Total Maximum Daily Loads for: St. Thomas East End Reserve, St. Thomas, USVI

SUBMITTED TO:

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ACRONYMS AND ABBREVIATIONS

ACOR	Alternate Contract Officer Representative
BASINS	EPAs Better Assessment Science Integrating Point and Nonpoint Sources
BMP	Best Management Practice
COR	Contract Officer Representative
CWA	Clean Water Act
DEM	Digital Elevation Model
DO	Dissolved Oxygen
DQO	Data Quality Objectives
ECHO	Enforcement and Compliance History Online
EMC	Event-Mean Concentration
FGDC	Federal Geographic Data Committee
GIS	Geographic Information System
HSPF	Hydrologic Simulation Program--FORTRAN
IP	Implementation Plan
LiDAR	Light Detecting and Ranging
LSPC	Loading Simulation Program C++
NCDC	National Climatic Data Center
NHDPlus	National Hydrography Dataset Plus
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
PCS	EPAs Permit and Compliance System
QA	Quality Assurance
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QC	Quality Control
QGIS	Quantum Geographic Information System (software)
STEER	St. Thomas East End Reserve
STORET	EPAs Storage and Retrieval System
STXEEMP	St. Croix East End Marine Park
SUSTAIN	System for Urban Stormwater Treatment and Analysis Integration Model
TMDL	Total Maximum Daily Load
TO	Task Order
TOL	Task Order Leader
USDA	United States Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFS	United States Forest Service
USGS	U.S. Geological Survey
USVI	United States Virgin Islands
WQS	Water Quality Standards

1 DESCRIPTION OF WATERBODY, POLLUTANT OF CONCERN, POLLUTANT SOURCES, AND PRIORITY RANKING

The United States Virgin Islands (USVI) are located in the Lesser Antilles of the eastern Caribbean and are comprised of more than 50 islands and cays, the largest and most widely known and visited being St. John, St. Thomas, and St. Croix. On each of the islands, the impacts from increased development and seasonal/year-round population increases has been observed in the degradation of coastal water quality and dramatic impacts to coral reef cover, which has declined significantly over the past several decades. The negative impacts to water quality have also led to beach closures. Without public understanding and planning for the control of pollutant sources, there may be significant impact on the tourism-driven economy due to chronic issues that impact human and ecological health. This Total Maximum Daily Load (TMDL) document focuses on the impacts observed in the St. Thomas East End Reserve (STEER) and presents the extent and basis of the pollutant impairment. This document details what is known about the sources of the pollutants, outlines the degree to which pollutant sources need to be reduced to meet water quality standards (WQS), identifies the source control practices that could reduce pollutant loadings, and describes the range of pollutant reductions that can be achieved from the practices. STEER assessment units include impairments caused by enterococcus bacteria, dissolved oxygen (DO), turbidity, and temperature. Previous TMDLs have been developed and approved for Benner Bay Lagoon Marina and Mangrove Lagoon for fecal coliform and DO.

1.1 Description of Waterbody and Background Information

The STEER is a 3.7 square mile collection of marine reserves and wildlife sanctuaries that includes the last remaining mangrove lagoon on St. Thomas. STEER is widely recognized as one of the USVI's most significant nursery grounds for commercially- and recreationally-important fisheries. STEER is comprised of Mangrove Lagoon, Benner Bay, Compass Pt. Salt Pond, Nazareth Bay, Cowpet Bay, and Great Bay. The STEER watershed is comprised of 6.2 square miles of upland area that drains directly to these waters. Table 1-1 summarizes the STEER assessment units included in this TMDL report and includes parameters listed on the 2020 303(d) list, unlisted but found to impaired through water quality modeling, or included to revise existing TMDLs. For Benner Bay (STT-33), Benner Bay Lagoon Marina (STT-34), and Mangrove Lagoon (STT-35) the DO TMDL was approved in 2003 and the Fecal Coliform TMDL in 2005.

Table 1-1. STEER Assessment Units and 303(d) Impairments

Location/WBID	303d listed	Unlisted but impaired	Revision to a TMDL
Great Bay (STT-25)	Enterococcus		
Cowpet Bay (STT-28)	Enterococcus	Turbidity; Dissolved Oxygen; Total Phosphorus; and Total Nitrogen	
Nazareth Bay (STT-31)	Enterococcus	Turbidity; and Total Nitrogen	
Benner Bay (STT-33)		Total Nitrogen; and Enterococcus	Dissolved Oxygen; and Fecal Coliform
Benner Bay Lagoon Marina (STT-34)	Turbidity; and Enterococcus	Total Nitrogen	Dissolved Oxygen; and Fecal Coliform
Mangrove Lagoon (STT-35)	Turbidity; and Enterococcus	Total Nitrogen	Dissolved Oxygen; and Fecal Coliform

The STEER watershed is one of the largest watersheds in the USVI. It includes a portion of Red Hook Bay Watersheds extending eastward from Bovoni to Cabrita Pt. northward to the ridge line above Anna's Retreat and New Tutu Valley (Horsley Witten Group, May 2013b). The STEER watershed is highly urbanized and is home to more than 33% of the population of St. Thomas—land uses include residential, commercial, and industrial (Figure 1-1). Included in the watershed are the Bovoni Landfill, Tutu Park Mall, and Heavy Materials quarry and a high density of marinas, boatyards, and condominiums line the shoreline (Horsley Witten Group, 2013a). Figure 1-2 highlights the listed assessment units and watershed boundaries.

When developing TMDLs and accounting for various land-based sources, a review of the land cover composition of the watersheds contributing to the assessment units is required. The land covers are often re-classified or condensed based on what is known about each, including rainfall-runoff characteristics and pollutant sources present. The National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) Regional Land Cover layer (NOAA, 2015) was used to develop a re-classified land cover representation for the STEER watersheds. In the STEER watersheds, land cover is generally comprised of a combination of forested cover (38%), urban development (32%), and grasses and shrubland (24%) (

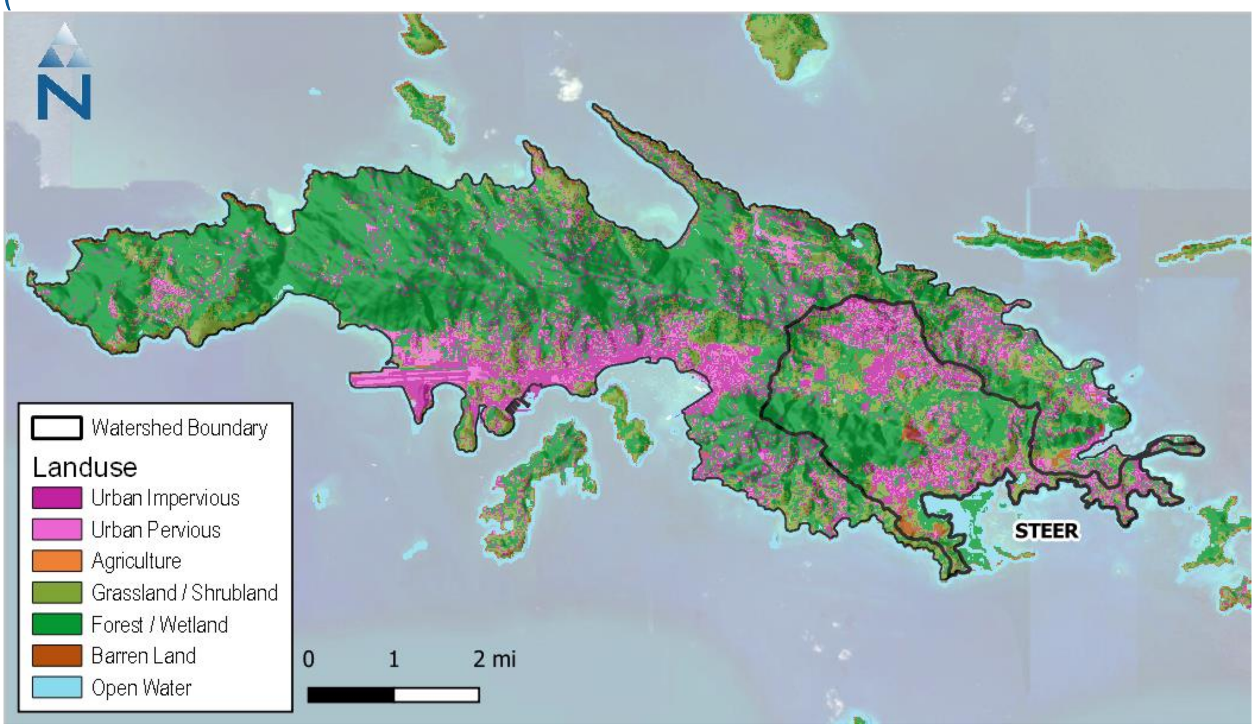

Figure 1-1. Land use distribution in STEER and across St. Thomas.

Table 1-2. Land Use Distribution for STEER

Land Use / Land Cover	Total Area (acre)	Area (percent)
Agriculture	3.9	0.1%
Barren	101.7	2.7%
Forest	1,419.4	38.2%
Grass/Shrub	878.7	23.7%
Urban	1,181.8	31.8%
Wetlands	129.9	3.5%
Total	**3,715.5**	**100%**

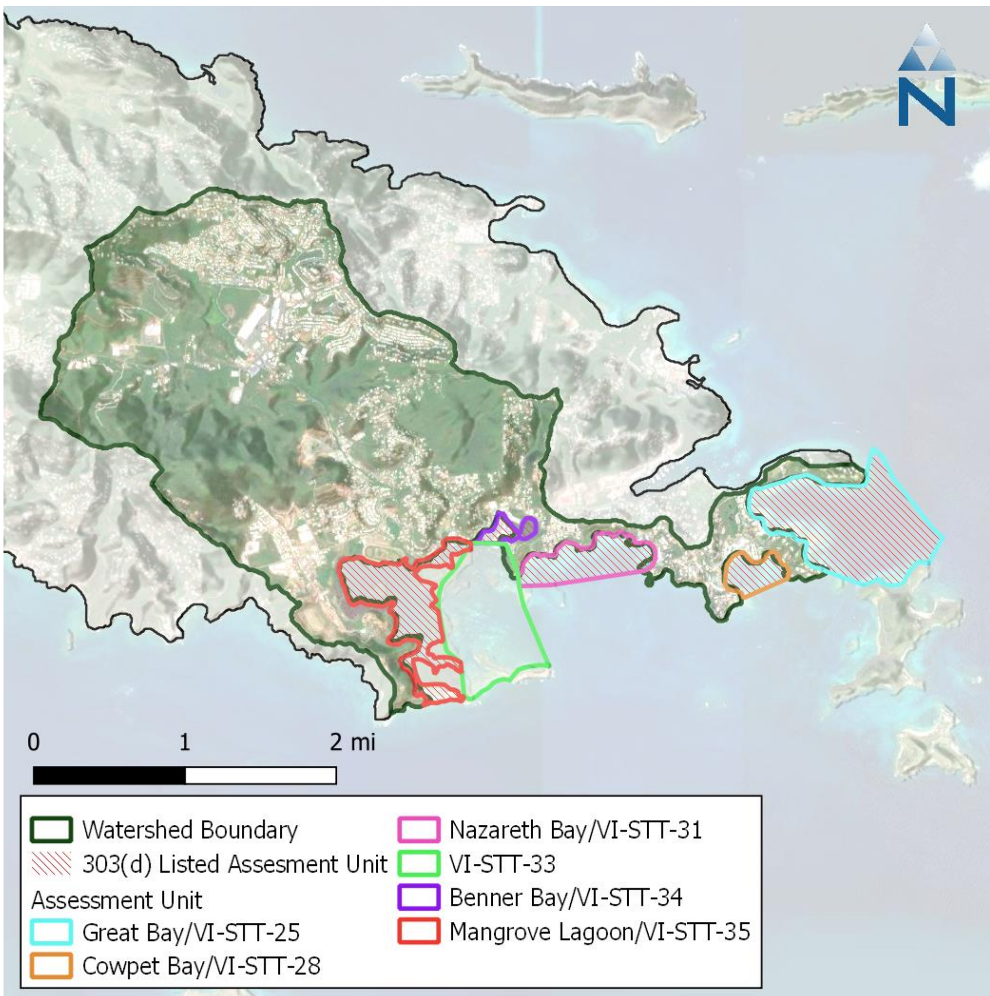

Figure 1-2. Spatial overview of STEER showing assessment units and contributing drainage area.

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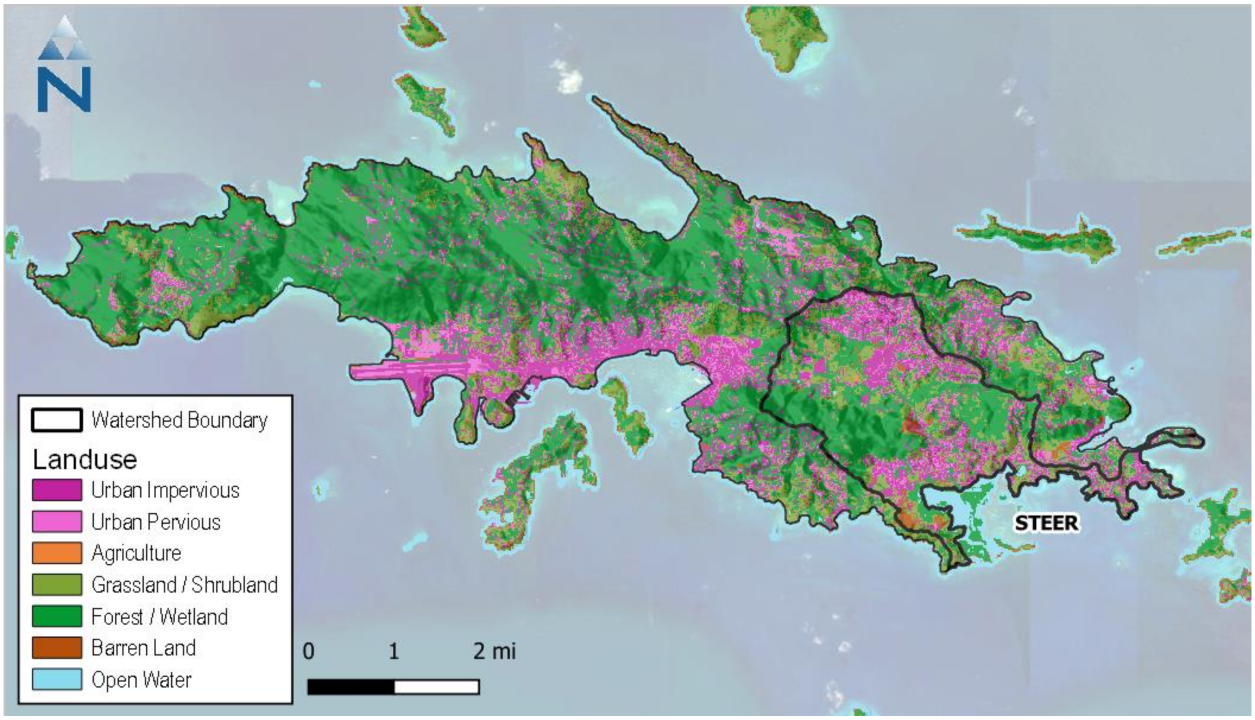

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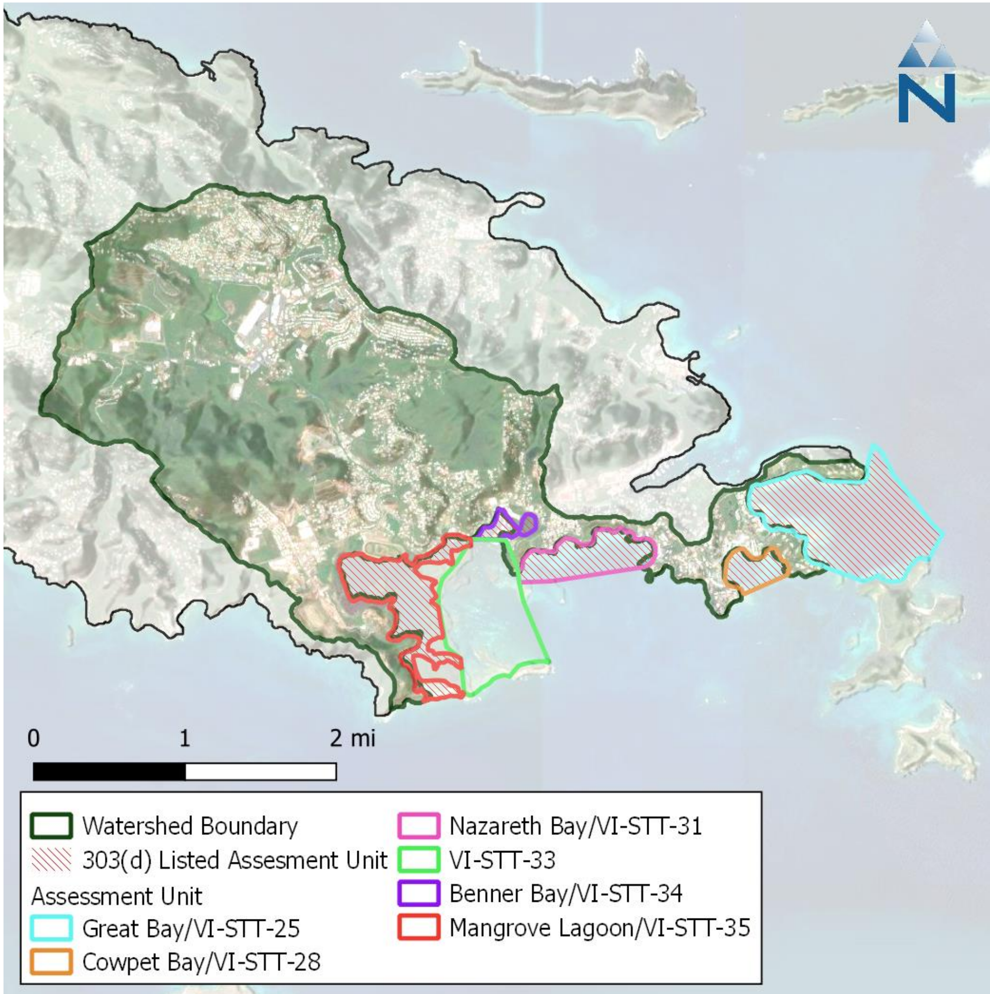

Figure 1-2. Spatial overview of STEER showing assessment units and contributing drainage area.

1.1.1 Summary of Monitoring Data

Monitoring data for STEER was compiled from multiple sources including EPA's Storage and Retrieval Data Warehouse (STORET) and more recent turbidity monitoring data collected by the National Park Services and obtained through this TMDL process. **Error! Reference source not found.** presents a spatial summary of the identified station locations within the STEER assessment units and contributing drainage area. These data were summarized and assessed using various tabular and graphical methods to assess the quality and representativeness of the available samples. The initial inventory of sampling data available for characterizing conditions in STEER is summarized as follows:

- Map showing the location(s) of each sampling location (**Error! Reference source not found.**)
- Tabular summary of Turbidity samples by station (**Error! Reference source not found.**)
- Tabular summary of Enterococcus samples by station (**Error! Reference source not found.**)
- Tabular summary of Dissolved Oxygen samples by station (**Error! Reference source not found.**)
- Tabular summary of Temperature samples by station (**Error! Reference source not found.**)
- Tabular summary of Total Nitrogen samples by station (Table 1-7)
- Tabular summary of Total Phosphorus samples by station (Table 1-8)

Appendix B includes all water quality monitoring data (in tabular format organized by data source) used for establishing the existing conditions for the STEER assessment unit(s). Note that sample locations for STT-25 have sample-specific latitude and longitude coordinates located in two assessment units, VI-STT-31 and VI-STT-32. These individual samples were left spatially referenced to the corresponding assessment unit based on documented coordinates for each sample.

