Total phosphorous concentrations (mg/L) per site by event type. Sites are organized by the northern most sites in the watershed and from west to east. The control sites are marked with an asterisk (OSB19 and OSB14). There is no associated standard error for the dry event results as this type of sampling occurred only once. The error bars represent +/- one (1) standard error of the mean.

Table 4: Pearson correlation coefficients comparing ammonia-nitrogen (mg/L), total nitrogen (mg/L), and total phosphorous (mg/L) to fecal coliforms (MPN/100 mL), *E. coli* (MPN/100mL), and *Enterococcus* (MPN/100mL) for wet weather events within the study area watershed (control sites were excluded).

Bacteriological Parameter	**Nutrient Correlation for Respective Bacteriological Parameter**		
	Ammonia-nitrogen	Total Nitrogen	Total Phosphorous
Fecal Coliforms	-0.14	-0.12	0.51
E. coli	-0.20	-0.18	0.44
Enterococcus	-0.18	-0.18	0.31

Bacteria

Bacteria results varied between sites for fecal coliform (Figure 9), *E. coli* (Figure 10), and *Enterococcus* (Figure 11). Overall, lower bacterial densities were observed during the dry event and greater densities were observed during the wet weather events.

Fecal coliform densities ranged from 1.8 MPN/100mL at OSB12, OB22, and OB6 to 92,000 MPN/100mL at OB21 and OB3. Site OSB2 had the lowest geometric mean (GM) fecal coliform density for the wet events (GM=142 MPN/100mL); OB20 had the greatest geometric mean fecal coliform density for the wet events (GM=7,900 MPN/100mL) (Figure 9). The State water quality standard for fecal coliform bacteria was exceeded at 50% of sites during the dry event and at 94% of sites during the wet events. Refer to Appendix 7 for fecal coliform densities at individual sites by sampling date.

E. coli densities ranged from 1 MPN/100mL at OSB12, OB22, and OB6 to 24,196 MPN/100mL at OB20. Site OSB2 presented the lowest geometric mean *E. coli* density for the wet events (GM=100 MPN/100mL);

OB20 had the greatest geometric mean *E. coli* density for the wet events (GM=7,039 MPN/100mL) (Figure 10). The State standard for *E. coli* was exceeded at 22% of sites during the dry event and at 65% of sites during the wet events. Refer to Appendix 8 for *E. coli* densities at individual sites by sampling date.

Enterococcus densities ranged from 1 MPN/100mL at OSB12 and OB21 to 120,980 MPN/100mL at OB23. Site OB5 had the lowest geometric mean *Enterococcus* density for the wet events (GM=47 MPN/100mL); OB23 had the greatest geometric mean *Enterococcus* density for the wet events (GM=12,532 MPN/100mL) (Figure 11). The State water quality standard for *Enterococcus* was exceeded at 17% of sites during the dry event and at 72% of sites during the wet events. Refer to Appendix 9 for *Enterococcus* densities of individual sites by sampling date.

The Kruskal-Wallis H test results did not show a significant difference in fecal coliforms ($p>0.05$), *E.* coli ($p>0.05$), or *Enterococcus* ($p>0.05$) among sites. Even though there was not a significant difference in bacterial parameters between sites, there were several sites with elevated bacterial densities that were consistent for each bacterial parameter measured (Table 5). OB20 and OB23 had the greatest wet event geometric means for all bacterial parameters measured. OB5 and OSB9 also had elevated geometric means for wet events; OSB9 and OSB8 had elevated bacterial densities during the dry event.

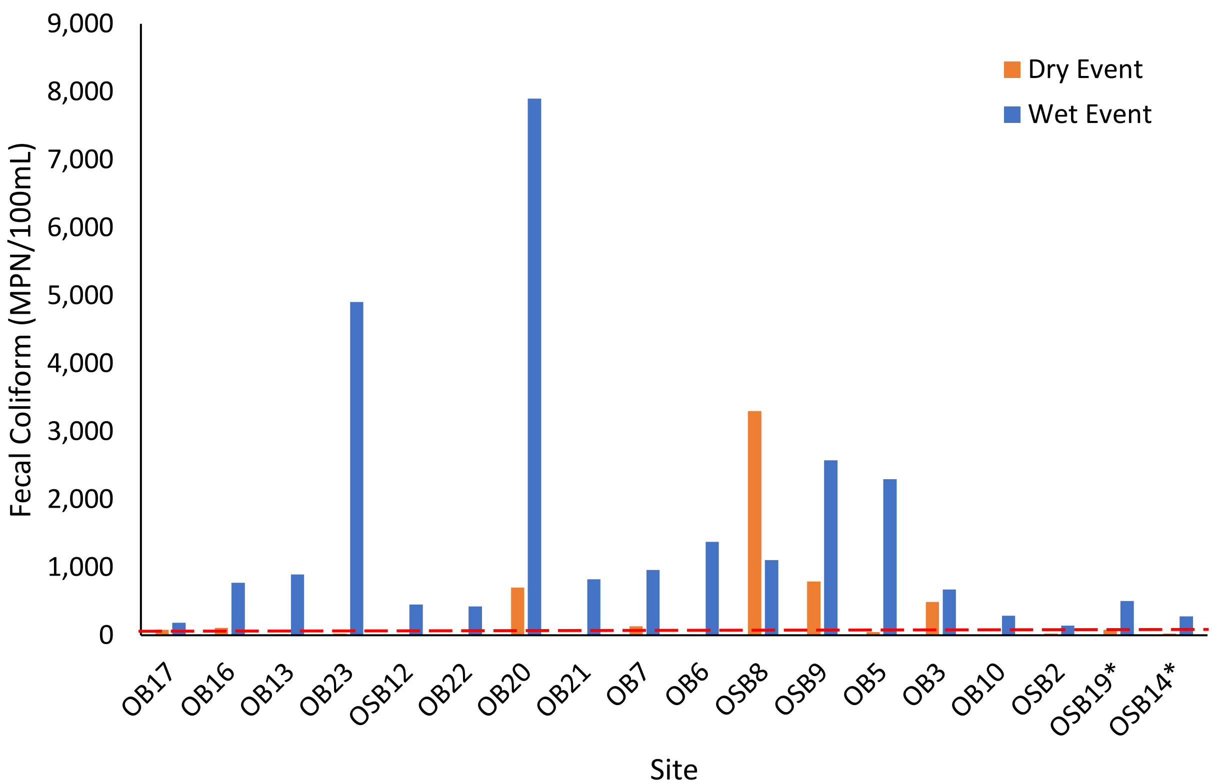


Figure 9: Fecal coliform densities (MPN/100mL) per site by event type. The geometric mean was calculated for the wet event values. Sites are organized by the northern most sites in the watershed and from west to east. The control sites are marked with an asterisk (OSB19 and OSB14). The red dotted line indicates the State standard for fecal coliforms for daily shellfish consumption (43 MPN/100mL).

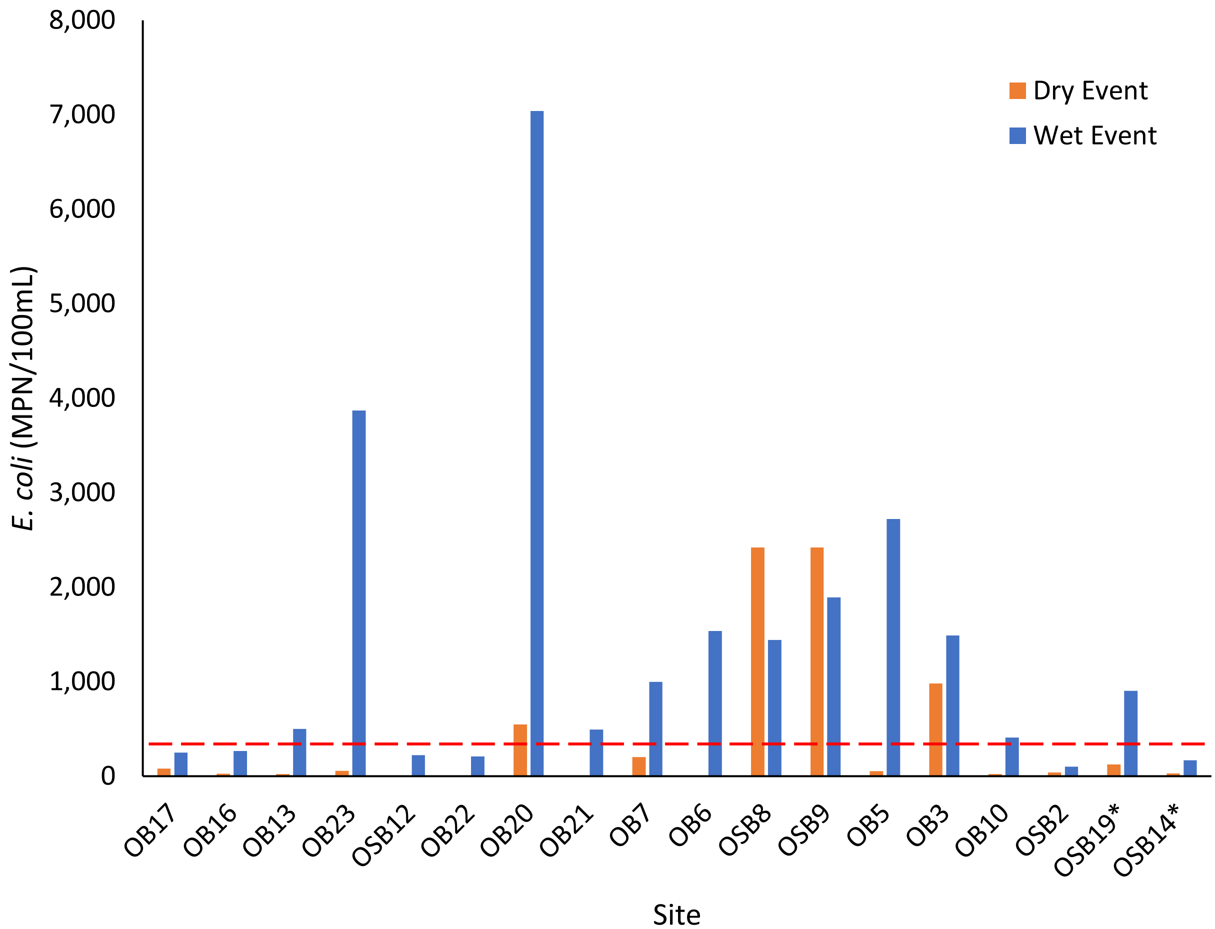


Figure 10: *E. coli* densities (MPN/100mL) per site by event type. The geometric mean was calculated for the wet event values. Sites are organized by the northern most sites in the watershed and from west to east. The control sites are marked with an asterisk (OSB19 and OSB14). The red dotted line indicates the State standard for *E. coli* for daily recreational activities (349 MPN/100mL).

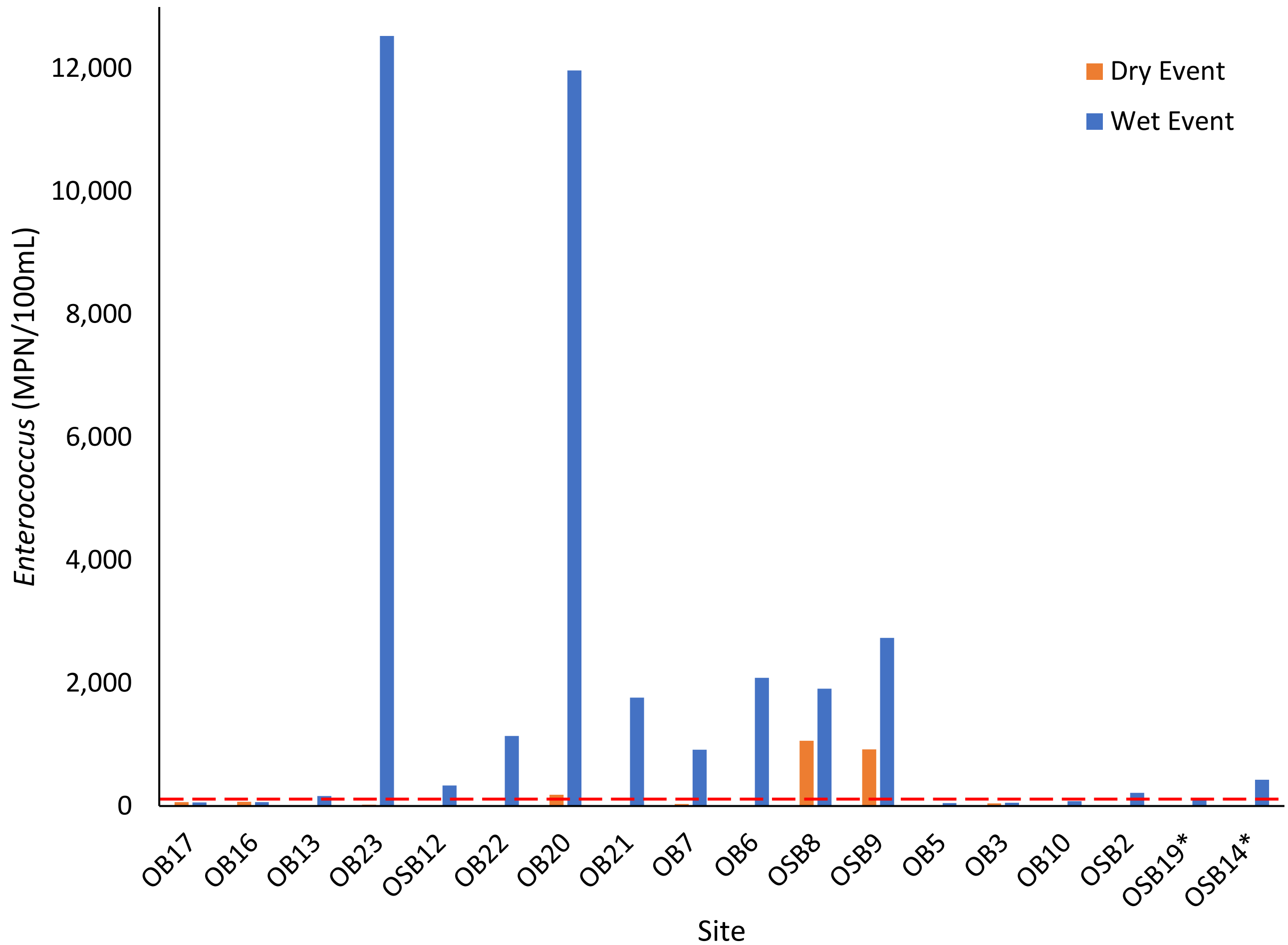


Figure 11: *Enterococcus* densities (MPN/100mL) per site by event type. The geometric mean was calculated for the wet event values. Sites are organized by the northern most sites in the watershed and from west to east. The control sites are marked with an asterisk (OSB19 and OSB14). The red dotted line indicates the State standard for *Enterococcus* for daily recreational activities (104 MPN/100mL).