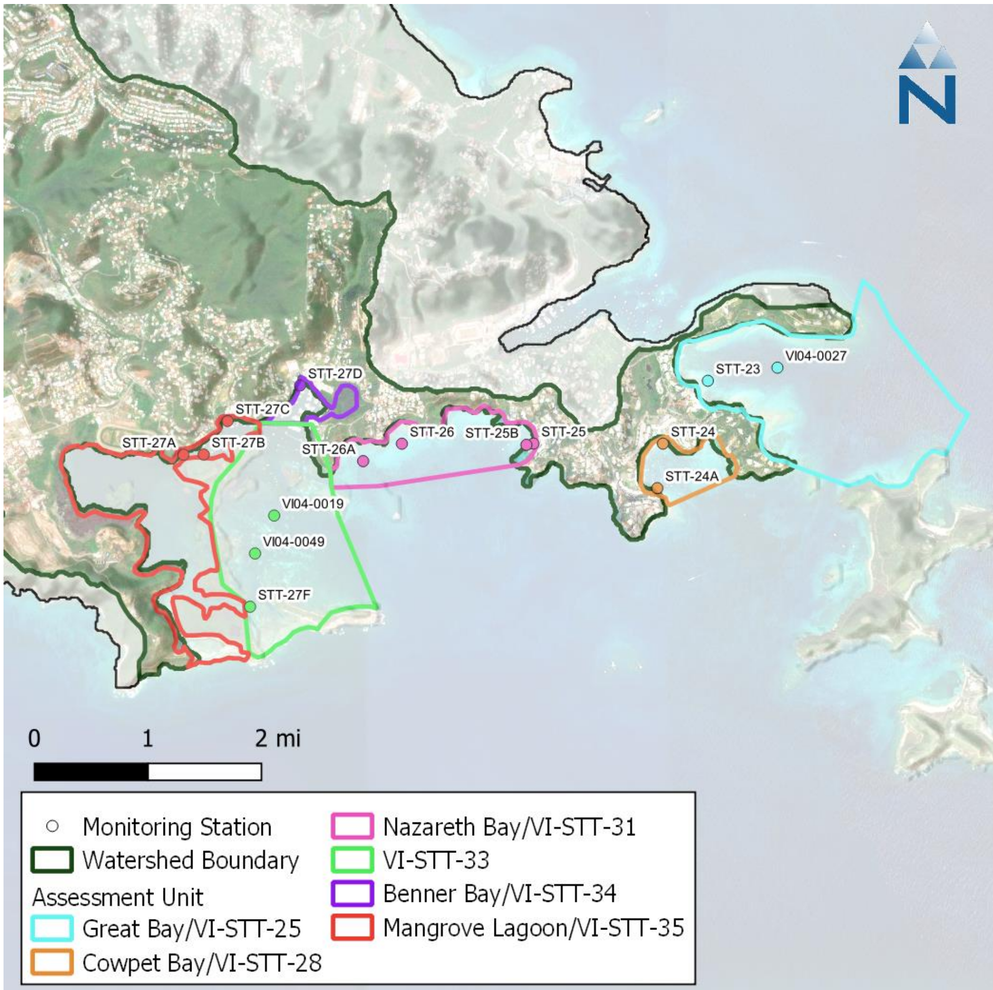

Figure 1-3. Locations of monitoring sites assessed for STEER.

Table 1-3. Summary of available Turbidity (NTU) data by station

Assessment Unit	Station ID	Start Year	End Year	Count	Min	Max	Mean
VI-STT-25	STT-23	1999	2019	139	0.0	6.4	0.7
VI-STT-31	STT-25	1999	2019	131	0.0	2.4	0.7
VI-STT-31	STT-25B	2003	2003	2	1.4	1.4	1.4
VI-STT-31	STT-26	2000	2019	121	0.0	12.6	0.9
VI-STT-31	STT-26A	1999	2005	7	0.2	1.5	0.6

Table 1-4. Summary of available Enterococcus (MPN/100mL) data by station

Assessment Unit	Station ID	Start Year	End Year	Count	Min	Max	Mean
VI-STT-34	STT-27D	2002	2019	58	0	1379	74.9
VI-STT-35	STT-27A	2002	2019	52	0	1670	76.6
VI-STT-35	STT-27B	2002	2019	58	0	749	39.0
VI-STT-35	STT-27C	2002	2019	57	0	906	79.7

Table 1-5. Summary of available Dissolved Oxygen (mg/L) data by station

Assessment Unit	Station ID	Start Year	End Year	Count	Min	Max	Mean
VI-STT-25	STT-23	1999	2019	102	4.2	10.7	7.0
VI-STT-25	VI04-0027	2004	2004	8	5.4	5.7	5.5
VI-STT-28	STT-24	1999	2019	98	5.3	10.1	6.8
VI-STT-28	STT-24A	2002	2003	8	6.3	7.6	7.0

Table 1-6. Summary of available Temperature (degrees C) data by station

Assessment Unit	Station ID	Start Year	End Year	Count	Min	Max	Mean
VI-STT-35	STT-26B	1999	1999	2	27.5	29.9	28.7
VI-STT-35	STT-27A	1999	2019	125	24.5	33.0	28.8
VI-STT-35	STT-27B	2000	2019	134	24.6	33.4	29.1
VI-STT-35	STT-27C	1999	2019	136	24.9	33.5	29.2

Table 1-7. Summary of available Total Nitrogen (mg/L) data by station

Assessment Unit	Station ID	Start Year	End Year	Count	Min	Max	Mean
VI-STT-25	STT-23	2018	2019	7	0.25	0.41	0.35
VI-STT-28	STT-24	2018	2019	7	0.22	0.38	0.28
VI-STT-31	STT-25	2018	2019	7	0.2	0.37	0.28
VI-STT-31	STT-26	2018	2019	7	0.19	0.3	0.25
VI-STT-35	STT-27A	2018	2019	9	0.21	0.43	0.28
VI-STT-35	STT-27B	2018	2019	7	0.27	0.39	0.32
VI-STT-35	STT-27C	2018	2019	7	0.3	0.46	0.40
VI-STT-34	STT-27D	2018	2019	7	0.26	0.32	0.29
VI-STT-33	STT-27E	2018	2019	7	0.21	0.51	0.29

Table 1-8. Summary of available Total Phosphorous (mg/L) data by station

Assessment Unit	Station ID	Start Year	End Year	Count	Min	Max	Mean
VI-STT-25	STT-23	2013	2019	23	0.002	0.028	0.240
VI-STT-28	STT-24	2013	2019	24	0.002	0.017	0.044
VI-STT-31	STT-25	2013	2019	24	0.003	0.017	0.043
VI-STT-31	STT-26	2013	2019	24	0.003	0.037	0.500
VI-STT-35	STT-27A	2013	2019	27	0.002	0.020	0.074
VI-STT-35	STT-27B	2013	2019	24	0.004	0.022	0.043
VI-STT-35	STT-27C	2013	2019	28	0.004	0.028	0.075
VI-STT-34	STT-27D	2013	2019	24	0.003	0.025	0.059
VI-STT-33	STT-27E	2013	2019	25	0.005	0.021	0.045
VI04-0018	VI04-0018	2004	2004	3	0.009	0.009	0.009
VI04-0027	VI04-0027	2004	2004	3	0.008	0.008	0.008

1.1.1.1 Turbidity

Turbidity represents an expression of water clarity as it describes light penetration of water. High turbidity in streams typically comes from streambank erosion and suspended sediment, transporting pollutants such as nutrients and bacteria, that washes into drainages during storms. In a receiving water, turbidity can also be caused by algae in the water column, re-suspension of settled material during boat activity, recreational activities, or storm events. Stream and coastal water turbidity can often be improved by controlling stormwater runoff and by adding or maintaining vegetation on stream banks and shorelines. Turbidity impairments caused by algal biomass can be controlled by reducing runoff and sedimentation (which carries nutrients) and reducing other nutrient sources (i.e., vessel waste discharge, permitted facilities).

High turbidity in the watershed above East End St. Thomas likely comes from stormwater runoff from a variety of large, active sources, including a landfill, resorts, housing developments, various commercial and small-scale industrial activities, an EPA Superfund Site, and a horse racetrack—all of these sources are potentially contributing to sedimentation. Pollutants such as nutrients and bacteria can also be transported with the suspended sediments. In a receiving water, turbidity can also be caused resuspension of settled, fine sediments during storm events and algal blooms triggered or enhanced by delivery of nutrients to waterbodies. Stream and coastal waters turbidity can often be improved by controlling stormwater runoff and by adding or maintaining vegetation on stream banks and shorelines. Turbidity impairments in STEER are likely driven by stormwater runoff from public housing projects, landfill runoff and runoff from impervious surfaces including roads, homes and boatyards and marinas.

Two STEER assessment units (Mangrove Lagoon (VI-STT-35) and Benner Bay Lagoon Marina (VI-STT-34)) had turbidity impairments delisted in 2014 because the original listing was incorrect based on exemptions in the WQS for these waters.

In Great Bay, the one available monitoring station (STT-23) has turbidity data for the period from 1999 to 2019, with a total of 139 observations over that time period. Of the 139 samples, six exceeded the standard of 3 NTU, with a maximum value of 6.4 NTU occurring on November 12, 2014. Two samples collected reported negative values and were removed. The average NTU for the 133 samples that are below the standard is 0.6 NTU.

In Nazareth Bay, four stations have a total 261 turbidity samples during the period from 1999 to 2019. Two of these stations (STT-25B and STT-26A) have only collected 2 and 7 samples, respectively. None of the samples from these two stations have exceeded the 3 NTU standard. Two other stations (STT-25 and STT-26) have collected 131 and 121 samples, respectively. No data from station STT-25 exceeded the 3 NTU standard. Of the 121 samples collected at STT-26, seven exceeded the turbidity standard, and a maximum value of 12.6 NTU was observed on October 12, 2000. Two pairs of samples collected in 2001 and 2003 both exceeded 3 NTU but appear to be replicate samples. The average for the samples that did not exceed the standard was 0.58 NTU.

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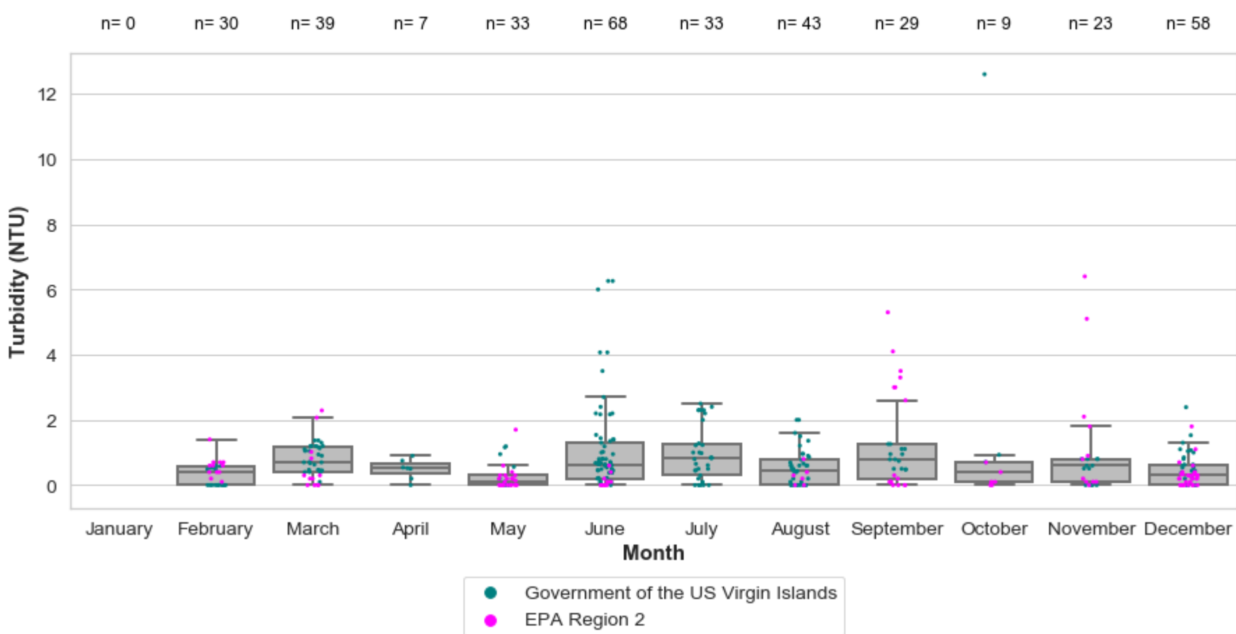

Figure 1-4. Monthly summary statistics describing observed Turbidity (NTU) for STEER waterbodies.

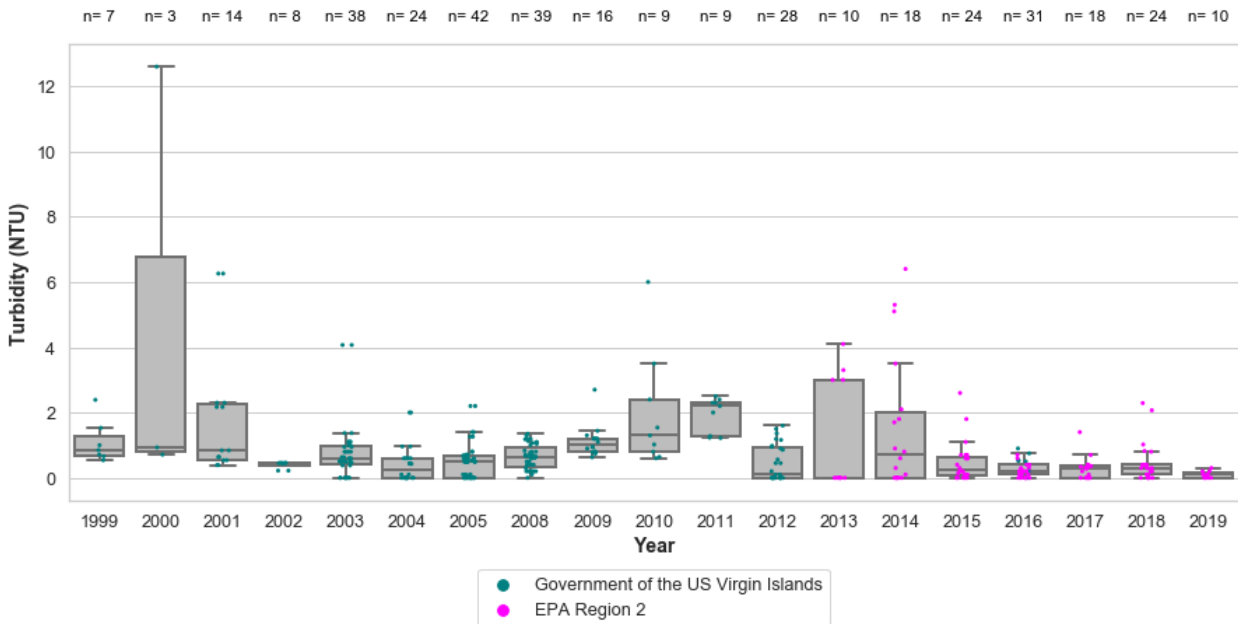

Figure 1-5. Annual summary statistics describing observed Turbidity (NTU) for STEER waterbodies.

1.1.1.2 Enterococcus Bacteria

Enterococci bacteria are found in the intestinal tracts and feces of warm-blooded animals, including humans. High counts of these bacteria indicate the presence of fecal contamination in water. Potential enterococcus sources include direct deposition of animal feces from livestock, pets, and wildlife into a waterbody; rural runoff polluted by fecal matter from livestock, pets, and wildlife; direct discharge of untreated sewage from vessels; urban runoff polluted by fecal matter from pets, stray animals, wildlife, and garbage that has not been disposed of properly; failing or poorly installed/maintained septic systems; straight pipes that deposit sewage directly in the waterbody; sewage spills; and permitted discharges. In addition, research has found that enterococcus bacteria can colonize soils and bottom sediments and be available to water column when these sediments are disturbed/re-suspended (Badgley et.al., 2011). However, the most controllable sources through implementation activities (that also reduce other pollutants) remain nonpoint source runoff, septic systems, and direct discharge of vessel waste to receiving waters. In STEER, two assessment units are listed as impaired by pathogens, including Benner Bay (enterococcus) and Mangrove Lagoon (enterococcus).

There are four stations in Benner Bay (VI-STT-34) and Mangrove Lagoon (VI-STT-35) that have collected enterococcus data for the period from 2002 through 2019 (one station in Benner Bay and three in Mangrove Lagoon). In Benner Bay, a total of 58 samples were collected, with four samples (collected in 2008, 2009, and 2016) exceeding the single sample standard of 110 MPN/100mL. Insufficient data are available to calculate and compare to the 30-day geometric mean standard. The maximum value observed at this station was 1,379 MPN/100mL on October 11, 2016. There was a total of 20 samples collected in the last five years. Two of these samples exceeded the single sample standard.

In Mangrove Lagoon, three stations collected enterococcus data for the period from 2002 through 2019—a total of 167 samples were collected at the three stations. There were 10 exceedances of the 110 MPN/100mL single sample standard. A maximum value of 1,670 MPN/100mL was observed on October 11, 2016. Insufficient data are available to calculate the geometric mean for comparison to the standard. There was a total of 64 samples collected in the last five years. Eight of these samples exceeded the single sample standard.

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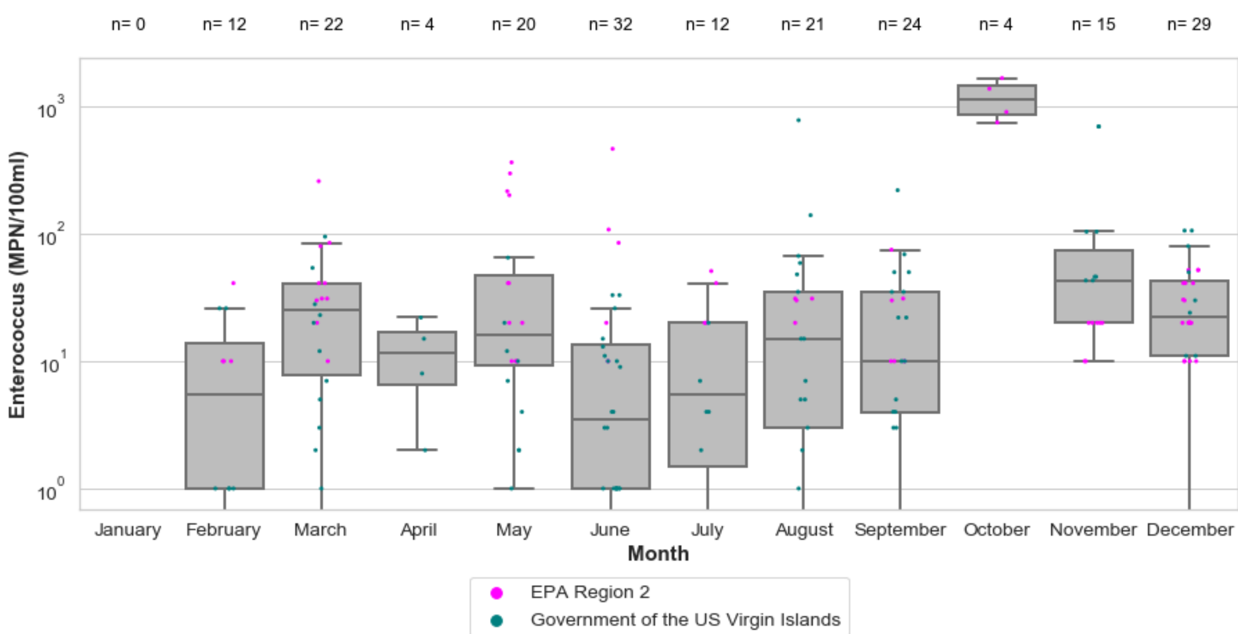

Figure 1-6. Monthly summary statistics describing observed Enterococcus for STEER waterbodies.