Table 5: Sites organized by decreasing order of density occurrence per wet event geometric mean in relation to each bacterial parameter. OB20, represented in red, generally had the greatest geometric mean for each bacterial parameter except for *Enterococcus*. OB23, represented in yellow, typically had the second greatest geometric mean for all bacterial parameters. OSB9 and OB5, represented in blue, had the third or fourth greatest geometric mean for at least two of the bacterial parameters. Sites in green had the lowest geometric means for at least two of the bacterial parameters.

Decreasing Order of Density Occurrence per Geometric Mean	Bacterial Parameter					
	Fecal Coliform		***E. coli***		***Enterococcus***	
	Location	**Range Grouping (MPN/100mL)**	**Location**	**Range Grouping (MPN/100mL)**	**Location**	**Range Grouping (MPN/100mL)**
1	**OB20**	4,908 - 7,900	**OB20**	3,869 - 7,039	**OSB23**	11,996 - 12,532
2	**OB23**		**OB23**		**OB20**	
3	**OSB9**	2,299 - 2,575	**OB5**	2,722	**OSB9**	2,087 - 2,736
4	**OB5**		**OSB9**	1,441 - 1,891	OB6	
5	OB6	1,107 - 1,375	OB6		OSB8	1,137 - 1,908
6	OSB8		OB3		OB21	
7	OB7	506 - 959	OSB8		**OB22**	
8	OB13		OB7	501 - 999	OB7	919
9	OB21		OSB19 [a]		**OSB14 [a]**	163 - 428
10	OB16		OB13		**OSB12**	
11	OB3		OB21	100 - 493	**OSB2**	
12	OSB19 [a]		**OB10**		OB13	
13	**OSB12**	142 - 450	OB16		OSB19 [a]	47 - 98
14	**OSB22**		**OB17**		**OB10**	
15	**OB10**		**OSB12**		OB16	
16	**OSB14[a]**		**OB22**		**OB17**	
17	**OB17**		**OSB14 [a]**		OB3	
18	**OSB2**		**OSB2**		**OB5**	

a. Control site

Conclusions

Elevated fecal coliform, *E. coli*, and *Enterococcus* densities were observed at a majority of the sites in this study, particularly after heavy rainfall events. Consistently elevated densities for all bacterial parameters were detected at OB20, OB23, OSB9, and OSB5, suggesting possible sources contributing to high bacteria counts. OSB8 and OSB9 also had elevated bacterial densities for all parameters during the dry event, which could indicate an ongoing source release. Further investigation into these sites and the area surrounding them would be beneficial in determining specific sources possibly contributing to these predominantly high bacteria densities.

Bacterial densities at the other sites were not as elevated as at OB20, OB23, OSB9, and OSB5; however, many of these sites still exceeded State standards over the course of this study. For instance, during wet weather events South Carolina State Standards were exceeded for fecal coliforms in 94% of samples. Additionally, the fecal coliform, *E. coli*, and *Enterococcus* densities did not have a significant difference among sites, and the nutrient concentrations (ammonia-nitrogen, total nitrogen, and total phosphorous) did not correlate with bacterial densities. Therefore, some of these sites that exceeded State standards may be subject to nonpoint source pollution. There is residential, industrial, and agricultural land use around the Okatee River drainage basin (SCDHEC, SCDNR, & NOAA, 2000), which can result in several bacterial sources including urban runoff, stormwater, agriculture runoff, animal feces, and polluted groundwater (Boehm & Sassoubre, 2014).

Implementing stormwater best management practices (BMPs) have been an effective method to mitigate bacterial pollution and prevent water quality degradation in watersheds. A main focus of the Okatee River Watershed Management Plan has been to reduce the volume of stormwater runoff, which include creation or expansion of sedimentation ponds, wetland enhancements, and end of pipe improvements (Ward Edwards Engineering, 2015). SCDHEC recommendations for reducing load to the Okatee River also include directing drainage to pervious surfaces, septic tank maintenance, and implementing rain barrels (SCDHEC, 2010a). Continued planning and management to control nonpoint source pollution to the Okatee River and surrounding watershed is necessary to improve water quality.

Overall Summary:

- Previous studies have indicated historic water quality issues in the Okatee River watershed (SCDHEC, SCDNR, & NOAA, 2000; SCDHEC, 2010a; SCDHEC, 2020a). The elevated bacterial densities, often greater than State standards, observed as part of this assessment indicated ongoing water quality issues in this portion of the basin. As such, recreational activities are not recommended in this area after rainfall.
- There were specific sites (OB20, OB23, OSB9, and OSB5) that had consistently elevated bacterial densities across all bacterial parameters (fecal coliforms, *E. coli*, and *Enterococcus*). Further investigation into these sites would be beneficial in determining specific sources contributing to the elevated bacterial densities.
- Some of the other sites that consistently exceeded State standards for most bacterial parameters (fecal coliform, *E. coli*, and *Enterococcus*) during wet events may be driven by nonpoint sources in this watershed. The elevated bacterial densities are likely, at least in no small part, related to the dense and intensive degree of mixed land uses (i.e., development) in the watershed.

- Water quality improvement initiatives, such as BMPs, are recommended to control nonpoint source pollution to the Okatee River and surrounding watershed.

References

Boehm, A. B., & Sassoubre, L. M. (2014). Enterococci as Indicators of Environmental Fecal Contamination. In M. S. Gilmore, D. B. Clewell, & Y. Ike, *Enterococci: From Commensals to Leading Causes of Drug Resistant Infection.* Boston: Massachusetts Eye and Ear Infirmary.

Huang, H., Changsheng, C., Blanton, J. O., & Andrade, F. A. (2007). A numerical study of tidal asymmetry in Okatee Creek, South Carolina. *Estuarine Coastal and Shelf Science*, 190-202.

Moore, W., Blanton, J. O., & Joye, S. B. (2006). Estimates of flushing times, submarine groundwater discharge, and nutrient fluxes to Okatee Estuary, South Carolina. *Journal of Geophysical Research*, 3:C09006.

National Research Council. (2010). *Acute Exposure Guideline Levels for Selected Airborne Chemicals: Volume 8.* Washington, D.C.: The National Academies Press.

Pruss, A. (1998). Review of Epidemiological Studies on Health Effects from Exposure to Recreational Water. *Internation Epidemiological Association*, 27: 1-9.

R Core Team. (2019). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Vienna, Austria. Retrieved from https://www.R-project.org

SCAC. (2019, April 26). *County Information*. Retrieved June 15, 2021, from South Carolina Association of Counties: https://www.sccounties.org/county-information

SCDHEC. (2010a). Shellfish Fecal Coliform Total Maximum Daily Load for Stations 18-07, 18-08, 18-16, 18-17. Technical Document: 012D-19. Bureau of Water.

SCDHEC. (2010b). Water Quality Assessment for Salkehatchie River Basin. Bureau of Water. 89-98.

SCDHEC. (2018a). BEHSPROC 108 - Standard Operating Procedures (SOP), Sample Containers, Preservation, and Maximum Holding Times for Chemistry and Microbiological Analyses. Bureau of Environmental Health Services.

SCDHEC. (2018b). BEHSPROC 200 - Ambient Surface Water Sampling Standard Operating Procedure. Bureau of Environmental Health Services.

SCDHEC. (2018c). BEHSPROC 205 - Multi-Parameter Field Measurements in Surface Water. Bureau of Health and Environmental Services.

SCDHEC. (2020a). Okatee River Environmental Condition Assessment. Technical Report No. 011-2020. Bureau of Water.

SCDHEC. (2020b). R.61-68, Water Classification and Standards. Bureau of Water.

SCDHEC. (2020c). R.61-69, Classified Waters. Bureau of Water.

SCDHEC. (2020d). Shellfish Management Area 18, 2020 Annual Update. Shellfish Sanitation Section, Environmental Affairs.

SCDHEC, SCDNR, & NOAA. (2000). *A Baseline Assessment of Environmental and Biological Conditions in Broad Creek and the Okatee River.* Beaufort County, SC.

U.S. Census Bureau. (2003). 2000 Census of Population and Housing. *Population and Housing Unit Counts*, PHC-3-42, South Carolina. Washington, DC.

Ward Edwards Engineering. (2015). Okatie River Watershed Management Plan. *Project No. 090099A.* Beaufort County.

Appendix 1: Okatee River Area Bacteria Special Study Quality Assurance Project Plan

South Carolina Department of Health and Environmental Control
Bureau of Water
Aquatic Science Programs

Class 3 QAPP

Section A. Project Management

A1. Title and Approval Sheet

Project: Okatee River Area Bacteria Special Study

Date: January 10, 2020

Date of initiation: January 10, 2020

Quality Assurance Manager
David Graves, EA
David Graves Date: 1/21/2020

Manager, Aquatic Science Programs
Bryan Rabon, BOW
Date: 1/10/2020

Project Manager:
David Chestnut, BOW
David Chestnut Date: 1/17/2020

Quality Assurance Liaison
Andrea Hughes, BOW
Andrea L H Hughes Date: 1/10/2020

Quality Assurance Liaison
Paul Miller, BEHS
Date: 01-13-2020

EA BEHS ARESD
Susan Jackson, Director, BEHS
Date: 1/13/20

EA BEHS Area Director
Wendy Boswell, Director, BEHS
Richard K. Sheatt for Wendy Boswell Date: 1/22/2020

A2. Table of Contents

A3. Distribution List

Recipient	Region/Office	Phone	Email
Susan Jackson	ARESD – Columbia	803-896-0856	jacksosb@dhec.sc.gov
David Graves	EA – Columbia	803-898-4272	GRAVESDA@dhec.sc.gov
David Chestnut	ASP – Columbia	803-898-4066	CHESTNDE@dhec.sc.gov
Bryan Rabon	ASP – Columbia	803-896-4402	raboneb@dhec.sc.gov
Chris Cole	ARESD – Columbia	803-896-0672	colecp@dhec.sc.gov
Andrea Hughes	BOW - Columbia	803-898-4318	hughesal@dhec.sc.gov
Paul Miller	BEHS - Columbia	803-896-0971	millerpm@dhec.sc.gov
Wendy Boswell	BEHS-Charleston	843-953-0150	BOSWELWM@dhec.sc.gov
Melissa Roberts	BEHS - Beaufort	843-846-1030	robertMD@dhec.sc.gov
Emily Bores	ASP - Columbia	803-898-4837	boreseb@dhec.sc.gov

A4. Project/Task Organization

David Chestnut will be the project manager and will distribute and maintain the QAPP.

Bureau of Water staff, Aquatic Science Programs, and Bureau of Environmental Health Services staff, Beaufort Office will collect all water samples under the direction of the project manager.

The Analytical and Radiological Environmental Services Division (ARESD) Lab, will be responsible for analysis of samples and verification of results for Total Kjeldahl Nitrogen (TKN), Nitrate-Nitrite ($NO_{2\text{-}3}$), Ammonia (NH_3), and Total Phosphorus (TP).

The EA Lowcountry Region, Beaufort Lab, will be responsible for analysis of samples and verification of results for Fecal Coliforms using the modified (A-1) method, as well as *Escherichia coli, and Enterococcus spp.* by Idexx's Enzyme Substrate Method.

Andrea Hughes (Bureau of Water, BOW) and Paul Miller (Bureau of Environmental Health Services, BEHS) will serve as Quality Assurance Liaisons for their respective bureaus. They will review the draft QAPP and submit comments to the Project Manager. David Graves (Quality Assurance Manager, QAM) will review the QAPP for completeness and forward additional comments to the Project Manager.

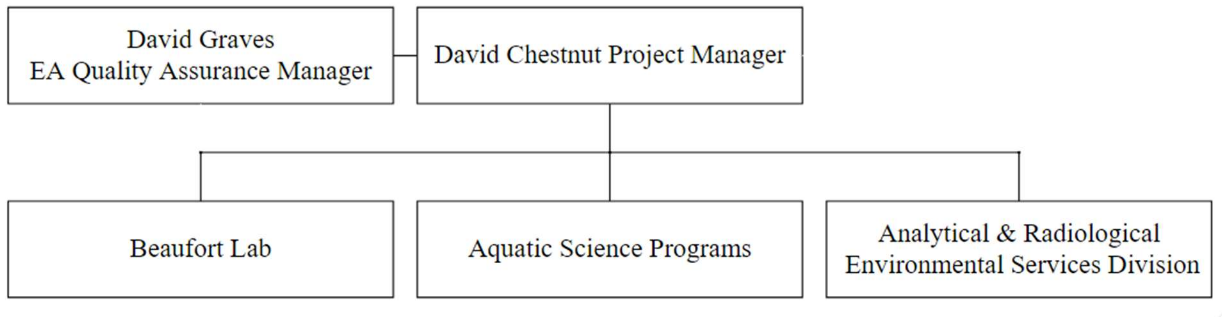


Figure 1 Organization Chart

A5. Project Definition/Background

In June of 2019 the pile of recycled material stored onsite at Able Contracting caught fire and burned for several weeks. Water samples collected by Beaufort Stormwater detected unusually high levels of bacteria in the waters draining from the Able Property.

The Okatee River, the ultimate receiving stream for the runoff of firefighting water, is heavily utilized by nearby residents for shellfish harvesting, fishing, crabbing, and other recreational activities.

Questions about the high levels of bacteria and their source have led the Bureau of Water to develop this study.

A6. Project/Task Description

The purpose of this study is to determine the potential sources of the high bacteria readings in the area of interest. Specifically, study scope questions to be answered are:

- What are the contributing factors to the high bacteria counts?
- Are high nutrient results associated with the high bacteria levels?

A7. Data Quality Objectives (DQOs) and Data Quality Indicators (DQIs)

Data Quality Objectives

The data collected during this study will be used to address the questions outlined. Stations were selected to represent the bacteria loadings throughout the watershed of interest and in an adjacent, control, watershed. Any samples that are missed or invalid will be omitted from the data set for this period and will not be repeated unless the number of valid samples falls below 60%.

Table 1: Analytical Data Quality Objectives.

Parameter	Units	Potential Range of Results	Method Detection Limit Objective	Precision Objective[a]	Method Derived From
Nitrate/Nitrite	mg/L	0.020-2.0	0.020	≤10% RPD	Lachat 10-107-04-1-C
Ammonia	mg/L	0.050-1.0	0.050	≤10% RPD	Lachat 10-107-06-5-J
Total Phosphorus	mg/L	0.020-2.0	0.020	≤10% RPD	Lachat 10-115-01-1-E
TKN-W	mg/L	0.10-5.0 mg/L	0.10	≤10% RPD	Lachat 10-107-06-2-H
E. Coli	MPN	1 - 2419.6 (x10 for saltwater)	1 (saltwater 10)		SM 9223 B-2004
Enterococci	MPN	1 - 2419.6 (x10 for saltwater)	1 (saltwater 10)		Enterolert (2002)
Fecal Coliform	MPN	1.8 - 1600	1.8		A-1 Medium AOAC

[a]Relative Percent Difference: ($\%RPD = \left(\frac{|R1-R2|}{\bar{R}}\right) \times 100\%$; *R1* and *R2* and replicate measurements and $\bar{R}$ is the mean value of the two measurements.