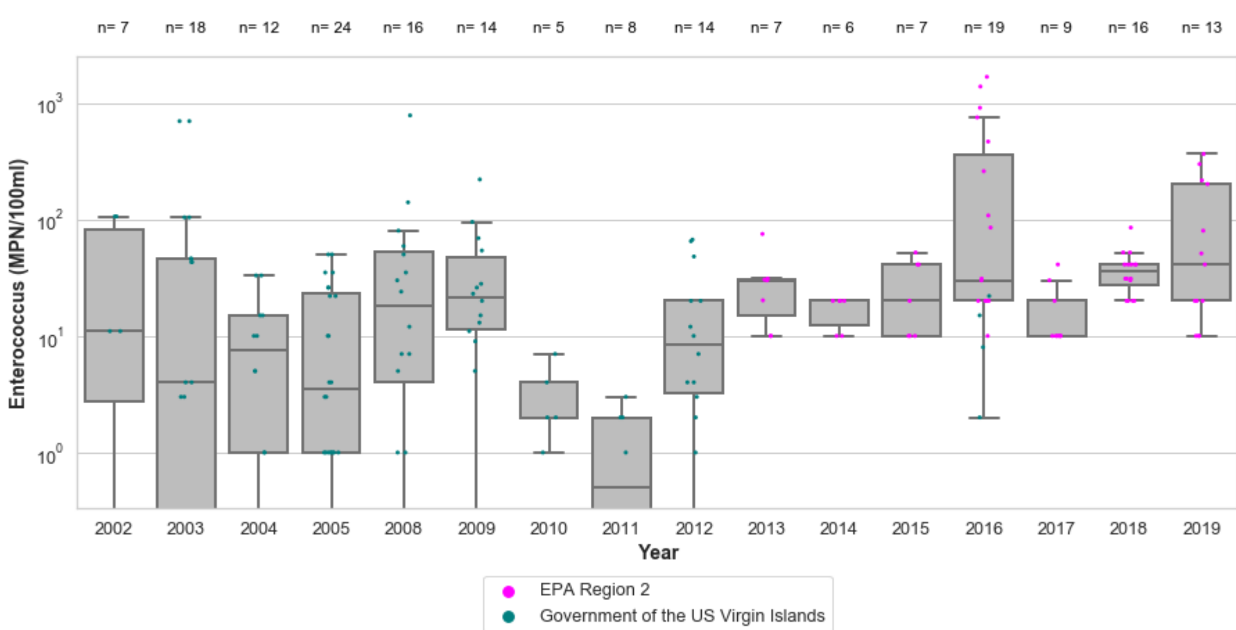

Figure 1-7. Annual summary statistics describing observed Enterococcus for STEER waterbodies.

1.1.1.3 Dissolved Oxygen

Dissolved oxygen (DO) concentrations reflect an equilibrium between oxygen-producing processes (e.g. photosynthesis) and oxygen-consuming processes (e.g. aerobic respiration, nitrification, chemical oxidation) and the rates at which DO is added to and removed from the system by atmospheric exchange and hydrodynamic processes (Connell and Miller, 1984). DO levels are correlated with salinity and water temperature as well as plant and algal biomass. DO concentrations vary diurnally due to photosynthesis during the daytime and respiration at night and highly productive estuarine systems usually have the highest diurnal swings. DO concentrations and diurnal ranges are greatly impacted by nutrient enrichment that stimulates plant and algal growth along with an associated settling of particulate organic matter to the sediments. The decomposition of this organic matter can lead to a rapid acceleration of oxygen consumption, and potential depletion of oxygen in bottom waters. Sources of nutrients include wastewater treatment plants, septic systems, and a wide variety of nonpoint sources.

In STEER, there are two assessment units listed as impaired due to low DO, including Great Bay (VI-STT-25) and Cowpet Bay (VI-STT-28). There are a total of 216 DO observations at four stations that collected data from 1999 to 2019. Two of the stations (STT-23 in Great Bay and STT-24 in Cowpet Bay) account for 200 of the observations. Of the 216 observations, there were 15 that were lower than the 5.5 mg/L standard for DO with a minimum value of 4.22 mg/L. Looking at data from 2015 to 2019 (most recent five years of data) shows a maximum value of 8.39 mg/L and a minimum of 5.76 mg/L with no exceedances at any of the monitoring locations.

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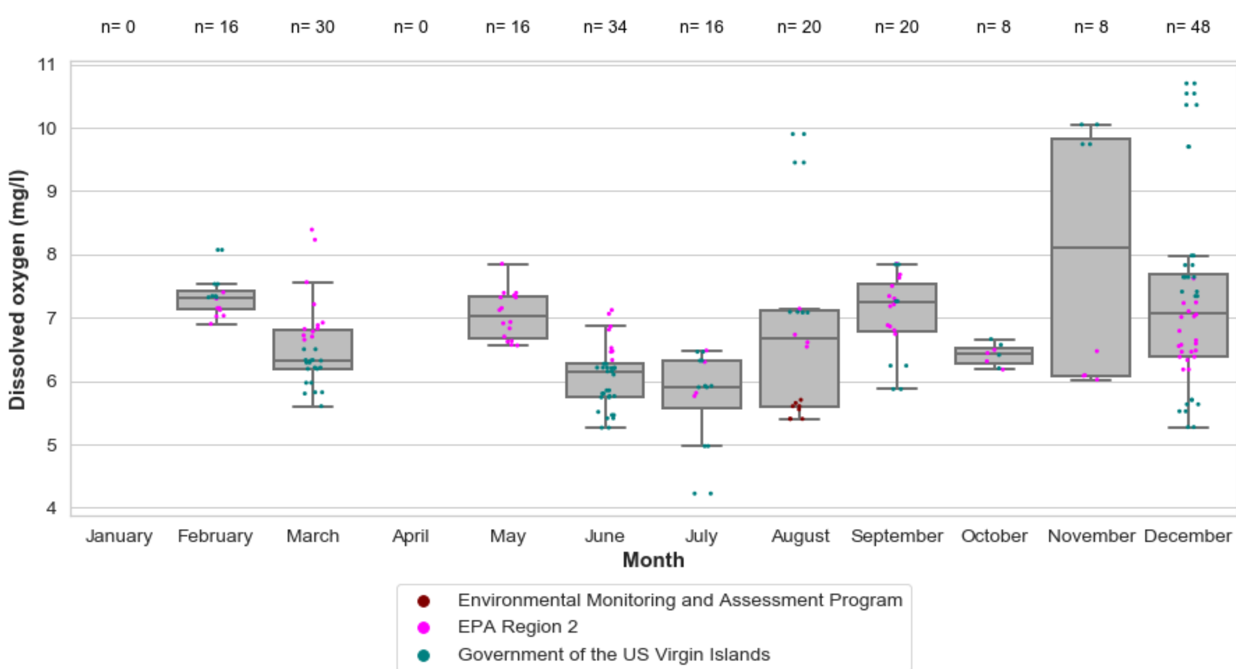

Figure 1-8. Monthly summary statistics describing observed dissolved oxygen for STEER waterbodies.

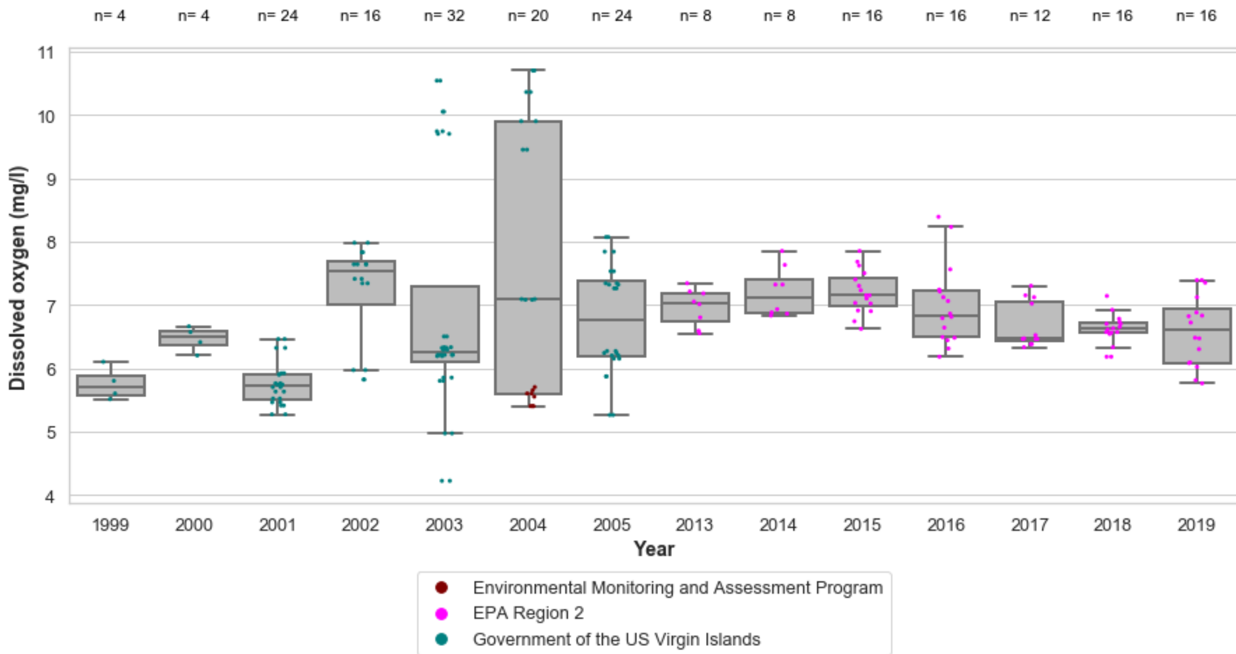

Figure 1-9. Annual summary statistics describing observed dissolved oxygen for STEER waterbodies.

1.1.1.4 Total Nitrogen

At the time of this report, none of the STEER waterbodies were specifically listed as impaired for total nitrogen (TN) on the 2020 303(d) list as the WQS were newly established. Sources of nutrients include wastewater treatment plants, septic systems, and a wide variety of nonpoint sources. There are a total of 65 TN observations at nine stations that collected data since 2018 (Table 1-7. Summary of available Total Nitrogen (mg/L) data by station). While the available data for TN only spans two years, the mean concentration across all nine stations is above the WQS of 0.207 mg/L. It's also worth noting that most of the minimum sample concentrations across all nine stations are also above the WQS. Figure 1-10 and Figure 1-11 summarize trends in observed TN concentrations for both long-term (annual) and seasonal (monthly) patterns using available monitoring data described previously.

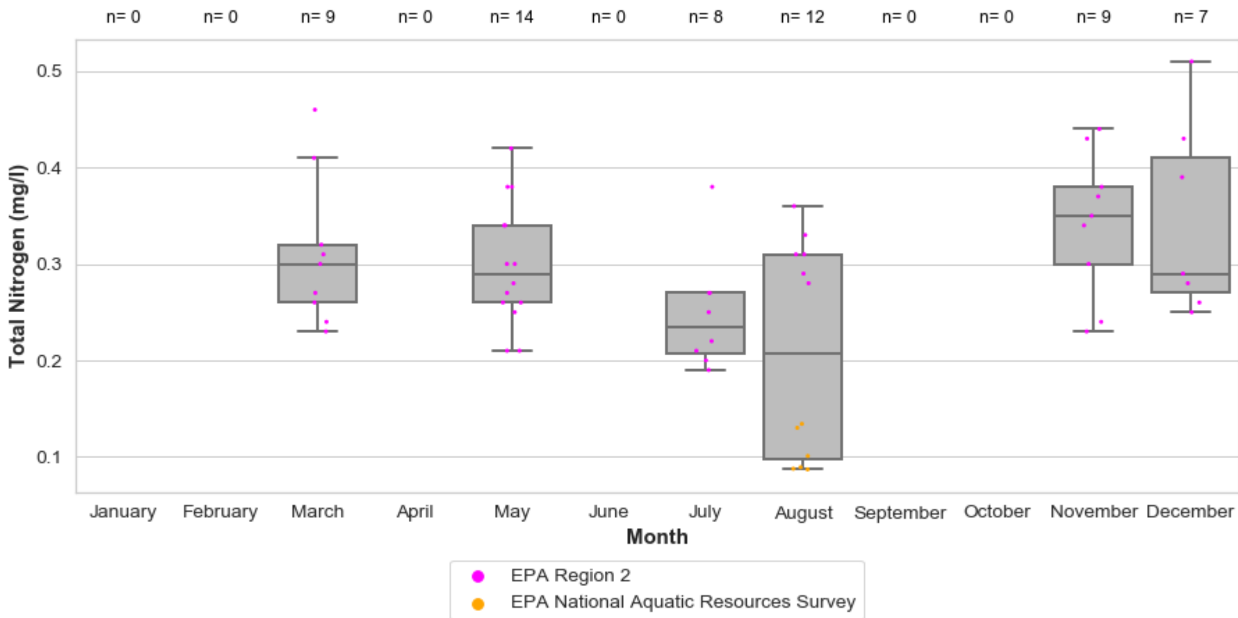

Figure 1-10. Monthly summary statistics describing observed total nitrogen for STEER waterbodies.

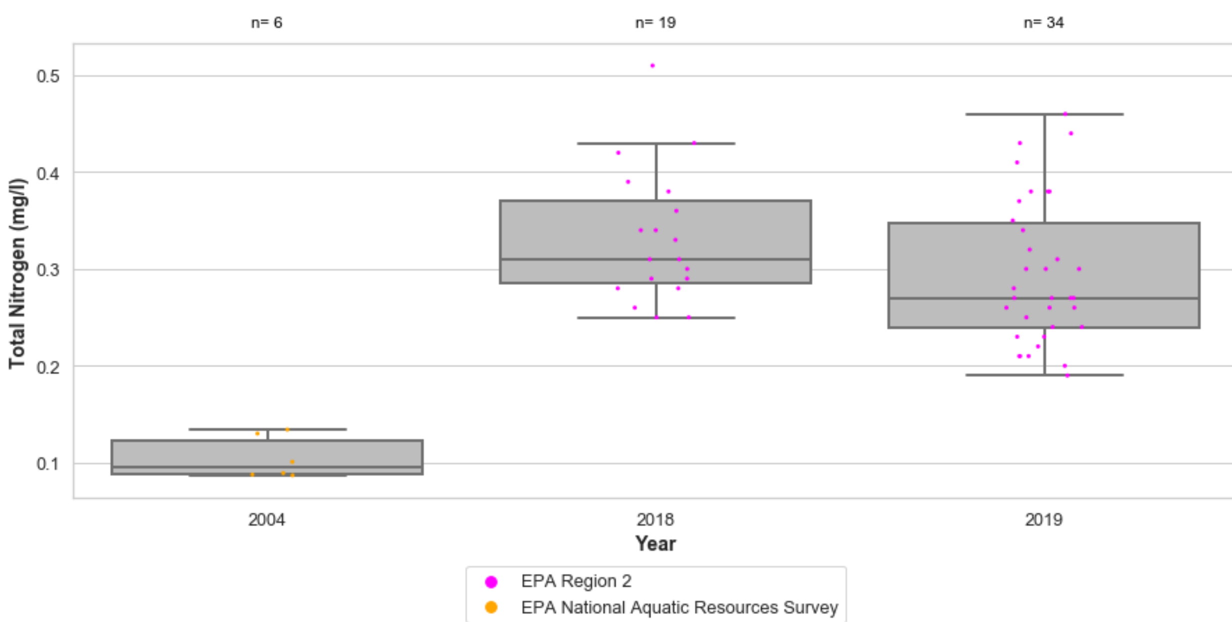

Figure 1-11. Annual summary statistics describing observed total nitrogen for STEER waterbodies.

1.1.1.5 Total Phosphorous

At the time of this report, none of the STEER waterbodies were specifically listed as impaired for total phosphorous (TP) on the 2020 303(d) list. Sources of nutrients include wastewater treatment plants, septic systems, and a wide variety of nonpoint sources. There are a total of 230 TP observations at eleven stations collected between 2013 and 2019 and some older sampling from EPA's National Aquatic Resource Survey in 2004 (Table 1-8). Only eight samples in the data set exceeded the water quality standard of 0.05 mg/L (see Section 2). For several of those samples, field notes indicate heavy rain one week prior to the sampling event suggesting that non-point source runoff may have led to the exceedances. Figure 1-12 and Figure 1-13 summarize trends in observed TP concentrations for both long-term (annual) and seasonal (monthly) patterns using available monitoring data described previously.

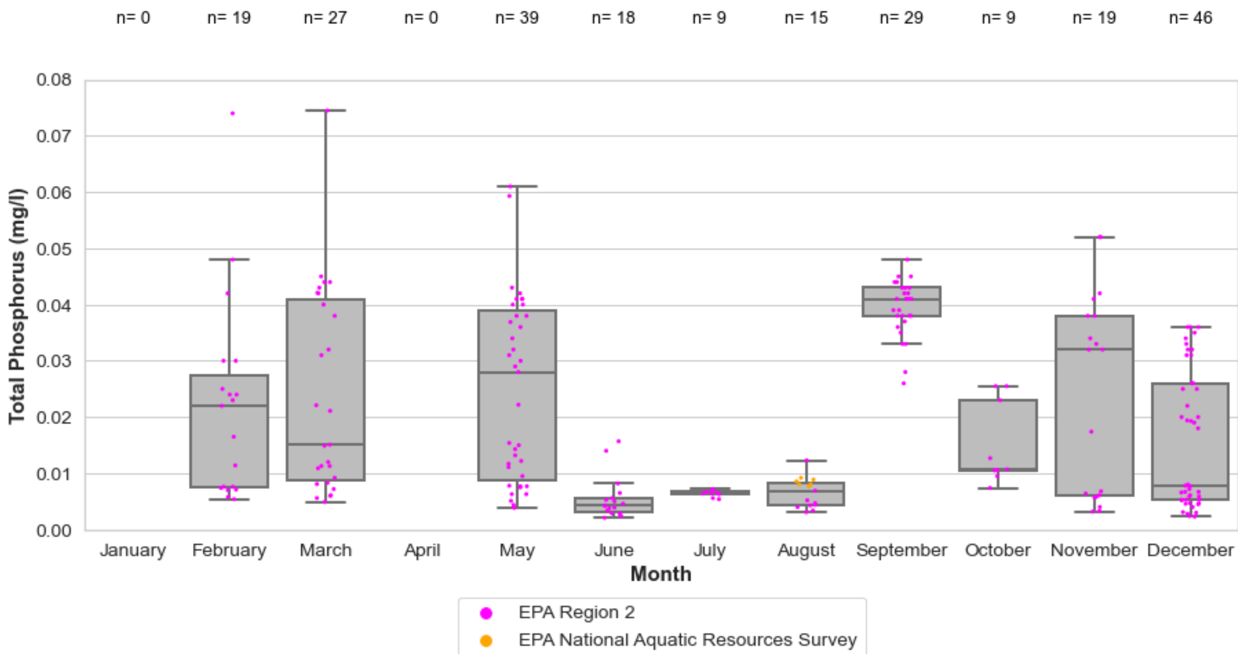

Figure 1-12. Monthly summary statistics describing observed total phosphorous for STEER waterbodies.

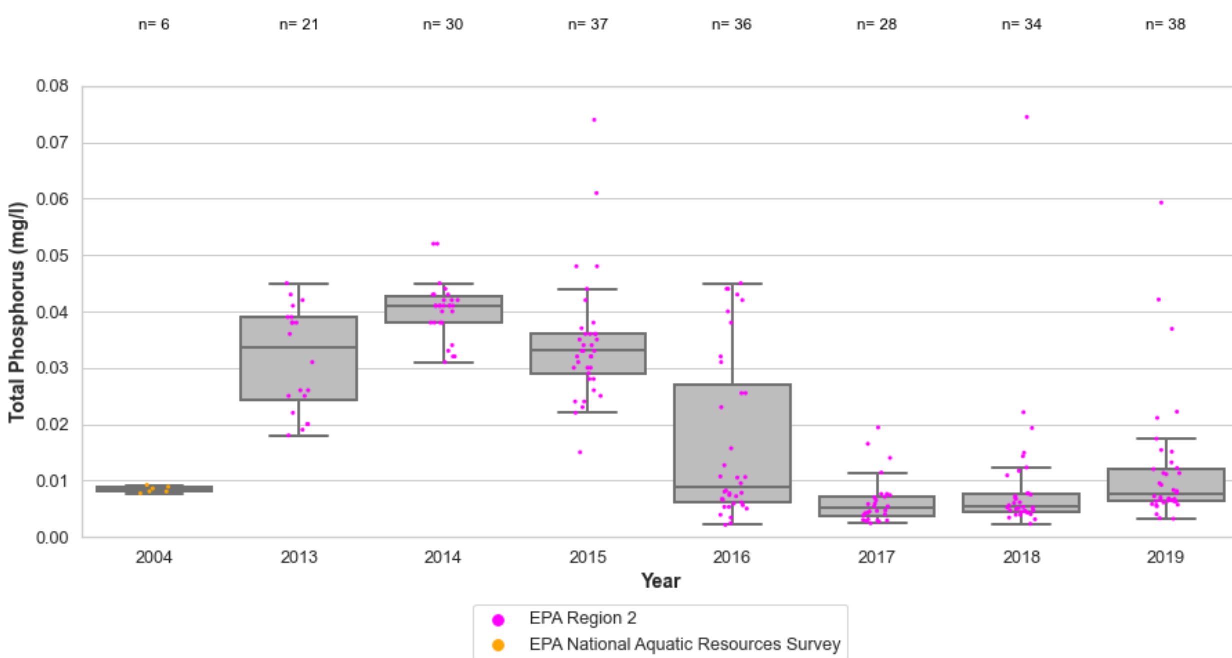

Figure 1-13. Annual summary statistics describing observed total phosphorous for STEER waterbodies.

1.2 Pollutants of Concern

Pollutants of concern can be discerned based on the impairments listed in Table 1-1. The pollutants of concern by waterbody are described as:

- Great Bay (STT-25): Enterococcus bacteria
- Cowpet Bay (STT-28): Total Suspended Solids (TSS); Biological Oxygen Demand (BOD); TP; and Enterococcus bacteria.
- Nazareth Bay (STT-31): TSS; Total Nitrogen (TN); and Enterococcus Bacteria.
- Benner Bay (STT-33): TN; and Enterococcus Bacteria.
- Benner Bay Lagoon Marina (STT-34): TSS; BOD; TN: and Enterococcus Bacteria
- Mangrove Lagoon (STT-35): TSS; TN; and Enterococcus Bacteria

An explanation and analytical basis for expressing the TMDL through surrogate measures is applicable for TSS and BOD and further explained in Section 1.5.

1.3 Pollutant Sources

This section summarizes the potential sources for each of the pollutants of concern. Presented in this section are information on types of pollutant sources, when they are most active (i.e., only during rainfall events); their magnitude relative to other sources, and how much is known about the source and the ability to characterize their loading to receiving waters. This information will inform the calculation of existing loading of the pollutants and the reductions needed from the sources to attain or maintain WQS. This TMDL effort is also contributing to a new EPA program vision that is focused on the development of TMDLs that leverage other programs and can lead to more rapid and successful implementation of actions that improves water quality. To further support this new vision, this effort included a comprehensive review of previous relevant studies with a focus on using the best of what's already been done; conducting detailed reconnaissance visits to each of the islands impaired watersheds to meet with federal, territorial, and other local contacts to develop a better understanding of the issues, obstacles or impediments to implementation and to ensure local practitioner viewpoints were considered; and to develop an understanding of implementation activities that are already occurring and their success (adoption and efficacy). A summary of the trips and key findings is included as Appendix A.

Detailed information on STEER can be found in the Watershed Characterization Report and Watershed Management Plan developed by the Horsley Witten Group (2013a and 2013b)—these reports provide a detailed description of these watersheds and information from these reports has been summarized for inclusion in this TMDL document. The reader of this TMDL is encouraged to refer to these documents for a more complete characterization of STEER watersheds.

The following information on sources is organized by point sources, where a Territorial Pollutant Discharge Elimination System (TPDES) permitted facility discharges to one of the assessment units and nonpoint sources, which includes runoff and other direct discharges not regulated by a permit.

1.3.1 Point Sources

The facilities/dischargers included in Table 1-9. Summary of active TPDES facilities permitted to discharge to STEER have an active TPDES permit that contains provisions allowing them to discharge a pollutant of concern to STEER and requiring them to conduct monitoring of the pollutants. The permitted point source permits represent some of the older established housing developments from the 1970's, larger resorts, and marinas where most of the boat maintenance and repair are conducted for the islands of St. Thomas and St. John. These facilities are primarily non-POTWs owned and operated by private resorts or residential communities. The Mangrove Lagoon POTW is the one publicly-owned facility which was updated in the early 2000s. Effluent from these facilities is primarily treated household wastewater making bacteria, BOD, and nutrients the primary constituents of concern. Major issues with point source discharge are older pipes, leaking manholes, bad joints, and flow volume relative to design maximums during rain events and high groundwater scenarios.

Table 1-9. Summary of active TPDES facilities permitted to discharge to STEER

Assessment Unit	NPDES ID	Facility Name	Permit Issued	Permit Expired	Discharged Pollutants
Great Bay (STT-25)	VI0040479	Ritz Carlton Hotel	6/1/2019	5/31/2024	BOD-5, TP, Enterococci, TSS, Flow
	VI0040517	Anchorage Condominiums	10/1/2015	9/30/2020	BOD-5, TP, Enterococci, TSS, Flow
	VI0040606	Water Point Estates	11/1/2016	10/31/2021	TSS, Flow
Cowpet Bay (STT-28)	VI0039853	Cowpet Bay West Condominiums	5/1/2016	4/30/2021	BOD-5, TSS. Flow
	VI0039900	Cowpet Bay East Condominiums	3/1/2021	2/28/2026	BOD-5, TP, TN, TSS, Flow, Enterococci,
	VI0040321	Elysain Beach Resort	11/1/2016	10/31/2021	BOD-5, TP, Enterococci, TSS, Flow
Nazareth Bay (STT-31)	VI0040398	Secret Harbor Beach Owners Association	12/1/2016	11/30/2021	BOD-5, TP, Enterococci TSS, Flow
	VI0080021	Dvergsten Company, Inc.	4/1/2019	3/31/2024	TSS, Flow
Benner Bay Lagoon Marina (STT-34)	VI0000716	SVB 155 Spring, LLC	8/1/2016	7/31/2021	TSS, Flow
	VI0040193	Point Pleasant Resort	8/1/2015	7/31/2020	BOD-5, Enterococci, TSS, Flow
	VI0040401	Compass Point Marina Inc.	5/1/2016	4/30/2021	BOD-5, Enterococci, TSS, Flow
Mangrove Lagoon (STT-35)	VI0002003	Mangrove Lagoon	5/1/2015	4/30/2020	BOD-5, TP, Enterococci, TSS, Flow
	VI0031114	Virgin Islands Housing Authority	6/1/2014	5/31/2019	TSS, Flow
	VI0040746	Market Square East	3/1/2019	2/28/2024	BOD-5, Enterococci, TSS, Flow

Vessel and live-aboard populations while generally smaller than land-based population estimates derived through the 2010 Census present an opportunity for direct loading of bacteria, nutrients, and BOD to local waterbodies through illicit discharges of onboard wastewater. Most waterbodies in the STEER watershed have vessels and live-aboard vessels present at least some parts of the year, with Benner Bay Lagoon Marina and Cowpet Bay have the most out the water-bodies presented in this document. Discharge from vessels and live-aboard vessels that are equipped with installed toilets and operating on U.S. navigable waters are consider unpermitted point sources, and must be treated with U.S. Coast Guard-certified marine sanitation devices (MSDs) onboard vessels, according to Section 312 of the Clean Water Act . Both Benner Bay Lagoon Marina and Cowpet are known to have regular live-aboard vessels year around. Benner Bay Lagoon Marina has an estimated 350 vessels (total length greater than 25 feet are anchored or at dock within Benner Bay) based on numerical estimates from GIS imagery from 2016 and conversations with live aboard vessel owners. While most of these vessels likely discharge sewage directly into the bay, estimates from the community suggest that roughly 10-20% of these vessels (35-70 boats) could be considered full time live-aboards (see Section 3.1.4). Cowpet Bay is the location of the St. Thomas Yacht Club, which has a small fleet of vessels offshore. While Cowpet Bay has an estimated 70-80 small vessels anchored within the bay, the majority of these are not live-aboards.

1.3.2 Nonpoint Sources

Nonpoint sources (NPS) of pollution in a watershed typically include rainfall-driven pollutant delivery from uplands and watercourses, known locally as ghuts. The term ‘ghut’ may be derived from a combination of the word ‘gutter’ and the Indian word ‘ghaut’ which has several meanings, including a pass through a mountain, stairs descending to a river, and the ford of a river. The Indian meanings for ghaut would aptly describe many ghuts in the USVI, particularly on St. Thomas and St. John, which have more mountainous terrain.

Erosion and sedimentation is a significant concern in USVI watersheds due to the steep slopes and intense rainfall events. In the STEER watershed, where a high degree of urbanization has occurred (and continues), there has been an increase in impervious cover percent (~20% for the STEER watershed). Some watersheds (i.e., Cowpet Bay) have impervious percentages approaching 40% and the impact of this is less infiltration of stormwater, increased runoff volumes and velocities (resulting in increased erosive power), and increased transport of pollutants or impacts to receiving waters. For example, in the Mangrove Lagoon watershed, which is listed for temperature, the increase in runoff from impervious land could also be leading to an increase in water temperature. In addition to rainfall-runoff events that deliver sediments, nutrients, bacteria, and other pollutants to coastal waters, other NPS sources contribute to pollutant loading during dry- and wet-weather. For example, poorly functioning or over-burdened septic systems and other on-site disposal systems can contribute significant loadings of nutrients and bacteria and the loadings can occur in the presence or absence of a rainfall event. The USVI is also the home to numerous wild (and feral) and domestic animals that contribute to nutrient and bacterial loadings. In some cases, the loading could be directly to a receiving water and easily transported and in other cases, this waste is washed off during rain events.

The high level of development in STEER and the associated increase in impervious cover results in an increase in runoff and pollutant delivery. In addition to the pollutants listed as impairing STEER waters, a wide variety of other pollutants can also be associated with urban runoff, including metals, organics, trash, and oil and grease. Ghuts can also experience an increase in erosion and delivery of sediment and sediment associated pollutants. Based on review of other planning documents and research, sediment from dirt roads, farmlands, construction sites, urban areas, and other disturbed soils is the primary nonpoint source pollutant threatening the islands waters. Topography, rainfall intensity, land conversion/development, and lack of adequate stormwater infrastructure make urban runoff a significant threat to receiving waters. Throughout the USVI, the combination of steep topography, erodible soils, intense rainfall, and rapid development that has occurred in the watershed has led to a significant increase in sediment erosion and delivery from roads and development sites. The sediment erosion and delivery to receiving waters is widely acknowledged as the primary contributor to increased turbidity throughout USVI waters (~34% of the 2020 USVI 303(d) list are waters impaired by turbidity). Numerous studies and watershed planning efforts have been conducted throughout the USVI, including STEER, that analyze, measure, and predict erosion are in general agreement that anthropogenic changes to USVI watersheds has led to a significant increase in sediment delivery (MacDonald et. al., 1997; Jeffrey et. al., 2005; Anderson and MacDonald, 1998; Nemeth et al., 2001; Ramos-Scharrón and MacDonald, 2007; IRF, 2009). Analyses by in these studies indicated that erosion from areas disturbed by road construction accounts for the majority of sediment reaching receiving waters (85% in Fish Bay; IRF, 2009) and that sedimentation from unpaved roads can be 300-900% higher than in undisturbed areas (Rothenberger, et. al. 2008; Rogers, 2006). In addition to the contribution of sediment from these exposed areas, other pollutants can be carried to receiving waters adsorbed to, or along with sediment. In addition, the ghuts are often perceived as dumping sites and are likely the largest sources of urban runoff delivering sediment, contaminants, and bacteria. Within STEER, contributors include schools, public housing projects, the Quarry, Independent Boatyard and a number of smaller marinas, new construction sites for tourism industry, commercial parks (Tutu Park Mall, Cost –U Less), and Bovoni Landfill. Few storm water control measures are in place within St. Thomas and where existing controls are in place, required maintenance does not always keep pace with inputs.

During rainfall events, STEER receiving waters are impacted by significant loadings of sediment, nutrients, and other pollutants. Many of these pollutants settle out, are flushed from the system, or they are otherwise assimilated. For those pollutants that settle to the bottom, particularly in areas like Mangrove Lagoon, where flushing/circulation limits export of the pollutants out to the open ocean, the potential exists for resuspension into the water column from storms, boat activities, or other recreational activities. When re-suspended they can contribute to WQS exceedances for turbidity. They can also influence DO or related water quality impairments as an internal load to the system. Most management practices focus on watershed source control activities and rely on the assimilative capacity of the receiving water to reduce the impact of internal pollutant loads. Some areas of STEER are more at risk from impacts associated with internal pollutant loads, including protected areas with little flushing (i.e., marinas). These areas are also more likely to have active sources of the pollutants.

To the extent information is available to characterize each of the major NPS of pollutants of concern, a loading will be calculated and included with the overall watershed loading. The following summarizes specific information known about probable pollutant sources for each assessment unit in STEER.

1.3.2.1 Benner Bay (VI-STT-33)

Benner Bay was not listed for any impairments on the 2020 303(d) list; however, potential sources of pollutant load to Benner Bay discharges from the storm sewer system, erosion and sedimentation from construction sites, residential neighborhoods, and other excavation activities could be possible sources of future impairments.

1.3.2.2 Benner Bay Lagoon Marina (VI-STT-34)

Benner Bay Lagoon Marina is listed as impaired by enterococcus bacteria. Potential sources of enterococci to Benner Bay Lagoon Marina includes fecal matter from feral animals including goats, horses from the racetrack, and nesting birds within the nearby Mangrove Lagoon. In addition, discharges from the storm sewer system, failing septic tanks and the sewage infrastructure system are also likely major contributors to the impairment.

1.3.2.3 Mangrove Lagoon (VI-STT-35)

Mangrove Lagoon is listed as impaired by temperature and enterococcus bacteria. Sources of bacteria are likely the same as identified for Benner Bay. Temperature increase is likely a combination of increased sea surface temperature, a long period of drought in USVI (inputs from freshwater decrease marine water temperature and increase flushing) and reduced flushing and movement of water within Mangrove Lagoon due to increased sedimentation and infilling of bay from land-based sources.

1.3.2.4 Great Bay (VI-STT-25)

Great Bay is listed as impaired by DO and turbidity. Due to exposure to both the south and north swell, Great Bay does not have a consistent liveaboard community, with a few boats visiting the bay periodically but no long-term live-aboards. Other possible explanations for the increased turbidity could be the loss of seagrass habitat that causes resuspension of fine sediment in water column. These resuspended particles could also contribute to the DO impairment.

1.3.2.5 Cowpet Bay (VI-STT-28)

Cowpet Bay is listed as impaired by DO. Several older resorts (Elysian Beach Club, St Thomas Yacht Club) and a network of residential homes contribute to wastewater loads of aging small capacity treatment systems. A network of more than 100 vacation rentals line Cowpet Bay. For many of these, septic systems designed for single family homes have been converted and modified to accommodate 10-15 people per unit, placing strain and over-burdening the systems.

1.3.2.6 Nazareth Bay (VI-STT-31)

Nazareth Bay is listed as impaired by turbidity. This is a relatively steep watershed with high erosion potential. Estate Nazareth has Secret Harbor resort, a number of small single-family homes for rental, and storm water runoff from the commercial center of Red Hook, the second largest town on St. Thomas. Erosion and sedimentation from construction sites, residential neighborhoods, and other excavation activities is believed to be the primary source leading to the impairment.

1.4 Priority Ranking

Table 1-10 summarizes the priority rankings for the establishment of TMDLs for the pollutants listed on the 2020 Section 303(d) list. There were no high priority waters included in this TMDL—all waterbodies and pollutants were addressed.

Table 1-10. Summary of 2020 303(d) Priority Ranking for STEER Assessment Units

Assessment Unit	AU Number	Pollutant	Priority
Great Bay	VI-STT-25	Enterococcus	High
Cowpet Bat	VI-STT-28	Enterococcus	High
Nazareth Bay	VI-STT-31	Enterococcus	High
Benner Bay	VI-STT-34	Enterococcus	High
Benner Bay	VI-STT-34	Turbidity	High
Mangrove Lagoon	VI-STT-35	Enterococcus	High
Mangrove Lagoon	VI-STT-35	Turbidity	High

1.5 Expressing the TMDL through Surrogate Measures

Surrogate measures are used for TMDL allocations when the direct pollutant does not have a quantifiable loading basis or is either too expensive or too difficult to measure. There will also be a correlation between the surrogate and the direct measure for which it characterizes. Surrogate measures are either indirect pollutant targets (e.g., measuring total suspended solids [TSS] as an indication of turbidity) or "other appropriate measures" (e.g. an effective shade target to shade and cool a stream). Surrogate measures are also used to set a target for implementation activities, such as how much stream shade is needed to reduce solar radiation that heats rivers. When a waterbody is listed for Turbidity, TSS concentrations are used as the surrogate pollutant, when listed for DO, BOD is a surrogate and when listed for pH, nutrients are surrogates. Processes involved in the pairing of surrogates to target pollutants is depicted in Figure 1-. For the STEER TMDL analysis, surrogate measures are used to address the impairments for turbidity, DO, temperature, and enterococcus.