Sampling Protocols and Standard Operating Procedures

Standard operating procedures (SOPs) for grab sample collection, field measurements, sample containers, holding times, and chain of custody are detailed in sections within the BEHSPROC 200 – Ambient Surface Water Sampling and BEHSPROC 108 Standard Operating Procedures, Sample Containers, Preservation, and Maximum Holding Times for Chemistry and Microbiological Analyses if required. Laboratory analytical methods are detailed Nitrate/Nitrite SOP IX-C-5, Ammonia SOP IX-C-4 (b), Total Phosphorus SOP IX-C-11 (a), TKN SOP IX-C-7. Samples will be collected in the Okatee River and tributaries.

Any samples that are missed or invalid will be omitted from the data set for this period. Inclement weather prior to or during the sampling period may postpone the sampling to the following day. If sampling cannot be conducted on the following day a new date will be selected for that round of sample collection.

A8. Special Training Requirements/Certifications

NA

A9. Documentation and Records

The fully executed QAPP and any subsequent revisions will be sent to the Distribution List via e-mail by the project manager, David Chestnut.

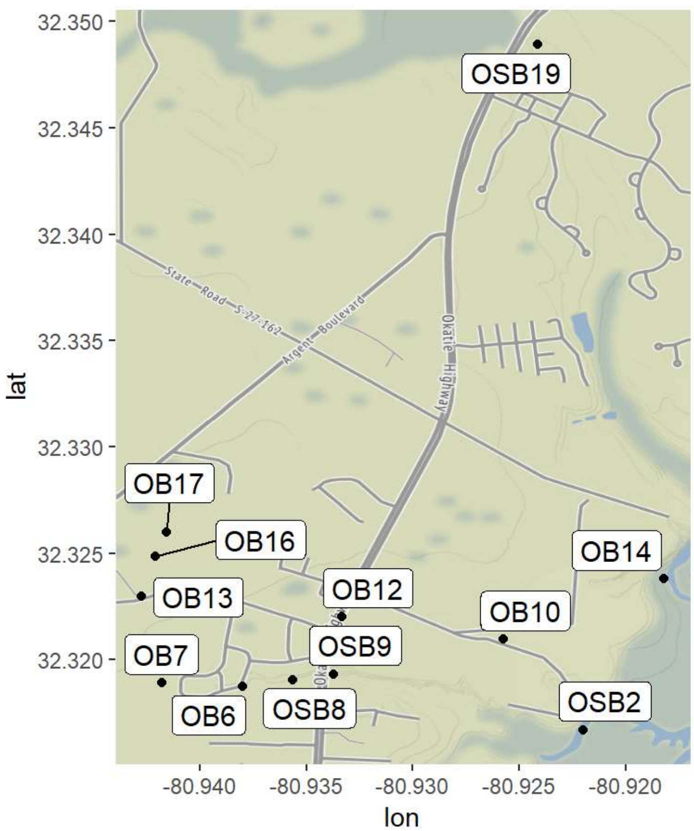
Laboratory results for Nitrate/Nitrite, TKN, Ammonia, total Phosphorus, E. coli, Enterococcus, and Fecal Coliforms will be stored in an Excel spreadsheet on a BOW server that is backed up nightly.

A brief discussion and comparison of the results from each station will be prepared in a summary report and sent to BOW management and the QAM.

Section B. Measurement/Data Acquisition

B1. Sampling Process Design

Station locations were determined by recon of the area of the industrial park and its drainage. 18 stations have been identified as sampling locations and are listed below. Prior sampling on August 29, 2019 showed there is a need to determine sources of high bacteria in the watershed.



Bacteria Data from Schinger Avenue, Ridgeland, SC Area[a]

Station	Bacterial Density		
	Fecal Coliform[b]	Enterococcus[c]	*E.Coli*[d]
	(MPN/100ml)	(MPN/100ml)	(MPN/100ml)
Standard	43	104	349
OB16	1600	364	113.7
OB17	180	97	29.9
OB13	>1600		43320
OB14	17	20	52
OB7	>1600	3654	4611
OB6	34	29.2	25.6
OSB8	1600	1483	2382
OSB2	23	20	20
OSB9	>1600	1333	2613
OB12	130	69.3	3.1
OB10	540	2755	1483
OSB19	79	2613	31.3

[a]Samples collected 2019-08-29; dry weather event
[b]by method A-1 Fecal Coliform
[c]by method Enterococci by Quanti-Tray
[d]by method Quanti-tray E.Coli Analysis

Four rounds of sampling will be done. One dry weather event and three following rainfall of at least 0.5 inches or more.

Table 2. General Sampling Location Descriptions

Site Number	Site Description	Latitude	Longitude
OSB2	Unnamed Creek to Okatee River Due South Bend in Cherry Point Rd N	32.316704	-80.921999
OB3	Unnamed Creek flowing to industrial area storm water at the end of Schlinger Ave. Intermittent Rain Event Only	32.316743	-80.942292
OB5	Unnamed Creek flowing to industrial area storm water at the end of Schlinger Ave. Head water to OB3 Intermittent Rain Event Only	32.317902	-80.951283
OB6	Outflow of Stormwater pond adjacent Browns Cove Rd	32.318746	-80.938003
OB7	Ditch to Pipe from ditch along Schinger Ave	32.318917	-80.9418
OSB8	Unnamed Creek to Okatee River draining industrial park upstream HWY 170 across from Williams Dr	32.319069	-80.935636
OSB9	Unnamed Creek to Okatee River draining industrial park downstream HWY 170 next to Williams Dr	32.319315	-80.933733
OB10	Unnamed creek at Cherry Point Rd below Okatie Elementary	32.320958	-80.925735
OSB12	Drain to Unnamed Creek at HWY 170 between Schinger AVE and Pearlstine Dr	32.322013	-80.933315
OB13	Ditch Just at Schinger Ave	32.322994	-80.942744

Site Number	Site Description	Latitude	Longitude
OSB14	Unnamed Creek to Okatee River At the adjacent the end of Cherry Point Rd N	32.323796	-80.918211
OB16	Ditch Just South of Kingsmore Cres	32.324863	-80.942081
OB17	Pond above at end of Kingsmore Cres	32.325982	-80.941586
OSB19	Unnamed Creek to Okatee River at HWY 170 north of Oldfield Way	32.348923	-80.924134
OB21	Pipe to ditch system outflow of drainage to north at Riverwalk Blvd and Old Coach Rd	32.31988	-80.93601
OB22	Ditch and pipe confluence west of Old Coach Rd halfway between Schinger Ave and Riverwalk Rain Event Only	32.32117	-80.93583
OB23	Impounded ditch North of Schinger Ave west of intersection with Browns Cove Rd	32.32316	-80.93927
OB20	Pipe to ditch system outflow of small retention pond between Mackinlay Way and Browns Cove Rd	32.320269	-80.939402