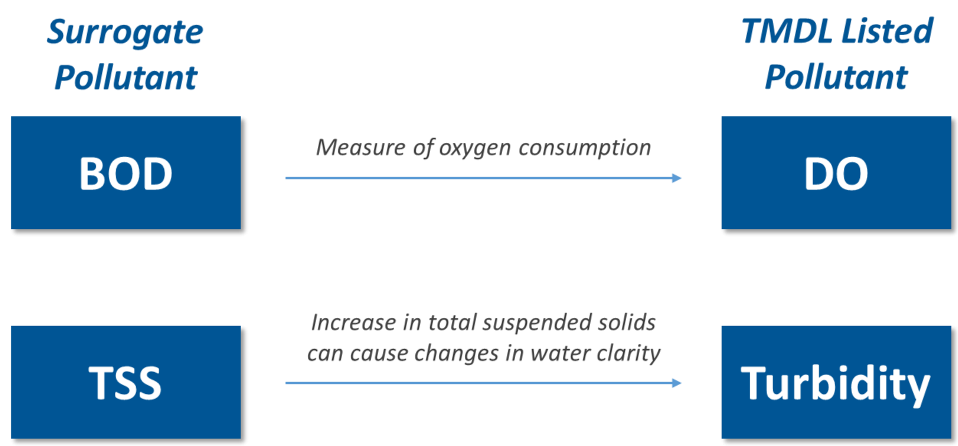

Figure 1-14. Linkages between surrogates and target pollutants and their corresponding processes

1.5.1 Turbidity

High turbidity may be the result of increased suspended soil or sediment particles, phytoplankton growth, and dissolved substances in the water column. Because turbidity is an optical measurement of light scatter and adsorption, a concentration-based turbidity surrogate is needed to develop the load estimates required for TMDLs. For the STEER turbidity TMDLs, total suspended solids (TSS), which measures the amount of sediment and organic matter suspended in water will be used as the surrogate for turbidity associated with watershed runoff. There are also turbidity data showing values that exceed the standard during dry periods.

1.5.2 Dissolved Oxygen

Low DO is addressed by establishing TMDLs that reduce BOD5 and. As BOD5 oxidize, they use up the available DO. If enough BOD5 is present in a waterbody, they can cause DO to fall below the applicable water quality standard. Therefore, by establishing TMDLs to reduce BOD5, compliance with the applicable DO standard may be achieved. BOD5 data in nearby unimpaired assessment units was assessed to derive a natural background concentration. Much of the sampling data constituted non-detects where the detection limit is 2 mg/L for analytical method APHA~5210-B assessing 5-day biochemical oxygen demand. The non-detect samples were set at half the detection limit (i.e., 1 mg/L) and the median of all the unimpaired sampling data was taken to derive a target of 1.5 mg/L. This value was also used as a background concentration value in the Salt River Dissolved Oxygen TMDL (USEPA, 2004).

2 DESCRIPTION OF THE APPLICABLE WATER QUALITY STANDARDS AND NUMERIC WATER QUALITY CRITERIA

The STEER assessment units are classified as "Class B" Marine and Coastal Waters. Designated uses for Class B Marine and Coastal Waters as defined by the Water Quality Standards (WQS) for Waters of the Virgin Islands (DPNR, 2020):

> *Maintenance and propagation of desirable species of wildlife and aquatic life (including threatened or endangered species), primary contact recreation, and for use*

as potable water sources for those waters being used currently or that could be used in the future as potable water sources.

Observed data for turbidity, enterococcus, DO, and temperature presented in Section 1 can be compared against specific numeric criteria established to support the designated uses for this class of coastal waters. The list of WQS applicable to Class B Marine and Coastal waters is presented below as Table 2-1. The water quality targets for the determination of the TMDL addressing turbidity, enterococcus, DO, and temperature impairments for STEER are based on the applicable WQS listed in Table 2-1.

Table 2-1. USVI water quality standards for 303(d) listed constituents in project watersheds

Constituent	Criteria	Units	Condition(s)
Enterococci	30	MPN/100mL	Geomean (30-day)
	110	MPN/100mL	single sample
Dissolved Oxygen	5.5	mg/L	single sample
Turbidity	3	NTU	maximum
	1	NTU	maximum; for coral reef ecosystems
Total Nitrogen	0.207	mg/L	in more than 10% of samples over 3-year period
Total Phosphorous	0.05	mg/L	single sample

3 LOADING CAPACITY – LINKING WATER QUALITY AND POLLUTANT SOURCES

A TMDL establishes the allowable load of a pollutant or other quantifiable parameter based on the relationship between pollutant sources and instream water quality. This document provides the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources and to restore and maintain the quality of the state's water resources (USEPA, 1991).

3.1 Loading Capacity

An important first step in the development of a TMDL is the calculation of the loading capacity for impaired waters identified on the 303(d) list. The loading capacity is defined as the greatest amount of loading that a water can receive without violating WQS. The loading capacity ultimately provides a reference point that informs the pollutant reduction efforts needed to comply with WQS. The loading capacity must consider the WQS for the USVI waters for each pollutant listed and, where a listed pollutant is not quantifiable as a source (i.e., temperature), utilize a surrogate measure. The remainder of this section outlines the approach utilized to calculate the loading capacities for each pollutant included on the 303(d) list (or its surrogate).

3.1.1 Watershed Model

Simulation of upland loading and transport of sediment and nutrients was conducted to develop estimates of the relative contribution of pollutants by source, ultimately supporting developing land-based mitigation strategies. Three previous modeling efforts were reviewed and referenced for this study:

1. DO TMDL for Salt River Bay, St. Croix (Tetra Tech, 2004). Continuous-simulation modeling using the LSPC watershed model.
2. Watershed Characterization and Planning for Pathogen Source Reduction in the USVI (Cadmus, 2011). Continuous-simulation modeling using the System for Urban Stormwater Treatment and Analysis INtegration (SUSTAIN).
3. St. Croix East End Watersheds Management Plan (Horsley Witten Group, 2011). Planning-level spreadsheet modeling using the Watershed Treatment Model (WTM).

The first two studies are process-based continuous simulation approaches that are capable of providing predicted flow and loading for a wide range of conditions that vary over space and time. Findings from those two studies provided directly-applicable reference material for parameterizing and calibrating parameters associated with hydrologic and water quality processes. The third modelling study provided locally-derived model coefficients and long-term estimated source loads for benchmark comparison of simulated model results.

The hydrologic and water quality model applied for this TMDL was the Loading Simulation Program in C++ (LSPC), a watershed modeling system that includes Hydrologic Simulation Program–FORTRAN (HSPF) algorithms for simulating watershed hydrology, erosion, water quality processes, and in-stream fate and transport processes. A full discussion of the watershed model development process is presented in Appendix D.

Annual average estimates of current condition loads are presented by model subwatershed in **Error! Reference source not found.** through **Error! Reference source not found.** and by relative source in Figure 3-1.

Table 3-1. Estimate of monthly average watershed loads for Great Bay (VI-STT-25) from 10/1/2009 through 9/30/2019

Constituent	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow	L/day	4.70	30.40	13.90	5.90	26.20	8.60	17.90	28.90	37.30	19.00	48.10	19.60
TSS	kg/day	0.37	4.05	1.83	0.68	3.67	1.13	2.52	4.11	5.22	2.56	6.67	2.43
BOD5	kg/day	0.02	0.26	0.11	0.04	0.23	0.07	0.16	0.26	0.33	0.16	0.42	0.16
Total Nitrogen	kg/day	0.01	0.09	0.04	0.02	0.07	0.03	0.05	0.08	0.11	0.05	0.14	0.06
Total Phosphorus	kg/day	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.01
Enterococcus	Billion MPN/day	0.24	2.65	1.17	0.43	2.37	0.72	1.62	2.65	3.39	1.64	4.32	1.58

Table 3-2. Estimate of monthly average watershed loads for Cowpet Bay (VI-STT-28) from 10/1/2009 through 9/30/2019

Constituent	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow	L/day	2.9	18.3	8.3	3.5	15.7	5.1	10.7	17.2	22.4	11.4	28.7	11.8
TSS	kg/day	0.224	2.449	1.093	0.403	2.195	0.671	1.503	2.458	3.137	1.529	3.995	1.462
BOD5	kg/day	0.014	0.159	0.068	0.025	0.138	0.041	0.094	0.153	0.2	0.095	0.252	0.093
Total Nitrogen	kg/day	0.008	0.053	0.024	0.01	0.045	0.015	0.03	0.049	0.064	0.032	0.082	0.034
Total Phosphorus	kg/day	5E-04	0.006	0.002	9E-04	0.005	0.001	0.003	0.005	0.007	0.003	0.009	0.003
Enterococcus	Billion MPN/day	0.144	1.6	0.703	0.26	1.424	0.433	0.974	1.59	2.043	0.985	2.593	0.949

Table 3-3. Estimate of monthly average watershed loads for Nazareth Bay (VI-STT-31) from 10/1/2009 through 9/30/2019

Constituent	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow	L/day	4.0	25.3	11.5	4.9	21.6	7.1	14.7	23.8	30.9	15.7	39.7	16.2
TSS	kg/day	0.309	3.381	1.509	0.556	3.031	0.926	2.075	3.393	4.332	2.111	5.516	2.019
BOD5	kg/day	0.019	0.22	0.093	0.034	0.19	0.057	0.13	0.212	0.276	0.131	0.347	0.129
Total Nitrogen	kg/day	0.012	0.073	0.033	0.014	0.062	0.02	0.042	0.067	0.088	0.045	0.113	0.047
Total Phosphorus	kg/day	0.007	0.008	0.003	0.001	0.007	0.002	0.005	0.007	0.01	0.005	0.012	0.005
Enterococcus	Billion MPN/day	0.199	2.209	0.971	0.359	1.965	0.598	1.344	2.195	2.82	1.36	3.579	1.31

Table 3-4. Estimate of monthly average watershed loads for Benner Bay (VI-STT-33) from 10/1/2009 through 9/30/2019

Constituent	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow	L/day	10.2	57.9	23.3	10.4	42.8	13.7	27.2	45.1	65.4	31.9	80.6	39.0
TSS	kg/day	0.618	7.992	2.779	0.995	5.821	1.611	3.718	6.289	9.19	3.979	10.73	4.647
BOD5	kg/day	0.035	0.47	0.162	0.058	0.344	0.095	0.224	0.371	0.542	0.23	0.638	0.264
Total Nitrogen	kg/day	0.028	0.161	0.063	0.029	0.117	0.038	0.076	0.123	0.179	0.085	0.217	0.103
Total Phosphorus	kg/day	0.001	0.017	0.006	0.002	0.012	0.003	0.008	0.013	0.019	0.008	0.022	0.01
Enterococcus	Billion MPN/day	0.36	4.649	1.673	0.61	3.517	0.997	2.322	3.823	5.451	2.37	6.507	2.62

Table 3-5. Estimate of monthly average watershed loads for Benner Bay Lagoon Marina (VI-STT-34) from 10/1/2009 through 9/30/2019

Constituent	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow	L/day	8.5	54.0	24.5	10.4	46.2	15.2	31.5	50.8	65.9	33.6	84.7	34.6
TSS	kg/day	0.661	7.219	3.221	1.187	6.471	1.977	4.43	7.245	9.248	4.508	11.78	4.311
BOD5	kg/day	0.041	0.469	0.199	0.073	0.406	0.122	0.277	0.452	0.589	0.28	0.741	0.275
Total Nitrogen	kg/day	0.025	0.155	0.07	0.03	0.132	0.044	0.089	0.144	0.188	0.095	0.24	0.099
Total Phosphorus	kg/day	0.001	0.017	0.007	0.003	0.014	0.004	0.01	0.016	0.021	0.01	0.026	0.01
Enterococcus	Billion MPN/day	0.424	4.717	2.073	0.766	4.196	1.277	2.87	4.686	6.022	2.904	7.642	2.797

Table 3-6. Estimate of monthly average watershed loads for Mangrove Lagoon (VI-STT-35) from 10/1/2009 through 9/30/2019

Constituent	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow	L/day	94	539	243	106	446	147	294	482	645	331	824	364
TSS	kg/day	7.185	93.99	32.46	11.43	68.43	18.48	43.2	73.58	107.6	46.38	125.8	54.21
BOD5	kg/day	0.397	4.522	1.876	0.692	3.842	1.14	2.571	4.252	5.613	2.652	7.009	2.697
Total Nitrogen	kg/day	0.273	1.526	0.691	0.309	1.27	0.425	0.843	1.367	1.82	0.932	2.317	1.018
Total Phosphorus	kg/day	0.014	0.168	0.067	0.025	0.138	0.04	0.091	0.152	0.205	0.095	0.252	0.099
Enterococcus	Billion MPN/day	4.051	44.32	19.27	7.159	39.09	11.83	26.43	43.48	56.2	27.12	71.04	26.74

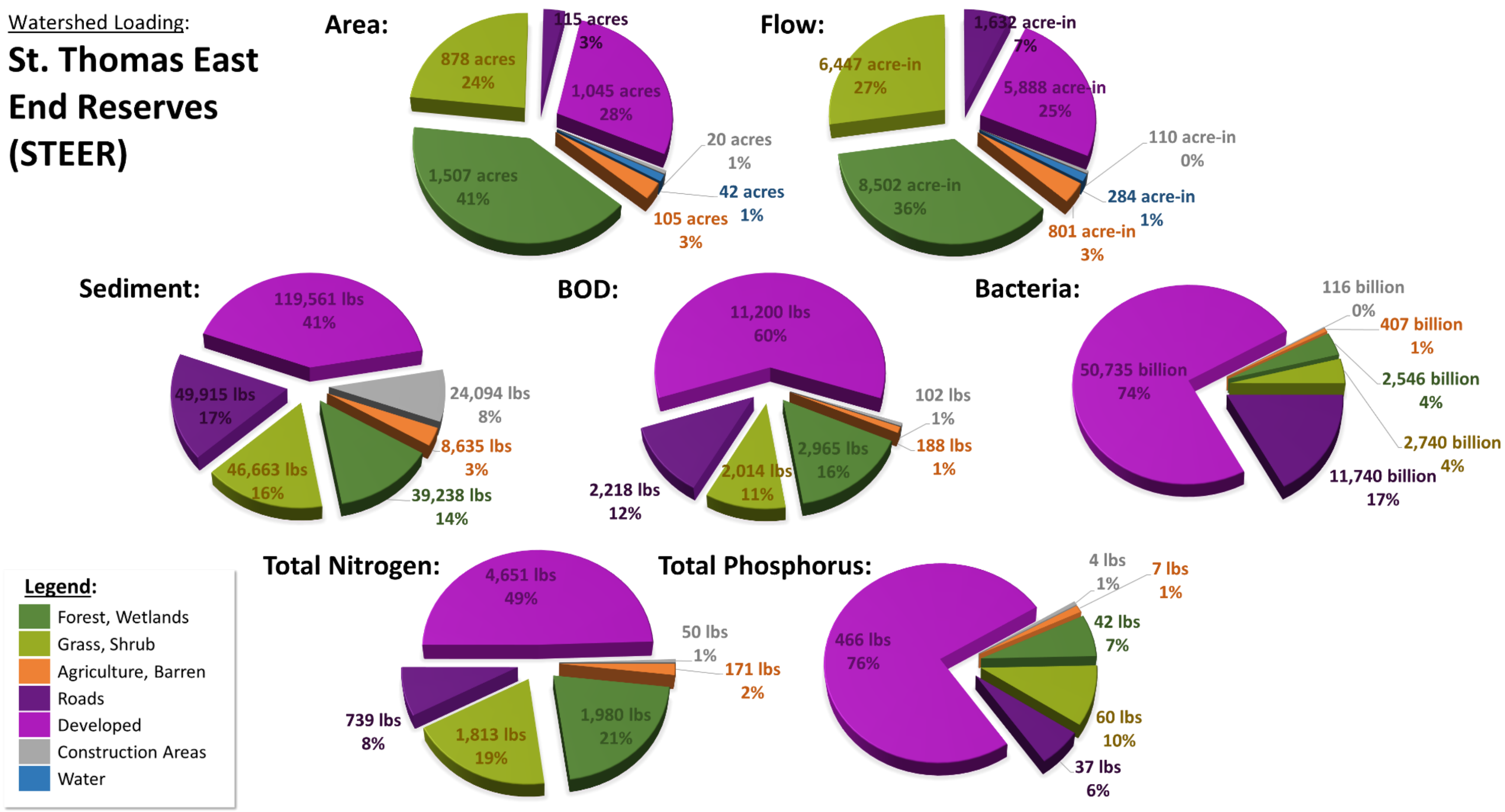

Figure 3-1. Distribution of annual watershed loads by source for STEER.

3.1.2 Permitted Discharges

According to the inventory presented in Section 1.3.1, there are 14 active TDPES permits identified as discharging into waterbodies within STEER. Table 3- presents a summary of the permit limits specified for each permit. For some constituents, such as bacteria, the permit limits generally align with the WQS presented in Section 2. For constituents where no permit limit was provided, the corresponding Class B waters WQS will be applied for representing the TMDL (italicized values in Table 3-). Little to no data was available to estimate TN and TP effluent loads and no permit limits were noted in EPA's Integrated Compliance Information System (ICIS) for the permits in Table 3-7 or similar facility permits across other USVI watersheds.

Table 3-7. Summary of TPDES permit limits for facilities discharging to STEER waterbodies

Waterbody ID	TPDES ID	NPDES Description	MGD	mg/L	mg/L	#/100mL	mg/L	mg/L
			Flow	TSS	BOD5	ENTERO	TN	TP
Great Bay (STT-25)	VI0040479	Ritz Carlton Hotel	0.140	30	30	104	*0.207*	*0.05*
	VI0040517	Anchorage Condominiums	0.023	30	30	104	*0.207*	*0.05*
	VI0040606	Water Point Estates	0.025	*30*	*30*	*104*	*0.207*	*0.05*
Cowpet Bay (STT-28)	VI0039853	Cowpet Bay West Condominiums	0.036	30	30	104	*0.207*	*0.05*
	VI0039900	Cowpet Bay East Condominiums	0.025	30	30	104	*0.207*	*0.05*
	VI0040321	Elysain Beach Resort	0.030	30	30	104	*0.207*	*0.05*
Nazareth Bay	VI0040398	Secret Harbor Beach Owners Association	0.007	30	30	104	*0.207*	*0.05*
	VI0080021	Dvergsten Company, Inc.	0.030	*30*	*30*	*104*	*0.207*	*0.05*
Benner Bay Lagoon Marina (STT-34)	VI0000716	SVB 155 Spring, LLC	0.028	*30*	*30*	*104*	*0.207*	*0.05*
	VI0040193	Point Pleasant Resort	0.025	30	30	104	*0.207*	*0.05*
	VI0040401	Compass Point Marina Inc.	0.004	30	30	104	*0.207*	*0.05*
Mangrove Lagoon (STT-35)	VI0002003	Mangrove Lagoon	1.200	30	30	104	*0.207*	*0.05*
	VI0031114	Virgin Islands Housing Authority	0.130	*30*	*30*	*104*	*0.207*	*0.05*
	VI0040746	Market Square East	0.010	30	30	104	*0.207*	*0.05*

Pollutant loads can be estimated based on the discharge monitoring reports (DMR) and reported permit limits. Due to the lack of DMR records or permit limits for TN and TP data at the permitted facilities listed in Table 3-7, comparable DMR data was analyzed for facilities from Puerto Rico. These data were downloaded from the USEPA Enforcement and Compliance History Online (ECHO) database for the period 2009-2022. The range of observed TP and TN for all facilities is shown in

Figure 3-2 and Figure 3-3, respectively. Facility records were filtered for gross effluent flow, TN, and TP observations for sewerage systems. Analog facilities were found by selecting facilities in the Puerto Rico data set whose maximum flow volume was closest to the permitted limits for USVI facilities. Based on data from the selected facilities presented in Figure 3-4, a median value of 6.6 mg/L for TN based on NPDES Permit #PR0020427 and 0.2 mg/L for TP based on NPDES Permit #PR0026042 were used to estimate current loads for the USVI facilities listed in Table 3-7.