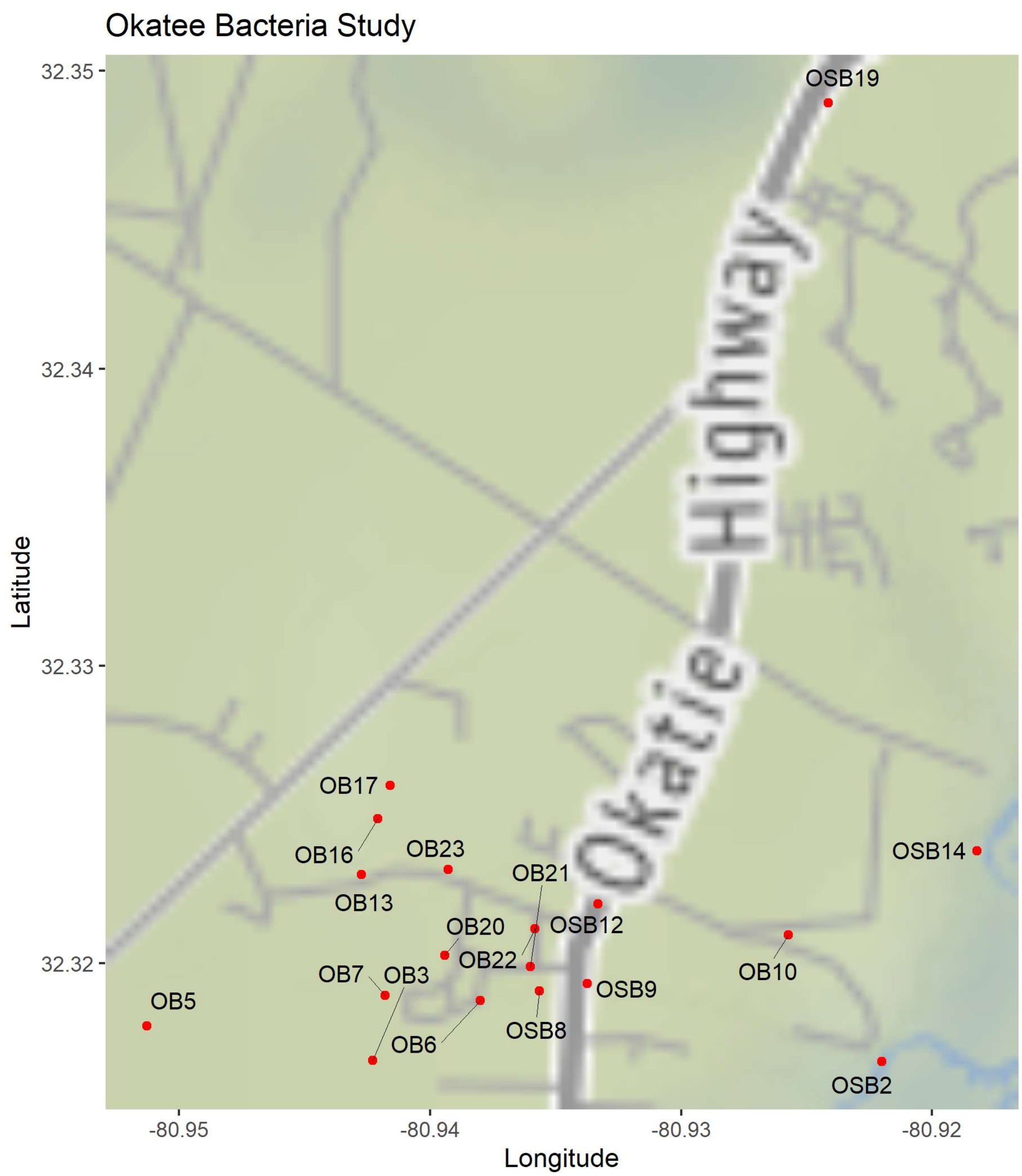


Figure 1. General Sampling Locations

For each sampling event, the total number of samples collected will be:
Table 3.

Number of Samples	Parameter	Processing Lab	BEHS SOP
18	Fecal Coliform (SFH A-1)	Beaufort	ARESD Sect. VII-A
18	*Escherichia coli*	Beaufort	ARESD Sect. VIII-B-1
18	*Enterococcus spp.*	Beaufort	ARESD Sect. VIII-B-2
18	Ammonia Nitrogen	Central Lab	ARESD Sect. IX-C-4(b)
18	Total Kjeldahl Nitrogen	Central Lab	ARESD Sect. IX-C-7
18	Nitrate & Nitrite Nitrogen	Central Lab	ARESD Sect. IX-C-5
18	Total Phosphorus	Central Lab	ARESD Sect. IX-C-11(a)
18	Dissolved oxygen	Field Staff	BEHSPROC 202
18	pH	Field Staff	BEHSPROC 203
18	Temperature	Field Staff	BEHSPROC 201
18	Conductivity	Field Staff	BEHSPROC 204
18	Salinity	Field Staff	BEHSPROC 204
18	Tidal Stage	Field Staff	*

* BPJ – ¼, ½, ¾, full, ebb or flood.

For each round of sampling, personnel will collect all samples on the same day. Weather conditions will be recorded. If problems occur in the field, David Chestnut will be responsible for the identification of the problem and corrective action. Corrective actions will be documented in the Ambient Water Field Logbook.

Data are to be used for comparison of individual sites against one another. No historic data exists for most of these analytes at these sampling locations.

No particular data point is critical and up to 40% of the samples could be lost before recollection would be required.

B2. Sampling Methods

Sampling will be conducted by Aquatic Science Programs staff and or BEHS Regional Staff, following the most current BEHSPROC 200 – Ambient Surface Water Sampling Standard Operating Procedures. All sample collection, sample handling, sample preservation, and chain of custody will follow all protocols given in the most current BEHSPROC 108 Standard Operating Procedures, Sample Containers, Preservation, and Maximum Holding Times for Chemistry and Microbiological Analyses All sample analysis and quality control for chemical analyses will be done according to the ARESD Procedures and QC Manual for Chemistry Laboratories.

Sample bottles will generally be labeled with the site number in the office before the sampling event. Sample collection date and time will be recorded in the field logbook and transferred to the chain-of-custody and sample request form DHEC 2186.

Sample Containers

The ARESD central laboratory will supply the nutrient sampling containers. BEHS Beaufort will supply the bacteria sampling containers. Arrangements will be made with the lab to obtain these sample containers prior to the week of sampling.

B3. Sample Handling and Custody

All sample collection, sample handling, sample preservation, and chain of custody will follow all protocols given in the most current BEHSPROC 108 and 200 SOP's. All sample analysis and quality control for chemical analyses will be done according to the ARESD Procedures and QC Manual for Chemistry Laboratories.

B4. Analytical Methods

See Section A7. Table 1: Analytical Data Quality Objectives.

For the Fecal Coliform A-1 method, where more dilutions are determined by lab staff to be needed the following will be used.

Adapted from EPA Method 1681 pg24 and pg28

A dilution refers to the mL of original sample that was inoculated into each series of tubes. For example, four, five-tube dilutions are used, with 10^{-3}, 10^{-4}, 10^{-5}, and 10^{-6} ml of the original sample in each tube. Only three of the four dilution series will be used to estimate the MPN. The three selected dilutions are called significant dilutions and are selected according to the following criteria. Examples of significant dilution selections are provided in Table 4, below. For these examples, the numerator represents the number of positive tubes per sample dilution series and the denominator represents the total number of tubes inoculated per dilution series. Choose the highest dilution (the most dilute, with the least amount of sample) giving positive results in all five tubes inoculated and the two succeeding higher (more dilute) dilutions (For Table 4, Example A, 10^{-4} is higher/more dilute than 10^{-3}). If the lowest dilution (least dilute) tested has less than five tubes with positive results, select it and the two next succeeding higher dilutions (Table 4, Examples B and C). When a positive result occurs in a dilution higher (more dilute) than the three significant dilutions selected according to the rules above, change the selection to the lowest dilution (least dilute) that has less than five positive results and the next two higher dilutions (more dilute) (Table 4, Example D). When the selection rules above have left unselected any higher dilutions (more dilute) with positive results, add those higher-dilution positive results to the results for the highest selected dilution (Table 4, Example E). If there were not enough higher dilutions tested to select three dilutions, then select the next lower dilution (Table 4, Example F).

Table 4.

Example	10^{-3} ml	10^{-4} ml	10^{-5} ml	10^{-6} ml	Largest Significant Dilutions	MPN from Table/Largest Sig Dilution = MPN
A	5/5	5/5	3/5	0/5	5-3-0	MPN/ 10^{-4}
B	4/5	5/5	1/5	1/5	4-5-1	MPN/ 10^{-3}
C	0/5	1/5	0/5	0/5	0-1-0	MPN/ 10^{-3}
D	5/5	3/5	1/5	1/5	3-1-1	MPN/ 10^{-4}
E	4/5	4/5	0/5	1/5	4-4-1	MPN/ 10^{-3}
F	5/5	5/5	5/5	2/5	5-5-2	MPN/ 10^{-4}

B5. Quality Control

For the laboratory analyses, QC will follow the current ARESD Laboratory SOP. For the field analyses, QC will follow the current BEHSPROC SOP.