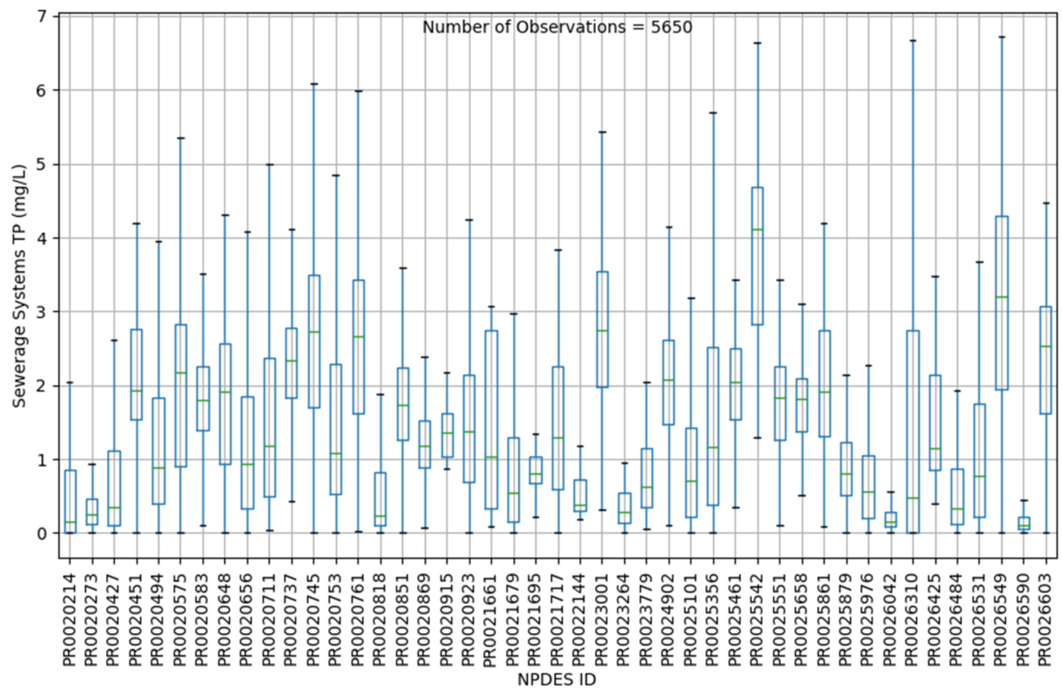

Figure 3-2. Summary of sewage system DMR effluent records for TP across Puerto Rico.

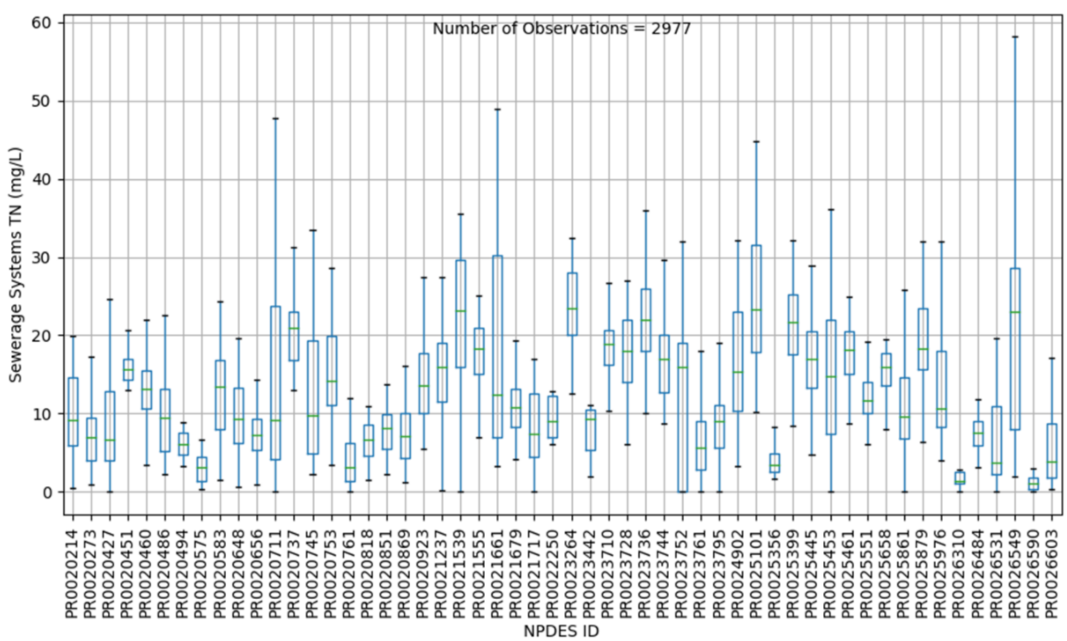

Figure 3-3. Summary of sewage system DMR effluent records for TN across Puerto Rico.

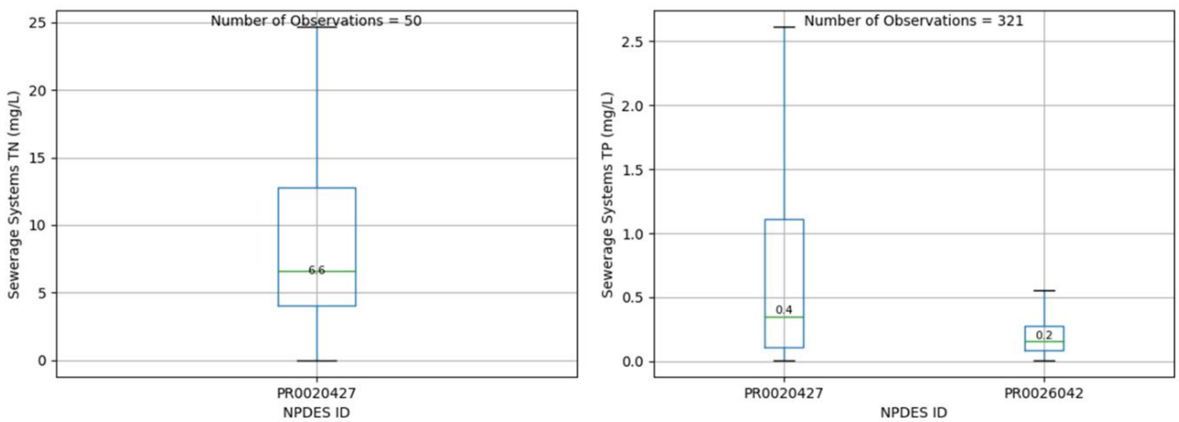

Figure 3-4. Selected facilities with maximum flow discharge limits similar to USVI facilities.

3.1.3 Onsite Sewage Disposal Systems (OSDS)

Failing OSDS such as septic systems were incorporated as sources of Enterococci bacteria by converting the estimated watershed population presented in Section 0 into a bacteria load delivered to the receiving water assessment units within STEER. Population estimates presented in Section 0 were based on the most recent 2010 Census. It was estimated that approximately 11,983 residents reside within STEER watersheds, with 43% of the population in units serviced by septic or other OSDS as presented preciously in Section 1.3.1 (US Census, 2013).

Using the Census estimate of population on OSDS infrastructure, an effluent load produced form system within the watershed can be calculated with an assumed flowrate and effluent concentration. A per capita discharge rate of 70 gallons/person/day and a failing OSDS Enterococci effluent concentration of 2,000 MPN/100mL were applied to the population estimates to derive a total bacteria load (Horsley and Witten, 1996). Similarly, an effluent concentration of 8 mg/L of Total Phosphorous and a daily loading rate of 0.18 kg/day/person of BOD were used in conjunction with the population estimates to derive loads (USEPA, 2010).

Past TMDLs developed for the USVI have assumed lower failure rates on the order of 10%. More recent work characterizing the suitability of parcels across USVI predicted high failure probabilities. The analysis estimated failure rates by parcel zoning with 80% of low-density residential parcels and 90% of medium/high density residential parcels characterized as having a *High* failure likelihood (USEPA, 2011). A high failure likelihood is described in the analysis as >35% failure rate. The estimate for STEER used a failure rate of 35% as a conservative assumption based on this more recent effort to characterize physical limitations to conventional OSDS on the islands. Of the total load produced by failing system, a 10% delivery rate was applied representing the load reaching the receiving water to account for losses through surface and subsurface transport pathways (USEPA, 2003).

Table 3- presents estimates of Enterococci bacteria, Total Phosphorous, and BOD delivered from the watershed into Salt River receiving waters by model subwatershed.

Table 3-8. Estimate of bacteria load production and delivery for STEER due to failing OSDS

Assessment Unit	Model Subwatershed	Population[1]		Volume & Delivered Load			
		Sewer	OSDS / Septic	Volume (L/day)	Enterococcus (Billion MPN/day)[2,3]	BOD-5 (kg/day)[3]	Total Phosphorous (kg/day)[3]
Mangrove Lagoon (STT-35)	1101	77	34	315.3	0.03	0.47	0.01
	1102	127	56	519.4	0.05	0.78	0.01
	1103	204	126	1,168.6	0.12	1.75	0.02
	1104	39	16	148.4	0.01	0.22	0.00
	1105	156	128	1,187.1	0.12	1.78	0.02
	1106	62	28	259.7	0.03	0.39	0.00
	1107	13	29	269.0	0.03	0.40	0.00
	1108	55	144	1,335.5	0.13	2.00	0.02
	1109	108	254	2,355.7	0.24	3.53	0.04
	1110	110	154	1,428.2	0.14	2.14	0.03
	1111	10	36	333.9	0.03	0.50	0.01
	1112	509	127	1,177.8	0.12	1.76	0.02
	1113	37	151	1,400.4	0.14	2.10	0.02
	1114	29	131	1,214.9	0.12	1.82	0.02
	1115	104	181	1,678.6	0.17	2.51	0.03
	1116	69	52	482.3	0.05	0.72	0.01
	1117	7	17	157.7	0.02	0.24	0.00
	1118	351	54	500.8	0.05	0.75	0.01
	1119	91	60	556.5	0.06	0.83	0.01
	1120	716	249	2,309.3	0.23	3.46	0.04
	1121	556	486	4,507.3	0.45	6.75	0.08
	1122	2309	701	6,501.3	0.65	9.74	0.11

Assessment Unit	Model Subwatershed	Population[1]		Volume & Delivered Load			
		Sewer	OSDS / Septic	Volume (L/day)	Enterococcus (Billion MPN/day)[2,3]	BOD-5 (kg/day)[3]	Total Phosphorous (kg/day)[3]
	1123	692	558	5,175.0	0.52	7.75	0.09
Benner Bay (STT-33)	1124	49	128	1,187.1	0.12	1.78	0.02
	1125	135	563	5,221.4	0.52	7.82	0.09
	1126[4]	38	142	1,315.1	0.13	1.97	0.02
Great Bay (STT-25)	1126[4]	37	137	1,267.5	0.13	1.90	0.02
	1127	3	3	27.8	0.00	0.04	0.00
Cowpet Bay (STT-28)	1126[4]	25	95	878.0	0.09	1.31	0.02
Nazareth Bay (STT-31)	1126[4]	35	131	1,217.7	0.12	1.82	0.02
Benner Bay Lagoon Marina (STT-34)	1126[4]	75	280	2,596.3	0.26	3.89	0.05

1. Population estimates based on the 2010 U.S. Census (US Census, 2013).
2. Assumes a 35% failure rate consistent with high-risk areas for OSDS failures (USEPA, 2011.)
3. Assumes a 10% delivery rate of load from failed system (USEPA, 2003).
4. Contributions from model SWS-1126 are split across multiple assessment units.

3.1.4 Vessels & Live-aboards

Vessel and live-aboard populations while generally smaller than land-based population estimates derived through the 2010 Census present an opportunity for direct loading of bacteria, nutrients, and BOD to local waterbodies through illicit discharges of onboard wastewater.

Estimates of the seasonal distribution of live aboard vessels across STEER waterbodies were developed through review of GIS maps, aerial imagery, interviews with individuals who reside in live-aboard vessels and local knowledge. Summaries of the field visits with notes related to these interviews are presented in Appendix A. Estimated seasonal distribution of live-aboard vessels for STEER is presented in Table 3-.

The number of live-aboards presented in Table 3- is likely an overestimate, with the average number of persons on a vessel 28-34 feet typically one individual, with guests periodically but not frequently. The live-aboard population will change seasonally based on the season, as well as based on the proximity of that particular bay to shelter, or the shelter offered by that particular bay. For instance, in mangrove areas or waterbodies that are more enclosed, the number of boats can actually increase during hurricane season as vessels move into these areas seeking shelter.

Table 3-9. Estimated seasonal distribution of live-aboard vessels across STEER waterbodies

Waterbody ID	Waterbody Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VI-STT-25	Great Bay	1	0	0	0	0	0	0	0	0	0	0	1
VI-STT-28	Cowpet Bay	25	25	25	20	20	15	15	5	5	5	20	20
VI-STT-31	Nazareth Bay	10	10	8	5	5	5	0	0	0	0	10	10
VI-STT-33	Benner Bay	10	10	8	5	5	5	0	0	0	0	10	10
VI-STT-34	Benner Bay Lagoon Marina	25	25	20	20	15	10	10	10	10	10	10	25
VI-STT-35	Mangrove Lagoon	0	0	0	0	0	0	0	0	0	0	0	0

Similar to the septic system loading analysis presented in Section 0, loading from live-aboards was estimated using a constant daily per capita flow rate of 1.4 purges per week of 40-gallon onboard tank, or approximately 212 liters per week (USEPA, 2010). This discharge volume was used in conjunction with a constant concentration of Enterococcus of 10,000 MPN/100mL, TN concentration of 32.0 mg/L, TP concentration of 8.0 mg/L, and BOD loading rate of 0.18 kg/day/person to derive daily load estimates (USEPA, 2010).

4 TMDL CALCULATIONS & ALLOCATIONS

A TMDL for a given waterbody and pollutant includes three fundamental components: (1) a wasteload allocation (WLA) for each point source contributing to the waterbody, (2) a load allocation (LA) for the sum of all nonpoint sources (including ambient sources) contributing to the waterbody, and (3) a margin of safety (MOS) that accounts for uncertainty in the waterbody's response to the application of the point source and nonpoint source loads. The basic TMDL equation, whether developed directly through a pollutant or through surrogate indicators, is commonly expressed using these three fundamental components as:

$$TMDL = WLA + LA + MOS$$

TMDLs are also often described as the total mass of a pollutant that a waterbody can assimilate and still maintain its designated uses as expressed via a TMDL target, and frequently related directly to a numeric water quality standard. In determining the three components of a TMDL, the total allowable pollutant loadings from each source category (or individual source where applicable) contributing to the waterbody must be less than or equal to the TMDL target. In accordance with 40 CFR 130.2(1), TMDLs may be expressed in terms of allowable mass loadings or in terms water quality concentrations that may not be exceeded. The following sections describe the calculated TMDLs for STEER assessment units.

4.1 Turbidity

Section 1.5.1 discussed how TSS, which measures the amount of sediment and organic matter suspended in water, is used as the surrogate for turbidity associated with watershed runoff. The USVI WQS for turbidity in Class B waters is expressed as both a single sample maximum of 3 NTUs, or 1 NTU within a coral reef ecosystem. Cowpet Bay assessment unit (STT-28), Nazareth Bay (STT-31), and Benner Bay Lagoon Marina (STT-34) were designated as Class B waters. Table 4-1 through Table 4-3 present the WLA, LA, and MOS for TSS, which was used as a surrogate for turbidity. An explicit MOS of 10% was included in the TMDL calculation.

Table 4-1. Turbidity TMDL WLA + LA + MOS for Cowpet Bay (STT-28)

Load Type	Source	Total Suspended Sediment (g/day)		
		Current Load	% Reduction	Load Capacity
Total Load		14,330	7.2%	13,293
MOS		10% explicit MOS applied		1,329
LA	Septics/OSDS	0.000	0.0%	0
	Roads	1,521	64.8%	535
	Construction	75	73.0%	20
	Dev. Impervious	1,929	56.7%	835
	Dev. Pervious	406	56.7%	176
	Agriculture	0	0.0%	0
	Forest/Wetland	12	0.0%	12
	Grass/Shrub	51	0.0%	51
WLA	Live-Aboard Vessels	0.45	0.0%	0.45
	Cowpet Bay West Condominiums (VI0039853)	4,088	0.0%	4,088
	Cowpet Bay East Condominiums (VI0039900)	2,839	0.0%	2,839
	Elysain Beach Resort (VI0040321)	3,407	0.0%	3,407

Table 4-2. Turbidity TMDL WLA + LA + MOS for Nazareth Bay (STT-31)

Load Type	Source	Total Suspended Sediment (g/day)		
		Current Load	% Reduction	Load Capacity
Total Load		6,254	8.5%	5,722
MOS		10% explicit MOS applied		572
LA	Septics/OSDS	0	0.0%	0
	Roads	2,100	20.7%	1,665
	Construction	104	0.0%	104
	Dev. Impervious	2,664	20.7%	2,111
	Dev. Pervious	561	20.7%	444
	Agriculture	0	0.0%	0
	Forest/Wetland	17	0.0%	17
	Grass/Shrub	70	0.0%	70
WLA	Live-Aboard Vessels	0.23	0.0%	0.23
	Secret Harbor Beach Owners Association (VI0040398)	738	0.0%	738
	Dvergsten Company, Inc. (VI0080021)	0	0.0%	0

Table 4-3. Turbidity TMDL WLA + LA + MOS for Benner Bay Lagoon Marina (STT-34)

Load Type	Source	Total Suspended Sediment (g/day)		
		Current Load	% Reduction	Load Capacity
Total Load		15,071	28.5%	10,774
MOS		10% explicit MOS applied		1,077
LA	Septics/OSDS	0	0.0%	0
	Roads	4,485	44.6%	2,484
	Construction	222	57.4%	95
	Dev. Impervious	5,687	47.2%	3,005
	Dev. Pervious	1,197	47.2%	633
	Agriculture	0	0.0%	0
	Forest/Wetland	35	0.0%	35
	Grass/Shrub	150	0.0%	150
WLA	Live-Aboard Vessels	0.45	0.0%	0.45
	SVB 155 Spring, LLC (VI0000716)	0	0.0%	0
	Point Pleasant Resort (VI0040193)	2,839	0.0%	2,839
	Compass Point Marina Inc. (VI0040401)	454	0.0%	454

4.2 Dissolved Oxygen

Section 1.5.2 discussed the use of BOD5 as a surrogate for DO. This TMDL addresses DO through removal of nutrients and organic matter addressing possible eutrophication that could drive DO and pH issues. A BOD-5 target of 1.5 mg/L was developed as a reference condition based on analysis of nearby unimpaired assessment units (see Section 1.5.2). An explicit MOS of 10% was also incorporated and applied to these water quality targets. Table 4-4 presents the TMDL showing the WLA, LA, and MOS for the surrogate addressing DO.

Table 4-4. BOD5 Allocation for Dissolved Oxygen TMDL WLA + LA + MOS for Cowpet Bay (STT-28)

Load Type	Source	BOD5 (g/day)		
		Current Load	% Reduction	Load Capacity
	Total Load	11,809	5.9%	11,116
	MOS	10% explicit MOS applied		1,112
LA	Septics/OSDS	1,315	55.0%	592
	Roads	27	41.5%	16
	Construction	0.44	55.0%	0.20
	Dev. Impervious	70	28.0%	51
	Dev. Pervious	59	28.0%	42
	Agriculture	0	0.0%	0
	Forest/Wetland	0.98	0.0%	0.98
	Grass/Shrub	1.64	0.0%	1.64
WLA	Live-Aboard Vessels	1.21	0.0%	1.21
	Cowpet Bay West Condominiums (VI0039853)	4,088	10%	3,679
	Cowpet Bay East Condominiums (VI0039900)	2,839	10%	2,555
	Elysain Beach Resort (VI0040321)	3,407	10%	3,066

4.3 Enterococcus

This section discusses and presents the TMDL tables for enterococcus bacteria. An enterococcus target of 110 mg/L was applied based on the Class B waters WQS presented in Section 2. An explicit MOS of 10% was also incorporated and applied to this water quality target. Table 4-5 through Table 4-8 present the TMDL tables showing the loading capacity, WLA, LA, and MOS for Nazareth Bay, Benner Bay, Benner Bay Lagoon Marina, and Mangrove Lagoon, respectively.

Table 4-5. Enterococcus TMDL WLA + LA + MOS for Nazareth Bay (STT-31)

Load Type	Source	Enterococcus (Million/Day)		
		Current Load	% Reduction	Load Capacity
Total Load		3,727	11.2%	3,309
MOS		10% explicit MOS applied		331
LA	Septics/OSDS	122	55.1%	55
	Roads	972	19.1%	787
	Construction	0.98	0.0%	0.98
	Dev. Impervious	2,114	19.1%	1,710
	Dev. Pervious	482	19.1%	390
	Agriculture	0	0.0%	0
	Forest/Wetland	2.15	0.0%	2.15
	Grass/Shrub	8.1	0.0%	8.1
WLA	Live-Aboard Vessels	0.015	0.0%	0.015
	Secret Harbor Beach Owners Association (VI0040398)	26	0.0%	26
	Dvergsten Company, Inc. (VI0080021)	0	0.0%	0

Table 4-6. Enterococcus TMDL WLA + LA + MOS for Benner Bay (STT-33)

Load Type	Source	Enterococcus (Million/Day)		
		Current Load	% Reduction	Load Capacity
Total Load		7,279	10.7%	6,500
MOS		10% explicit MOS applied		650
LA	Septics/OSDS	772	57.0%	332
	Roads	1,835	0.0%	1,835
	Construction	7.2	0.0%	7.2
	Dev. Impervious	3,231	22.7%	2,499
	Dev. Pervious	1,397	18.4%	1,141
	Agriculture	0	0.0%	0
	Forest/Wetland	18	0.0%	18
	Grass/Shrub	18	0.0%	18
WLA	Live-Aboard Vessels	0.015	0.0%	0.015

Table 4-7. Enterococcus TMDL WLA + LA + MOS for Benner Bay Lagoon Marina (STT-34)

Load Type	Source	Enterococcus (Million/Day)		
		Current Load	% Reduction	Load Capacity
Total Load		8,016	37.0%	5,053
MOS		10% explicit MOS applied		505
LA	Septics/OSDS	260	55.1%	116
	Roads	2,076	41.7%	1,211
	Construction	2.1	55.1%	0.94
	Dev. Impervious	4,514	44.4%	2,511
	Dev. Pervious	1,028	44.4%	572
	Agriculture	0	0.0%	0
	Forest/Wetland	4.6	0.0%	4.6
	Grass/Shrub	17	0.0%	17
WLA	Live-Aboard Vessels	0.03	0.0%	0.03
	SVB 155 Spring, LLC (VI0000716)	0	0.0%	0
	Point Pleasant Resort (VI0040193)	98	0.0%	98
	Compass Point Marina Inc. (VI0040401)	16	0.0%	16

Table 4-8. Enterococcus TMDL WLA + LA + MOS for Mangrove Lagoon (STT-35)

Load Type	Source	Enterococcus (Million/Day)		
		Current Load	% Reduction	Load Capacity
Total Load		79,301	55.0%	35,719
MOS		10% explicit MOS applied		3,572
LA	Septics/OSDS	3,498	55.8%	1,545
	Roads	17,295	42.6%	9,932
	Construction	193	55.8%	85
	Dev. Impervious	43,381	70.8%	12,648
	Dev. Pervious	9,878	70.8%	2,880
	Agriculture	0.46	0.0%	0.46
	Forest/Wetland	142	0.0%	142
	Grass/Shrub	150	0.0%	150
WLA	Live-Aboard Vessels	0	0.0%	0
	Mangrove Lagoon (VI0002003)	4,724	0.0%	4,724
	Virgin Islands Housing Authority (VI0031114)	0	0.0%	0
	Market Square East (VI0040746)	39	0.0%	39

4.4 Total Phosphorus

This section discusses and presents the TMDL tables for TP. A TP target of 0.05 mg/L was applied based on the Class B waters WQS presented in Section 2. An explicit MOS of 10% was also incorporated and applied to this water quality target. Table 4-9 presents the TMDL tables showing the loading capacity, WLA, LA, and MOS for Cowpet Bay.

Table 4-9.Total Phosphorus TMDL WLA + LA + MOS for Cowpet Bay (STT-28)

Load Type	Source	Total Phosphorus (g/day)		
		Current Load	% Reduction	Load Capacity
Total Load		93	65.7%	32
MOS		10% explicit MOS applied		3.196
LA	Septics/OSDS	15	55.0%	7.0
	Roads	1.0	41.5%	0.59
	Construction	0.011	55.0%	0.005
	Dev. Impervious	6.4	28.0%	4.6
	Dev. Pervious	1.5	28.0%	1.0
	Agriculture	0	0.0%	0
	Forest/Wetland	0.012	0.0%	0.012
	Grass/Shrub	0.056	0.0%	0.056
WLA	Live-Aboard Vessels	0.005	0.0%	0.005
	Cowpet Bay West Condominiums (VI0039853)	27	77.5%	6.1
	Cowpet Bay East Condominiums (VI0039900)	19	77.5%	4.3
	Elysain Beach Resort (VI0040321)	23	77.5%	5.1

4.5 Total Nitrogen

This section discusses and presents the results for TN. A TN target of 0.207 mg/L was applied based on the Class B waters WQS presented in Section 2. An explicit Margin of Safety (MOS) of 10% was also incorporated and applied to this water quality target. Tables 4-10 through 4-15 presents the TMDL tables showing the loading capacity, WLA, LA, and MOS for Great Bay, Cowpet Bay, Nazareth Bay, Benner Bay, Benner Bay Lagoon Marina, and Mangrove Lagoon, respectively.

Table 4-10. Total Nitrogen TMDL WLA + LA + MOS for Great Bay (STT-25)

Load Type	Source	Total Nitrogen (g/day)		
		Current Load	% Reduction	Load Capacity
Total Load		4,924	93.3%	329
MOS		10% explicit MOS applied		32.861
LA	Septics/OSDS	91	58.5%	38
	Roads	35	0.0%	35
	Construction	0.21	0.0%	0.21
	Dev. Impervious	74	0.0%	74
	Dev. Pervious	23	0.0%	23
	Agriculture	0	0.0%	0
	Forest/Wetland	1.03	0.0%	1.03
	Grass/Shrub	2.73	0.0%	2.73
WLA	Live-Aboard Vessels	0	0.0%	0
	Ritz Carlton Hotel (VI0040479)	3,498	97.4%	91
	Anchorage Condominiums (VI0040517)	575	97.4%	15
	Water Point Estates (VI0040606)	625	97.4%	16

Table 4-11. Total Nitrogen TMDL WLA + LA + MOS for Cowpet Bay (STT-28)

Load Type	Source	Total Nitrogen (g/day)		
		Current Load	% Reduction	Load Capacity
Total Load		2417	93.2%	165
MOS		10% MOS applied to TMDL Target		16.491
LA	Septics/OSDS	62	55.1%	28
	Roads	20	41.6%	12
	Construction	0.147	55.1%	0.066
	Dev. Impervious	45	28.1%	32
	Dev. Pervious	14	28.1%	10
	Agriculture	0	0.0%	0
	Forest/Wetland	0.55	0.0%	0.55
	Grass/Shrub	1.7	0.0%	1.7
WLA	Live-Aboard Vessels	0.021	0.0%	0.021
	Cowpet Bay West Condominiums (VI0039853)	899	97.2%	25
	Cowpet Bay East Condominiums (VI0039900)	625	97.2%	18
	Elysain Beach Resort (VI0040321)	750	97.2%	21

Table 4-12. Total Nitrogen TMDL WLA + LA + MOS for Nazerath Bay (STT-31)

Load Type	Source	Total Nitrogen (g/day)		
		Current Load	% Reduction	Load Capacity
Total Load		1,110	84.4%	173
MOS		10% explicit MOS applied		17.321
LA	Septics/OSDS	86	55.1%	39
	Roads	28	19.2%	22
	Construction	0.20	0.0%	0.20
	Dev. Impervious	62	19.2%	50
	Dev. Pervious	20	19.2%	16
	Agriculture	0	0.0%	0
	Forest/Wetland	0.76	0.0%	0.76
	Grass/Shrub	2.33	0.0%	2.33
WLA	Live-Aboard Vessels	0.011	0.0%	0.011
	Secret Harbor Beach Owners Association (VI0040398)	162	97.2%	5
	Dvergsten Company, Inc. (VI0080021)	750	97.2%	21

Table 4-13. Total Nitrogen TMDL WLA + LA + MOS for Benner Bay (STT-33)

Load Type	Source	Total Nitrogen (g/day)		
		Current Load	% Reduction	Load Capacity
Total Load		762	37.3%	477
MOS		10% explicit MOS applied		48
LA	Septics/OSDS	544	55.8%	241
	Roads	52	0.0%	52
	Construction	1.7	0.0%	1.7
	Dev. Impervious	94	20.4%	75
	Dev. Pervious	57	16.0%	48
	Agriculture	0	0.0%	0
	Forest/Wetland	6.3	0.0%	6.3
	Grass/Shrub	5.4	0.0%	5.4
WLA	Live-Aboard Vessels	0.011	0.0%	0.011

Table 4-14. Total Nitrogen TMDL WLA + LA + MOS for Benner Bay Lagoon Marina (STT-34)

Load Type	Source	Total Nitrogen (g/day)		
		Current Load	% Reduction	Load Capacity
Total Load		1,853	84.4%	290
MOS		10% explicit MOS applied		29
LA	Septics/OSDS	183	55.1%	82
	Roads	59	41.7%	35
	Construction	0.44	55.1%	0.20
	Dev. Impervious	132	44.3%	73
	Dev. Pervious	42	44.3%	23
	Agriculture	0	0.0%	0
	Forest/Wetland	1.6	0.0%	1.6
	Grass/Shrub	5.0	0.0%	5.0
WLA	Live-Aboard Vessels	0.021	0.0%	0.021
	SVB 155 Spring, LLC (VI0000716)	705	97.2%	20
	Point Pleasant Resort (VI0040193)	625	97.2%	18
	Compass Point Marina Inc. (VI0040401)	100	97.2%	3

Table 4-15. Total Nitrogen TMDL WLA + LA + MOS for Mangrove Lagoon Bay (STT-35)

Load Type	Source	Total Nitrogen (g/day)		
		Current Load	% Reduction	Load Capacity
Total Load		38261	91.4%	3274
MOS		10% explicit MOS applied		327
LA	Septics/OSDS	2466	55.1%	1106
	Roads	494	41.7%	288
	Construction	34	55.1%	15
	Dev. Impervious	1267	70.4%	375
	Dev. Pervious	429	70.4%	127
	Agriculture	0.28	0.0%	0.28
	Forest/Wetland	50	0.0%	50
	Grass/Shrub	43	0.0%	43
WLA	Live-Aboard Vessels	0	0.0%	0
	Mangrove Lagoon (VI0002003)	29980	97.2%	844
	Virgin Islands Housing Authority (VI0031114)	3248	97.2%	91
	Market Square East (VI0040746)	250	97.2%	7.0

5 SEASONAL & CLIMATE VARIATION

The U.S. Virgin Islands experience frequent precipitation events with some rainfall occurring about once every 2-3 days, and rainfall events >= 0.1 inches occurring at least once a week. Most rainfall occurs between August and November coinciding with hurricane season which runs from June to November, with most frequent occurrences in August and October. Showers, which can be locally heavy, can be expected any time of the year. Most showers have a short duration. Runoff events are infrequent, sudden, and dramatic and are characterized by high flows. Table 5-1 summarizes these, and other long-term monthly rainfall statistics, for the Charlotte Amalie Cyril E. King Airport.

Table 5-1. Summary of monthly rainfall statistics at the Charlotte Amalie Cyril E. King Airport (ISD-11640) from October 1, 2010 through September 30, 2019

Period	Mean	High		Low		1-Day Maximum		Average No. Rain Days			
		(in.)	Year	(in.)	Year	(in.)	Date	≥0.01	≥0.10	≥0.50	≥1.00
Jan	1.76	3.42	2018	0.57	2013	1.13	01/07/2010	13	5	0	0
Feb	2.53	13.35	2015	0.0	2013	10.39	02/14/2015	13	5	0	0
Mar	2.35	5.83	2017	1.28	2011	1.7	03/25/2017	11	4	1	0
Apr	1.94	3.5	2011	1.02	2017	1.35	04/14/2011	11	4	1	0
May	4.53	8.04	2011	1.21	2016	3.84	05/16/2015	15	7	2	1
Jun	2.4	7.8	2010	0.08	2012	2.9	06/20/2010	11	4	1	0
Jul	3.48	7.45	2019	0.33	2015	4.66	07/31/2019	16	6	1	0
Aug	5.17	9.05	2011	1.75	2015	4.04	08/22/2011	18	8	2	1
Sep	3.68	9.82	2013	0.92	2012	5.17	09/06/2013	13	7	2	0
Oct	5.29	16.03	2010	1.8	2011	6.02	10/06/2010	15	7	2	1
Nov	6.16	10.85	2013	0.0	2017	2.88	11/30/2013	17	10	3	1
Dec	2.89	7.6	2013	1.18	2017	2.19	12/01/2013	16	6	1	0
Annual	**42.19**	**59.29**	**2010**	**33.4**	**2017**	**10.39**	**02/14/2015**	**174**	**79**	**21**	**9**

The previously presented TMDLs for the STEER watersheds were developed based on long-term climate conditions representing the period from 10/1/2010 through 9/30/2019. Seasonal variation has been captured using this long-term representative condition capturing a range of wet years, dry years, hurricanes and other seasonal patterns. Establishment of the TMDLs in Section 4 focused on the identification of a critical month which was selected uniquely for each constituent to capturing the fundamental limiting condition associated with the highest frequency of water quality exceedances. Selection of these critical conditions benefited from using the long-term observed climate record in both the watershed and receiving water models. The use of this long-term data set in simulating watershed processes and selecting a critical condition appropriately captures the seasonal variation observed over the past two decades.

The scientific uncertainties related to our understanding of the physical climate system are large, and they will continue to be large for the foreseeable future, and changes in these climate systems could impact the predictions in this TMDL. Figure presents a summary of annual and 5-year moving average rainfall tends for the Charlotte Amalie Cyril E. King Airport (ISD-11640). The trends in this figure suggest rainfall may decrease with the current changes in climate patterns, possibly resulting in less non-point source runoff; However, a decrease in the available water resources may have other impacts including stresses on crop yields and natural environments like forests and wetlands. The loss of vegetation in these settings could lead in increases in erosion and sediment production. This finding is supported by additional USEPA research addressing sea level rise, impacts to coral reef systems, and human health implications (USEPA 2016).

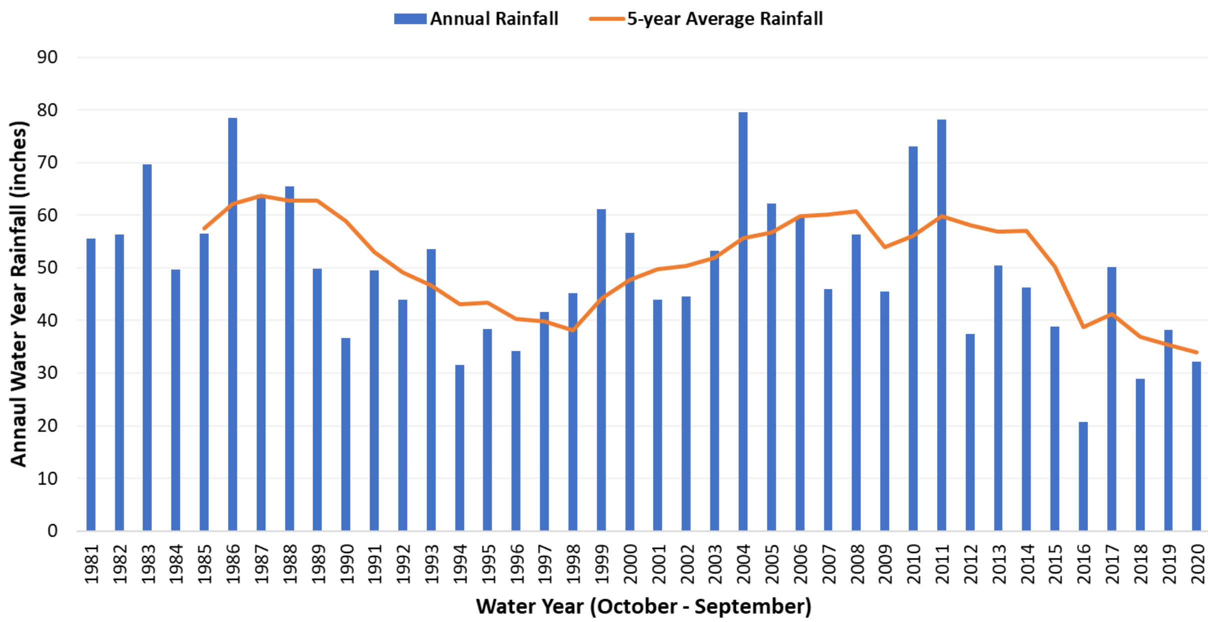

Figure 5-1. Summary of annual and 5-year average rainfall trends at Charlotte Amalie Cyril E. King Airport (ISD-11640) from October 1, 1980 through September 30, 2020.

6 REASONABLE ASSURANCE

When a TMDL is developed for waters that are impaired by point sources alone, the issuance of National Pollutant Discharge Elimination System (NPDES) permits (Territorial Pollutant Discharge Elimination System (TPDES) permits in the case of USVI), provides the reasonable assurance that wasteload allocations (WLA) identified in the TMDL will be achieved. The limits provided in the NPDES/TPDES permits are set at a level protective of water quality. Detailed monitoring requirements assure compliance with the limits and enforcement actions can be taken when out of compliance. When a TMDL is developed that allocates pollutant loads to both point and nonpoint sources, the TMDL should demonstrate reasonable assurance that the load allocations (LAs) will be achieved and the water quality standards (WQS) will be attained. The rationale for the reasonable assurance is to ensure that the WLAs and LAs established in the TMDL are not based on unreasonable or unrealistic assumptions regarding the amount of nonpoint source pollutant reductions that will occur. This is necessary because the WLAs for point sources are determined, in part, on the basis of the expected contributions made by nonpoint sources to the total pollutant reductions necessary to achieve WQS. If the reductions embodied in LAs are not fully achieved because of a failure to fully implement needed nonpoint source pollution controls or if the reduction potential of the proposed best management practices (BMPs) was overestimated, the collective reductions from all sources will not result in attainment of WQS. In waters impaired by nonpoint sources alone and where no WLA's are assigned, there is no requirement to demonstrate reasonable assurance as a condition of EPA approval of the TMDL.