B6. Instrument/Equipment Testing, Inspection, and Maintenance

For the laboratory analyses, testing, inspection, and maintenance will follow the current ARESD Chemistry Laboratory SOP. For the field analyses, QC will follow the current BEHSPROC SOP.

B7. Instrument/Equipment Calibration and Frequency

For the laboratory analyses, calibration will follow the current ARESD Laboratory SOP. For the field analyses, QC will follow the current BEHSPROC SOP.

B8. Inspection/Acceptance for Supplies and Consumables

For the laboratory analyses, acceptance for supplies and consumables will follow the current ARESD Laboratory SOP. For the field analyses, QC will follow the current BEHSPROC SOP.

B9. Non-direct Measurements

Rainfall is being estimated from radar by the Southeast regional river forecast group. We have access to these measurements and are using the gridded point to determine if enough rainfall has occurred to trigger a sampling event.

B10. Data Management

Analytical results produced by SC DHEC Central Lab are uploaded to the SC DHEC Laboratory Information Management System (LIMS), and paper copies of the results are forwarded to the project manager. Electronic data files can be provided from LIMS by ARESD staff upon request by the project manager.

The Project Manager is responsible for storing all data in a folder that is maintained indefinitely on SC DHEC internal server which is backed up daily.

All processes which involve data handling have been reviewed to ensure that data integrity is maintained by the Agency's IT Department.

All laboratory data are backed up daily. As per the Agency's QMP, the IT Department processes ensure that both software and hardware configurations are acceptable.

Section C. Assessments and Oversight

C1. Assessments and Response Actions

The ARESD Laboratory is evaluated and certified by EPA Region 4 under the Safe Drinking Water Act. The laboratory is evaluated every three years and the Laboratory Director is responsible for corrective action. The laboratory also participates in both WP and WS Proficiency Testing. These results are sent to the Laboratory Director and EPA Region 4.

Senior analysts are assigned internal evaluations of sections other than their own. The Laboratory Director and the Section Manager receive the evaluation results, and corrective action is overseen by the Section Manager and reviewed by the Laboratory Director.

The ASP participates in annual proficiency testing (PTs) and each new analyst is required to perform an initial demonstration of capability.

C2. Reports to Management

Corrective action for field issues are included in the field logbooks along with a narrative about the issues.

The Project Manager is responsible for collating data and ensuring validation is performed on data received from all sources. Bryan Rabon, manager of the ASP, reviews the project for completeness. The Project Manager is responsible for contacting the analytical labs if there are problems with data quality or completeness in the data received (missing values, a high percentage of data not meeting QC criteria) and resolving any recurring data problems. The

Project Manager is responsible for correcting problems that arise in the field.

A brief discussion and comparison of the results from each station will be prepared in a summary report and distributed to BOW management and the Quality Assurance Manager.

Section D. Data Validation and Usability

D1. Data Review, Verification, and Validation

For the data review, verification, and validation will follow the current ARESD Laboratory SOP. For the field analyses, QC will follow the current BEHSPROC SOP.

D2. Verification and Validation Methods

Verification:

Verification is done by the laboratories as per the ARESD Laboratory Manuals. Verification by Emily Bores will consist only of a completeness check. This check will ensure that all sample data was received. Any problems will be noted in an email to Bryan Rabon who will validate the data.

Validation:

The Project Manager will note the problems seen by the verifiers. He will then examine the data and compare sample results with historical data, where available, and determine if the data agrees with the project data. After these assessments, the Validator researches the data and/or documentation that are inconsistent. This is done by contacting Lab and Field Personnel to correct and/or explain inconsistencies. After the Validation steps have been completed, the Validator will include this information in the final report.

D3. Reconciliation with User Requirements

Any issues with the data found during the verification or validation will be transmitted to data users in the final report. This includes the process for reconciling project results with DQOs and reporting limits of data use.

References

South Carolina Department of Health and Environmental Control. 2018a. Bureau of Environmental Health Services. BEHSPROC 200 Standard Operating Procedures, Ambient Surface Water Sampling.

South Carolina Department of Health and Environmental Control. 2018b. Bureau of Environmental Health Services. BEHSPROC 108 Standard Operating Procedures, Sample Containers, Preservation, and Maximum Holding Times for Chemistry and Microbiological Analyses.

Appendix 2: Ammonia-nitrogen concentrations by sampling event.

Site	Ammonia-nitrogen Concentration (mg/L)[a]			
	22-Jan-2020[b]	**7-Feb-2020**	**21-Feb-2020**	**26-Feb-2020**
OB17	6.800	6.400	4.200	2.700
OB16	7.500	5.900	4.300	2.700
OB13	4.200	4.100	3.300	2.300
OB23	0.050	0.050	0.050	0.050
OSB12	0.050	0.050	0.050	0.050
OB22	0.074	0.050	0.050	0.082
OB20	0.160	0.077	0.063	0.210
OB21	0.052	0.050	0.050	0.050
OB7	3.700	2.200	1.700	2.100
OB6	0.050	0.050	0.050	0.050
OSB8	1.100	0.340	0.300	1.000
OSB9	0.440	0.092	0.160	0.940
OB5	0.050	0.050	0.050	0.050
OB3	0.050	0.050	0.050	0.050
OB10	0.360	0.050	0.050	0.050
OSB2	0.050	0.050	0.050	0.050
OSB19[c]	0.050	0.050	0.050	0.050
OSB14[c]	0.050	0.050	0.050	0.050

a. mg/L = milligrams per liter (parts per million)
b. Dry weather event
c. Control site

Appendix 3: Total Kjeldahl Nitrogen (TKN) concentrations by sampling event.

Site	TKN Concentration (mg/L)[a]			
	22-Jan-2020[b]	7-Feb-2020	21-Feb-2020	26-Feb-2020
OB17	10	9.5	9.2	6.2
OB16	10	8.9	7.3	0.6
OB13	7.5	6.1	3.2	4.2
OB23	1.3	0.62	0.14	0.7
OSB12	0.49	0.51	0.23	0.83
OB22	0.35	0.42	0.26	0.91
OB20	0.71	1	0.82	2
OB21	0.1	0.36	0.36	0.76
OB7	8.1	3.6	1.9	4
OB6	0.46	0.39	0.19	0.58
OSB8	2.3	0.95	0.88	2.3
OSB9	1.7	0.82	0.73	2
OB5	1.5	0.36	0.52	0.71
OB3	0.6	0.57	0.56	0.92
OB10	0.78	0.53	0.15	0.46
OSB2	0.35	–[c]	–[c]	0.28
OSB19[d]	0.63	0.59	0.67	0.9
OSB14[d]	0.22	–[c]	–[c]	0.47

a. mg/L = milligrams per liter (parts per million)
b. Dry weather event
c. Dashed mark indicates no data available
d. Control site

Appendix 4: Nitrate/nitrite-nitrogen concentrations by sampling event.

Site	Nitrate/nitrite-nitrogen Concentration (mg/L)[a]			
	22-Jan-2020[b]	**7-Feb-2020**	**21-Feb-2020**	**26-Feb-2020**
OB17	0.02	0.11	0.02	0.02
OB16	0.02	0.18	0.025	0.02
OB13	0.02	0.25	0.061	0.045
OB23	0.02	0.029	0.02	0.022
OSB12	0.02	0.02	0.02	0.02
OB22	0.82	0.02	0.02	0.02
OB20	0.02	0.24	0.16	0.045
OB21	0.26	0.046	0.02	0.02
OB7	0.088	0.8	0.19	0.23
OB6	0.02	0.02	0.02	0.02
OSB8	0.63	0.39	0.13	0.18
OSB9	0.75	0.17	0.072	0.2
OB5	0.02	0.02	0.02	0.02
OB3	0.02	0.02	0.02	0.02
OB10	0.02	0.02	0.02	0.02
OSB2	0.02	–[c]	–[c]	0.02
OSB19[d]	0.02	0.02	0.02	0.02
OSB14[d]	0.02	–[c]	–[c]	0.02

a. mg/L = milligrams per liter (parts per million)
b. Dry weather event
c. Dashed mark indicates no data available
d. Control site

Appendix 5: Total nitrogen concentrations by sampling event.

Site	Total Nitrogen Concentration (mg/L)[a]			
	22-Jan-2020[b]	**7-Feb-2020**	**21-Feb-2020**	**26-Feb-2020**
OB17	10.020	9.610	9.220	6.220
OB16	10.020	9.080	7.325	0.620
OB13	7.520	6.350	3.261	4.245
OB23	1.320	0.649	0.160	0.722
OSB12	0.510	0.530	0.250	0.850
OB22	1.170	0.440	0.280	0.930
OB20	0.730	1.240	0.980	2.045
OB21	0.360	0.406	0.380	0.780
OB7	8.188	4.400	2.090	4.230
OB6	0.480	0.410	0.210	0.600
OSB8	2.930	1.340	1.010	2.480
OSB9	2.450	0.990	0.802	2.200
OB5	1.520	0.380	0.540	0.730
OB3	0.620	0.590	0.580	0.940
OB10	0.800	0.550	0.170	0.480
OSB2	0.370	–[c]	–[c]	0.300
OSB19[d]	0.650	0.610	0.690	0.920
OSB14[d]	0.240	–[c]	–[c]	0.490

a. mg/L = milligrams per liter (parts per million)
b. Dry weather event
c. Dashed mark indicates no data available
d. Control site

Appendix 6: Total phosphorous concentrations by sampling event.

Site	Total Phosphorous Concentration (mg/L)[a]			
	22-Jan-2020[b]	7-Feb-2020	21-Feb-2020	26-Feb-2020
OB17	0.073	0.078	0.088	0.052
OB16	0.090	0.076	0.069	0.068
OB13	0.066	0.062	0.053	0.049
OB23	0.170	0.079	0.070	0.041
OSB12	0.026	0.048	0.039	0.036
OB22	0.020	0.058	0.048	0.021
OB20	0.600	0.300	0.300	0.540
OB21	0.026	0.066	0.047	0.037
OB7	0.068	0.061	0.046	0.045
OB6	0.043	0.049	0.031	0.039
OSB8	0.110	0.064	0.060	0.051
OSB9	0.130	0.076	0.070	0.064
OB5	0.073	0.021	0.023	0.023
OB3	0.038	0.020	0.020	0.023
OB10	0.230	0.037	0.040	0.046
OSB2	0.045	0.043	0.036	0.037
OSB19[c]	0.020	0.030	0.031	0.025
OSB14[c]	0.044	0.040	0.036	0.037

a. mg/L = milligrams per liter (parts per million)
b. Dry weather event
c. Control site

Appendix 7: Fecal coliform density (MPN/100mL) by sampling event. Results in red indicate densities exceeding the State standard for daily shellfish consumption of 43 MPN/100mL (SCDHEC, 2020b).

Site	Fecal Coliform Density (MPN/100mL)[a]				
	22-Jan-2020[b]	7-Feb-2020	21-Feb-2020	26-Feb-2020	30-Sept-2020
OB17	79	1,300	220	23	170
OB16	110	3,300	1,400	49	920
OB13	14	3,500	1,300	70	1,600
OB23	22	17,000	17,000	790	1,600
OSB12	1.8	7,900	–	33	350
OB22	1.8	790	790	33	>1,600
OB20	700	54,000	92,000	490	>1,600
OB21	2	2,400	700	170	>1,600
OB7	130	4,900	2,200	49	>1,600
OB6	1.8	2,400	4,900	330	920
OSB8	3,300	2,400	2,300	170	1600
OSB9	790	3,300	4,900	1,700	>1,600
OB5	49	1,700	13,000	790	>1,600
OB3	490	2,400	–[c]	79	>1,600
OB10	6.8	790	330	49	540
OSB2	23	330	130	33	170
OSB19[d]	79	4,900	–	49	540
OSB14[d]	23	790	460	46	350

a. MPN/100mL = most probable number per 100 milliliters
b. Dry weather event
c. Dashed mark indicates no data available
d. Control site

Appendix 8: *Escherichia coli* density (MPN/100mL) by sampling event. Results in red indicate densities exceeding the State standard for daily recreational activities of 349 MPN/100mL (SCDHEC, 2020b).

Site	*E. coli* Density (MPN/100mL)[a]				
	22-Jan-2020[b]	7-Feb-2020	21-Feb-2020	26-Feb-2020	30-Sept-2020
OB17	79.8	1203.3	488.4	27.5	235.9
OB16	25.6	1119.9	410.6	39.9	275.5
OB13	24.1	1723	686.7	332.5	160.7
OB23	56.5	19863	14136	866.4	920.8
OSB12	1	2723	920.8	13	75.9
OB22	1	501.2	161.6	42.6	547.5
OB20	547.5	>24196	>24196	1732.9	2419.6
OB21	2	980.4	328.2	75.9	>2419.6
OB7	201.4	4884	2419.6	80.5	1046.2
OB6	1	5172	2987	116.9	307.6
OSB8	>2419.6	2419.6	3255	387.3	1413.6
OSB9	2419.6	3873	2419.6	686.7	1986.3
OB5	53	2359	10462	1119.9	1986.3
OB3	980.4	6131	2723	122.3	>2419.6
OB10	22.6	1203.3	290.9	85.7	920.8
OSB2	41	241	160	31	85
OSB19[c]	125.9	6488	727	108.6	1299.7
OSB14[c]	30	464	203	98	86

a. MPN/100mL = most probable number per 100 milliliters
b. Dry weather event
c. Control site

Appendix 9: *Enterococcus* density (MPN/100mL) by sampling event. Results in red indicate densities exceeding the State standard for daily recreational activity of 104 MPN/100mL (SCDHEC, 2020b).

Site	*Enterococcus* Density (MPN/100mL)[a]				
	22-Jan-2020[b]	7-Feb-2020	21-Feb-2020	26-Feb-2020	30-Sept-2020
OB17	62.6	97	31.6	30	131
OB16	67.3	168	56.1	10	153
OB13	10.1	730	211.4	10	457
OB23	23.3	>24196	120980	4884	1723
OSB12	1	1986.3	3654	6.2	280.9
OB22	11.1	5794	1918	62.2	>2419.6
OB20	185	64985	52310	464	12997
OB21	1	7701	2419.6	30	17329
OB7	30.2	504	2419.6	241.5	>2419.6
OB6	12.2	4884	7270	269	1986.3
OSB8	1063	3282	5794	287.8	2419.6
OSB9	920.8	5172	8664	517.2	2419.6
OB5	5.1	107	10	10	465
OB3	44.7	86	12.6	30	211
OB10	9.2	579.4	21.3	7.2	436
OSB2	10	1014	203	20	529
OSB19[c]	7.2	1046.2	21.8	8.4	488.4
OSB14[c]	10	2755	379	52	620

a. MPN/100mL = most probable number per 100 milliliters
b. Dry weather event
c. Control site