For this TMDL, the allocations were established for point and nonpoint sources. However, the nonpoint source LAs make up the majority of the pollutant contributions and, therefore, proposed NPS control measures will be critical to meeting WQS.

There is reasonable assurance that the goals of these TMDLs can be met with continued watershed planning efforts of the kind referenced in this TMDL document. Watershed planning efforts focus on control of sediments and adherence to the Earth Permitting process, including writing of comprehensive permit requirements to reduce sediment loading, routine inspection at multiple planning and pre-construction phases, and wiliness to inspect and enforce requirements of the permit. As a component of this TMDL effort, a program inventory was created to provide information on the types of programs that could be leveraged to provide technical, programmatic, or educational support for watershed protection efforts, including availability of funding. As an example, Section 319 of the CWA can provide funding for the installation of best management practices that prevent or reduce frequent NPS pollution in the USVI. The 319 program is focused on implementation, and it has been the source of numerous watershed improvements in the USVI. Appendix F provides a draft of the program inventory developed for this project. A summary of the programs, which provides reasonable assurance that the means to reduce LAs exists, is provided below:

- USDA EQUIP: provides financial assistance to implement conservation practices to address natural resource concerns on agricultural land and private forestland.
- CWA State Revolving Fund (SRF): provides loans for the construction of wastewater and drinking water treatment. USVI was recently allotted more than $8M from the SRF to help finance improvements in wastewater treatment and drinking water systems throughout the USVI.
- EPA Five-star Restoration Program: supports community-based wetland and riparian restoration projects. Prioritizes funding where community partnership/stewardship efforts are active.

Over the years, the Virgin Islands Coastal Zone Management Program (VICZMP) has embarked on multiple initiatives to lessen the negative impacts on the coastal zone and its resources. An inventory of existing programs is presented in Appendix F that could be leveraged to provide additional management. For example, one of these efforts has been the development and implementation of regulatory procedures for alternative OSDS. This TMDL document finds that septic and other onsite disposal systems are a major source of pollutants to coastal waters. Development and enforcement of consistent and protective standards for design and construction (including inspection and monitoring) would provide reasonable assurance that the reductions identified can be achieved. In addition, the load reduction from boat/marina waste can be addressed through the development of consistent standards and enforcement that prevents or limits future discharges from boats.

New implementation recommendations specific to STEER watersheds are also presented in Section 8.1, while initiatives recommended island-wide are presented in Section 8.2. STEER specific actions are categorized as short-term (i.e., 1-2 years), medium-term (i.e., 5 years), and long-term (i.e., 10 years) with a qualitative estimate of funding required for each. This would allow for planning a phased, adaptive implementation where short-term and low-cost actions can happen first. These early actions can be monitored for effectiveness while medium and long-term actions are planned and funded to achieve final water quality goals.

7 MONITORING PLAN TO TRACK TMDL EFFECTIVENESS

After management recommendations for improving water quality have been implemented, TMDL effectiveness monitoring and assessment are conducted to determine if the TMDL targets and water quality standards have been met. This information serves as an important source of feedback for refining and optimizing management approaches. Documenting improvements in water quality is important to demonstrate success, which is also required to obtain funding. Most states rely on their current ambient monitoring network to evaluate TMDL effectiveness. This reliance is not ideal because ambient water quality networks are not typically designed to provide targeted data. Instead, they are often focused on condition assessment and characterizing conditions at a watershed scale. Effectiveness monitoring should instead involve targeted sample collection on a smaller scale and should provide specific feedback on how implementation efforts are leading to water quality improvement.

Many variables, including variations in precipitation, wind direction and speed, water and air temperature, currents, and seasonal population fluctuations impact the water quality within STEER. From a review of the data available for the assessment units listed as impaired, it is recommended that the post-TMDL monitoring program reassess the available data, including sample locations and timing and work on developing a well-defined monitoring plan that is consistent and focused on locations that provide additional information on impact of sources (land uses, discharge points, areas of concentrated boat activity). In addition, adding sample locations should be considered that can help capture ambient water quality and flow/current conditions outside of the direct influence of land-based sources as a means of better understanding natural sources, particularly where turbidity or pH changes could be influenced by off-shore currents or winds. Once determined, the sample locations should be used for all sampling events and should not be moved or modified without a compelling reason. Understanding the trends in water quality requires this consistency over time.

Consideration should also be given to water quality monitoring during "first flush" events in key watersheds. Monitoring would include strategic timing to sample priority waterbodies during the first storm event(s) following a prolonged dry period. Sampling during these times will provide the magnitude of stored pollutants (e.g., septic effluent, created eroded materials, etc.) during the dry period. This sampling will also illuminate the magnitude of stored land-based pollutant loads and prioritize watersheds for water quality mitigation activities.

Given the typical impairments observed, the following is recommended as a minimum sampling parameter suite. Sampling data should include metadata that documents conditions during sampling, including the presence of significant offshore wind, tide conditions, presence of possible pollution sources (live-aboard vessel presence/estimate), etc. All of this information provides supporting information that can help interpret data, particularly when the data are out of the ordinary for a specific location.

- TSS
- Total Suspended Sediment
- Turbidity
- pH
- Water Temperature
- Chlorophyll a
- BOD
- DO

- TP
- Orthophosphate
- Nitrate/Nitrite
- Ammonia
- Total Kjeldahl Nitrogen
- Air and Water Temperature
- Enterococcus bacteria

In addition to more focused and targeted monitoring programs, the following actions are also recommended to support the TMDL effectiveness monitoring:

- The number of new waste water treatment facilities will increase for large public treatment facilities as well as smaller package plants will adopt new technologies. Track changes in centralized treatment capacity and treatment efficiency. Can track increase in volume treated, increase in level of treatment (by volume), or removal of underperforming systems.
- Stormwater runoff problem areas in commercial areas will be addressed by priority and sequentially targeting places such as Tutu Park Mall, the concrete factory, Bovoni dump, Turpentine Run. Develop tracking system to inventory best management practices implemented as well as removal of activities contributing to pollutant loadings.
- Develop plan and track progress for protection of the Mangrove Lagoon for East End Reserve.
- Develop and implement community-based education and outreach projects that focus on ghuts.
- Inventory the miles of unpaved roads in the watershed and track the reduction in miles as roads are paved or reconditioned. Metric to track would be miles of reduced unpaved roads
- Institute and track the number of inspections conducted per construction site (this requires a renewed emphasis on writing, tracking, and inspecting earth change permits. A database should be set up to track all permits, including the inspection history and outcomes. Metric for success would be an increase in permits AND an increase in inspections (and enforcement actions if appropriate)
- Increase the number of protected mangroves/wetlands/salt ponds. This would require a baseline inventory of the aerial extent and location of these natural protections to the coast and annual tracking of the increase or protection from development. A tracking system should be developed to maintain the inventory over time.
- Place an emphasis on cleaning up, stabilizing, and protecting ghuts, which experience significant erosion and serve as dumping areas. Inventory ghuts and prioritize several miles for cleaning up each year. Metric for success will be based on miles of ghut inspected and cleaned.

8 IMPLEMENTATION PLAN

This project was awarded by the United States Environmental Protection Agency (USEPA) with a goal of promoting a new collaborative framework for implementing the Clean Water Act (CWA) Section 303(d) program with the USVI. The new Program Vision leverages the experience gained over the past two decades in assessing and reporting on water quality and provides an opportunity to focus attention on priority waters. In addition, the program gives States the flexibility to use available tools beyond TMDLs to attain water quality restoration and protection. An important component of this effort is the development of comprehensive implementation plans for each of the watersheds. A review of the existing research and literature, site visits to St. John, St. Thomas, and St. Croix, and interviews with academics, industry personnel, residents, federal and territorial agency personnel were conducted to identify major implementation opportunities. A summary of the program inventory and trip reports can be found in Appendix A. The major stressors and priority implementation foci for this project can be generally categorized into:

- Unpaved Roads
- Construction sites
- Stressed septic systems
- Remodels
- Dumping Sites
- Live aboard communities

This section provides a general summary of findings and recommendations. A more detailed implementation plan is provided in Appendix G. It is important to note that the implementation plan included with this TMDL, along with some of the outstanding watershed planning efforts previously completed in the USVI, should be viewed as the starting point and as highly dynamic, living documents. Numerous other opportunities not identified in this TMDL should be added continuously to the watershed protection toolbox for consideration. In general, implementation options can be roughly divided into the following categories:

- Technical assistance capacity and training
- Infrastructure improvements and planning
- Policy and governance

The following summarizes the implementation recommendations for STEER—actions that apply specifically to issues observed in STEER these recommendations for actions that apply territory-wide. Implementation actions were identified based on extensive stakeholder interviews, site visits, existing reports including watershed plans and research studies and observations and discussions with a variety of residents and experts. See Table 8-1 for an overview of effectiveness for each implementation action including cost, overall effectiveness, time-scale, and addressed pollutants.

8.1 St. Thomas East End Reserve Implementation Actions

1. Pollutant sources in the vicinity of St. Thomas East End are primarily driven by high density residential and commercial urban activities within a large portion of the watershed. Identifying the major polluters would be a first priority and include Tutu Park Mall, Four Winds Plaza, port Mylner Plaza, Home Depot, Price Smart, and Cost-U-Less. The majority of these areas are impervious surfaces with runoff directed into the ghuts.

    a. Ghut cleanup and protection (stabilization, vegetation) should be prioritized.
    b. Turpentine Run and Nadir Ghuts are the primary ghuts that should be prioritized to protect water quality in St. Thomas East End. Currently there is trash, sediment, wastewater runoff, and active erosion in these ghuts.
2. Address residential sewage discharge problems with the wastewater facilities (improve wastewater management) and enforce policy of shift from failing septic systems to more modern wastewater treatment.
3. Protect the mangroves, salt ponds and freshwater wetlands of STEER watershed using the 2010 Wetlands Inventory of the USVI including Benner Bay Lagoon, and Tutu Park Marsh. Subwatershed priorities include Hernhut Pond, Patricia Cay, Compass Pt Salt Pond, Cabrita Salt Pond, and Turpentine Pond.
4. The Bovoni Landfill discharges contaminated leachate into the adjacent wetlands; control of discharge and protection of the remaining wetlands for STEER is a priority.
    a. Control solid waste and runoff from Bovoni Landfill into Mangrove Lagoon. Currently, the mangrove lagoon is acting as a buffer and likely sink for contaminants from landfill from entering the coastal waters.
    b. Cutting, filling in or damage to the Mangrove lagoon could result in the release of heavy metals and contaminants from the sediment.
5. Provide incentives for waterfront businesses to install, replace and maintain failing wastewater treatment systems (small package plants, commercial properties, housing projects) which will reduce pollutant loads, specifically nutrients (i.e., total nitrogen) to local waterbodies.
6. There are many opportunities to retrofit existing or install new facilities on developed properties to improve stormwater management
    a. Consultation with DPW who have a list of priority projects, many of which coincide with hazardous areas susceptible to natural disaster and sea level rise and increased storm incidence.
    b. Schools, commercial properties, housing developments including public projects ripe for retrofit for stormwater control.
7. Improve territorial wastewater treatment and address overflow problems associated with rainfall events at public facilities.

Table 8-1. Effectiveness of Implementation Actions for STEER

Implementation Action	Cost	Effectiveness	Time-Scale	Pollutant(s) Addressed			
				Sediment	BOD	Nutrients	Bacteria
Inventory and map large impervious surfaces and stormwater runoff conditions	$	Medium	1 yr	●	●	●	●
Inventory and map unpaved roads/surfaces and connectivity to STEER to prioritize treatment	$	Medium	1 yr	●	●	●	●
Implement ghut cleanup and protection (vegetation, stabilization)	$$	High	2 yrs	●	●	●	●
Improve and inventory wastewater management systems	$ - $$$	High	5 yrs		●	●	●
Protect the mangroves, salt ponds and freshwater wetlands	$$	High	2 yrs	●	●	●	●
Control solid waste and runoff from Bovoni Landfill to Mangrove Lagoon	$$	High	2 yrs	●	●	●	●
Protect and enhance Mangrove Lagoon wetlands; assess contaminant load	$	High	2 yrs	●	●	●	●
Provide incentives for waterfront businesses to install, replace and maintain wastewater treatment systems	$-$$$	High	5 yrs	●	●	●	●
Improve wastewater treatment and address overflow associated with heavy rainfall events	$$$	High	10 yrs	●	●	●	●

8.2 Territory-wide Recommended Actions

1. Inadequate (or absent) erosion and sediment control practices are observed in all locations including construction sites. Non permitted earth change work was observed on many occasions. This is attributed to a lack of presence of enforcement staff, inexperienced contractors, and lack of public awareness about permitting requirements. A program to mobilize and incentivize DPNR staff to spend time in the watersheds and inspect earth change, construction, and subdivisions is underway.

2. Increase fines or create incentives for repeat violators for permitting process. The current implementation system penalizes good behavior and rewards poor behavior.
3. Enhance and foster water quality sampling training for CZM, DPRN, NPS, and NGO staff who handle water quality samples or manage a water quality monitoring program, in collaboration with University of the Virgin Islands.
4. Create a certified water quality laboratory, support system, or network to facilitate and standardize handling and processing of water quality samples for USVI.
5. Implement training for wastewater engineers, construction traders, homeowners, developers, CZM, and engineers conducted territory-wide.
6. Create a wetland identification workshop for CZM, architects, real estate agents, NPS, and NGOs.
7. Install a territorial-wide research and management network to facilitate integration of research into management and collaboration between federal and territorial agencies with research institutions locally and nationally.
8. Implement a territorial-wide program to increase opportunities for local capacity to develop among the youth.
9. All development throughout the Territory should be reviewed at the same level of scrutiny as those permit applications in Tier 1.
10. The CZM permit system should be consistently and aggressively administered to provide the appropriate information on potential impacts of proposed development for water quality improvement and natural hazard mitigation.

9 ADMINISTRATIVE RECORD

An electronic copy of the administrative record was compiled to support these TMDLs.

10 REFERENCES

Badgley, B.D, F. Thomas, and V. Harwood, 2011. Quantifying environmental reservoirs of fecal indicator bacteria associated with sediment and submerged aquatic vegetation. Environmental Microbiology, 13(4) 932-942.

Cadmus, 2011. Watershed Characterization and Planning for Pathogen Source Reduction in the USVI.

Connell, D.W., and Miller, G.J. 1984. Chemistry and Ecotoxicology of Pollution. John Wiley & Sons, N.Y.

Devine B, Bacle J, Lindsey K et al. (2004). The Virgin Islands Wetlands and Riparian Areas Inventory: A Pilot Study to Characterize Watersheds and Wetlands Ecosystems. Report, Island Resources Foundation, Washington, DC

DPNR (Department of Natural Resources). 2012. *USVI Integrated Water Quality Monitoring & Assessment Report*. Prepared by Department of Planning and Natural Resources Division of Environmental Protection.

DPNR (Department of Natural Resources). 2020. *Amended Virgin Islands Water Quality Management Program Water Quality Standards Rules and Regulations: Title 12, Chapter 7, Amendments to Subchapter 186.* Adopted December 31, 2019.

Horsley and Witten. 1996. Identification and evaluation of nutrient and bacterial loadings to Maquoit Bay, New Frunswick and Freeport, Maine.

Horsley Witten Group (2011). St. Croix East End Watersheds Management Plan.

Horsley Witten Group (2013a). St. Thomas East End Reserves Watershed Existing Conditions Report. Prepared for NOAA Coral Reef Conservation Program, USVI Department of Planning and Natural Resources, and The Nature Conservancy.

Horsley Witten Group (2013b). St. Thomas East End Reserves Watershed Management Plan. Prepared for NOAA Coral Reef Conservation Program, USVI Department of Planning and Natural Resources, and The Nature Conservancy.

IRF, 2009. Erosion Control Strategy for the Fish Bay Watershed.

Jeffrey, CFG, et. al., 2005. The state of coral reef ecosystems of the U.S. Virgin Islands. pp. 45-90. In: The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005. NOAA Technical Memorandum NOS NCCOS 11.

MacDonald, L.H., Anderson, D.M., Dietrich, W.E. 1997. Paradise threatened: Land use and erosion on St. John, U.S. Virgin Islands. Environmental Management 21(6): 851-863.

NOAA (National Oceanic and Atmospheric Administration) Coastal Services Center. 2015. The Coastal Change Analysis Program (C-CAP) Regional Land Cover. Charleston, SC NOAA Coastal Services Center. Accessed at www.csc.noaa.gov/digitalcoast/data/ccapregional/index.html

Ramos-Scharrón, C.E. 2004. Measuring and predicting erosion and sediment yields on St John, US Virgin Islands. PhD dissertation, Department of Geosciences, Colorado State University, Fort Collins, CO.

Ramos-Scharrón, C.E., MacDonald L.H., 2007. Development and application of a GIS-based sediment budget model. Journal of Environmental Management, 84: 157-172.

Rogers, C.S. 2006. Threats to Coral Reefs in the US Virgin Islands. In: 16th Meeting of the United States Coral Reef Task Force, Status of USVI Coral Reefs Workshop. St. Thomas, U.S. Virgin Islands. 30 pp. http://epscor.uvi.edu/events/crtf_06_docs.html.

Waddell, J.E. and A.M. Clarke (eds.), 2008. The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008. NOAA Technical Memorandum NOS NCCOS 73. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 569 pp.

Rothenberger, P., J. Blondeau, J., C. Cox, S. Curtis, W. Fisher, V. Garrison, C. Jeffrey, E. Kadison, I. Lundgren, W. Miller, E. Muller, R. Nemeth, C. Rogers, T. Smith, A. Spitzack, M. Taylor, W. Toller, J. Wright, Z. Hillis-Starr, S. Paterson, D. Wusinich-Mendez, J Waddell (2008). The State of Coral Reef Ecosystems of the U.S. Virgin Islands. pp. 29-74. In: J.E. Waddell and A.M. Clarke (eds.), The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008. NOAA Technical Memorandum NOS NCCOS 73. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 569 pp

Tetra Tech, 2004. DO TMDL for Salt River Bay, St. Croix.

US Census (United States Census Bureau). 2013. *2010 Census of Population and Housing, Public Use Microdata Sample, U.S. Virgin Islands: Technical Documentation*, 2013.

USEPA (United States Environmental Protection Agency). 1991. Guidance for Water Quality-based Decisions: The TMDL Process. EPA 440/4-91-001.

USEPA (United States Environmental Protection Agency). 2003. Total Maximum Daily Loads (TMDLs) for Mangrove Lagoon and Benner Bay/Lagoon Marina. Region II. New York, New York.

USEPA (United States Environmental Protection Agency). 2004. *Dissolved Oxygen Total Maximum Daily Load, Salt River Bay, St. Croix, USVI*. September 21, 2004. Prepared for U.S. Environmental Protection Agency, Region 2 and U.S. Virgin Islands Department of Planning and Natural Resources.

USEPA (U.S. Environmental Protection Agency). 2010. FINAL Total Maximum Daily Load, St. Thomas Harbor, United States Virgin Islands. U.S. Environmental Protection Agency, Region 2, New York, N.Y.

USEPA (U.S. Environmental Protection Agency). 2011. Watershed Characterization and Planning for Pathogen Source Reduction in the U.S. Virgin Islands. U.S. Environmental Protection Agency, Region 2, New York, N.Y.

USEPA (U.S. Environmental Protection Agency). 2016. What Climate Change Means for the U.S. Virgin Islands. U.S. Environmental Protection Agency. EPA 430-F-16-065.